Draft UK Air Quality Plan for tackling nitrogen dioxide

Technical Report

May 2017

This publication is available at www.gov.uk/government/publications

Any enquiries regarding this publication should be sent to us at

Joint Air Quality Unit
Area 2C
Nobel House
17 Smith Square
London
SW1P 3JR
Email: 2017airqualityplan@defra.gsi.gov.uk

www.gov.uk/defra

Corrigendum

Amendment	Justification
Page 77, Table 4.13 Public impact figure changed from £2,700m to £1,900m.	Public cost incorrectly transposed from modelling to this document. The previous figure did not include the traffic flow benefit of £718m set out on page 73. The amendment reduces the net cost from £2,700m to £1,900m.
Page 187, Table 10.1 Public impact figure changed from £2,700m to £1,900m.	Public cost incorrectly transposed from modelling to this document. The previous figure did not include the traffic flow benefit of £718m set out on page 73. The amendment reduces the net cost from £2,700m to £1,900m.

The amendments are highlighted in the main text.

Contents

Executive Summary

The air quality challenge

The quality of our air is important for public wellbeing. Over recent decades, air quality has improved significantly. However, there is increasing evidence to suggest that air quality can adversely affect health, the natural environment, and economic performance. For example the Department of Health has identified air pollution as one of the biggest health risks across the UK.

The most immediate action required on air quality is tackling the problem of nitrogen dioxide (NO_2) concentrations around roads - the only statutory air quality limit value that the UK is currently failing to meet. There are a range of challenges associated with tackling NO_2, including:

- Firstly, the uncertainty that is inherent to assessments of this kind. Some of this relates to the need to model changes into the future, such as uncertainty about how future vehicle standards will perform. Previous standards to control emissions from cars have not performed as expected, which has led to revised emission projections revealing more areas with high NO_2 than previously modelled.

- Secondly, any plan to improve air quality is part of a wider landscape. Air pollution is an unintended consequence of many everyday activities, including driving and manufacturing. These activities cannot stop but the impacts on air quality need to be reduced, which can create challenging trade-offs and mean the impacts of actions need to be assessed closely.

- Finally, air quality is often a local environment problem. This means that local characteristics can affect local levels of air pollution. In these circumstances, national modelling will not pick up all the local detail and so it is important that local information and evidence are considered as part of decision making.

These challenges and uncertainties are discussed in this technical report and must be borne in mind when considering the results of the analysis presented. It is important that the development of options to address the high NO_2 concentrations follows an adaptive approach whereby actions can be adjusted in response to emerging evidence.

This technical report presents the current evidence base for a range of versatile policies aimed at improving NO_2 concentrations as quickly as possible. In doing so, it takes important steps towards building greater understanding of the impacts these options could have on air pollution and the most effective ways of managing air quality. By taking action to reduce $NO_{2,}$ it is also expected that this will have a number of co-benefits including reducing other pollutants such as particulate matter.

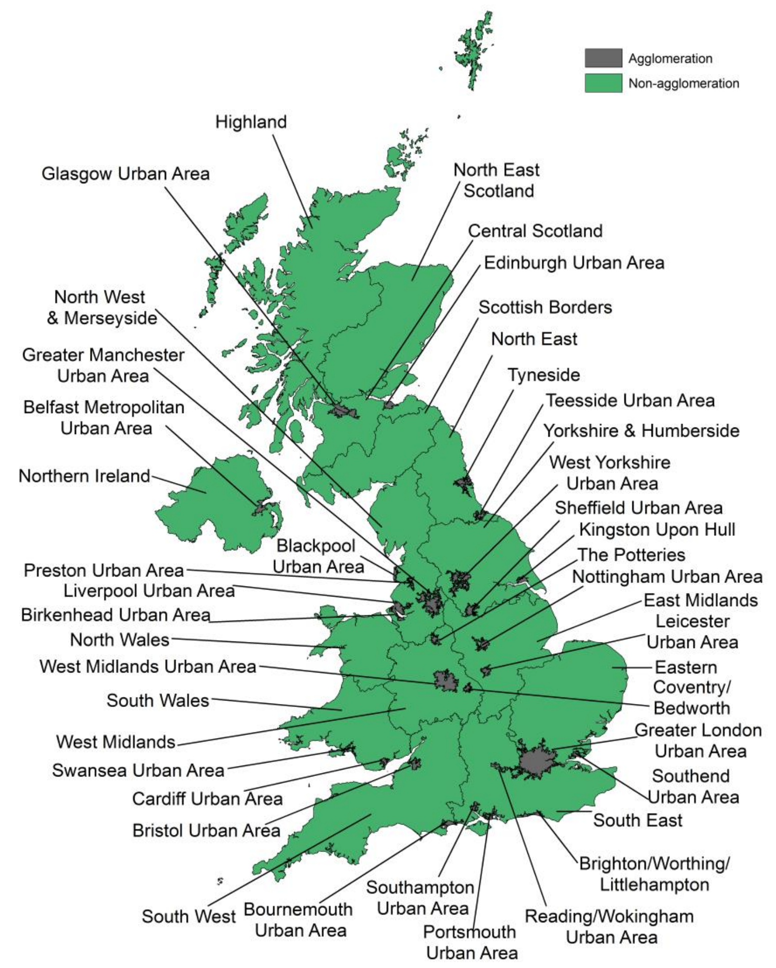
Scale of the challenge

Under existing legislation, the annual average concentration of NO_2 in the air needs to be less than 40μg/m^3 across a calendar year in each of the 43 air quality assessment zones of the UK (Fig. **Ex.1**). The UK assesses air quality as well as legal compliance with this obligation via a combination of monitoring data and modelling.

The UK monitors air quality via a national network of over 200 monitoring stations. This network is used to assess air quality in the immediate area and to provide information to calibrate the modelling of concentrations of key pollutants in the atmosphere. The modelling is also underpinned by knowledge of the location and magnitude of pollution sources (including industrial, transport, and domestic sources). For assessing $NO_{2,}$ the model provides the average annual concentration at a 1km x 1km spatial scale across the whole of the UK and for approximately 9,000 urban major roads. Data from independent monitoring stations is used to validate these results.

The same modelling system is used to project future levels of air pollution. This estimation system is built upon a rigorous four-step process involving data collection, modelling and analysis, calibration, and validation. This sequence of processes is collectively referred to as the Pollution Climate Mapping (PCM) model, which together with monitoring is used to assess compliance. Due to the large amount of time required for a full assessment of the PCM model, its outputs have been adapted to produce a rapid assessment tool. The simplified model, called the Streamlined Pollution Climate Mapping (SL-PCM) model, allows the projection of air quality under different policy interventions to support decision-making. The SL-PCM model provides substantially faster analysis without a notable loss in integrity as it builds on information previously prepared for and by the PCM model.

Figure Ex.1: UK air quality reporting zones, categorised into agglomeration and non-agglomeration zones; and average NO_2 concentrations (µg/m^3) for each UK reporting zones in 2015



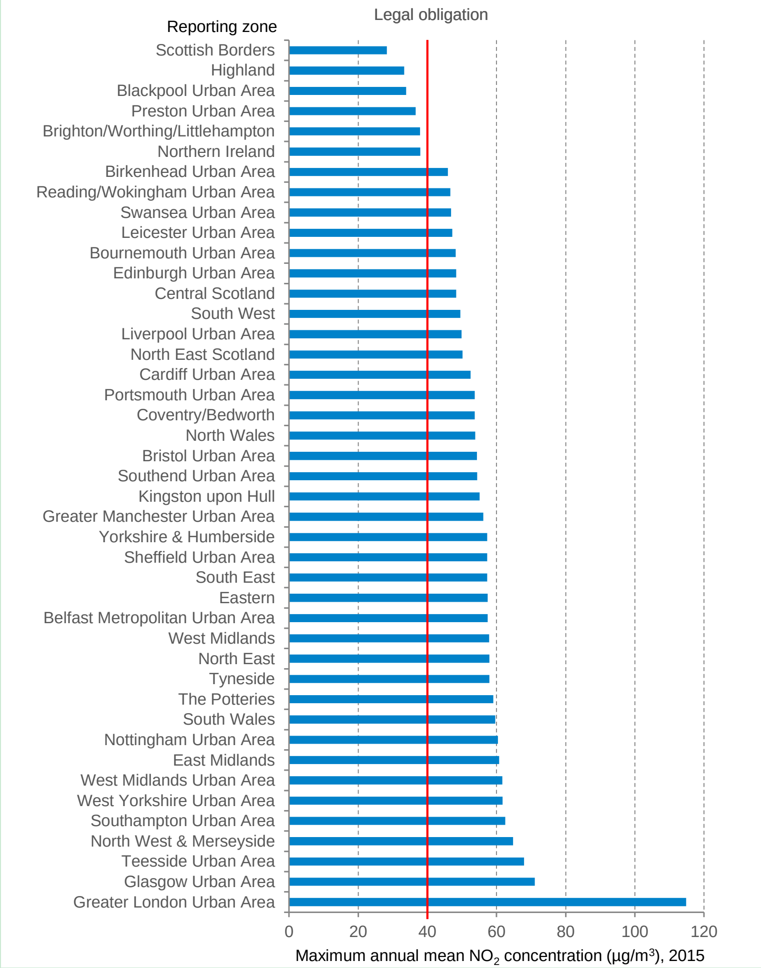


Table **Ex.2** presents the results of this modelling to show the projected number of reporting zones not in compliance between 2017 and 2030. However, it is important to stress that these estimates of future air quality are subject to a level of uncertainty.

Table Ex.2: Number of zones[I] projected to be non-compliant with the limit value for NO_2 assuming no additional policy interventions to those currently in place[II]

Year	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
No. of zones	37	36	34	31	22	18	9
Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
No. of zones	3	3	3	1	1	1	1

[I] Out of the total 43 reporting zones.

[II] These projections are based on COPERT 5 emission factors. If Euro standards are less effective than predicted (as has been the case with historical real-world operations), the number of non-compliant zones will be higher.

Identifying options for improving air quality

Given the scale of the challenge, a diverse range of policy options to reduce NO_2 concentrations were considered; a list of 60 possible options were narrowed down to eight shortlisted options using the best available evidence and expert judgement. The shortlisted options were considered to be the most effective options for reducing NO_x emissions according to three critical success factors: air quality impact, timing to impact and deliverability.

To help prioritise and shape the eight options a high level assessment of the theoretical maximum technical potential (MTP) was undertaken. The MTP indicates the theoretical maximum reduction in NO_2 concentration that could be the result of a particular option. Crucially, this assessment fails to take account of potential real-world constraints such as market capacity, practical deliverability and associated costs of implementation. Thus, exploration of the MTP informed the scale of each option that could feasibly be introduced.

This work fed into the process of identifying a range of feasible policy options. The key conclusions from this analysis were that support for retrofitting vehicles, scrappage, and Ultra Low Emission Vehicles would look to be targeted to focus benefits in non-compliant areas and therefore maximise efficiency of the options. For example, the MTP scrappage option looked at scrapping all pre-Euro 6 diesel cars. This would involve scrapping almost a quarter of the UK car fleet, at a cost of £60 billion. Delivering and implementing a scheme of this scale was considered infeasible given the number of vehicles involved. Instead, it was used as an initial step in the process of defining more feasible variants of the shortlisted options to take forward for further analysis.

Each of the shortlisted options can have notable overlaps. To reflect these connections the list of options can be separated into three broad groups:

- **Clean Air Zones (CAZs):** a CAZ defines an area where targeted action is taken to improve air quality as well as being prioritised and coordinated in a way that delivers improved health benefits and supports economic growth. This option looks at expanding the number of CAZs to all areas of exceedance where they could feasibly be implemented, reflecting the latest evidence on emissions from diesel vehicles.

- **National actions to support Clean Air Zones:** comprising national action undertaken to aid the transition to effective CAZs.

- **Supplementary national options:** to cover identified options that are complementary to the improvements delivered through CAZs.

Assessing the shortlisted options

In addition to reducing NO_2 concentrations, the options identified have a range of additional impacts. The most significant impacts that have been assessed are: the health improvements; public costs and benefits (including operating costs and traffic flow improvements); costs to central Government (in setting up and running options); greenhouse gas emissions; and the potential impact on economic growth. In order to quantify these impacts, a cost-benefit analysis for each proposed option was conducted over a ten-year appraisal period, consistent with Government appraisal guidance.

As far as possible, the identified impacts were monetised using consistent valuation approaches:

- Health benefits have been valued to reflect the latest health evidence of the impacts linked to NO_2. A monetary value has been placed on health outcomes associated with changes in air pollution emissions.

- Wider societal impacts have been valued through several techniques tailored to the specific nature of the impact (e.g. time saving). The most significant of these uses the Fleet Adjustment Model (FAM), which quantifies the societal costs and benefits associated with changes in the UK’s vehicle fleet composition (number of vehicles by age, vehicle type, and fuel type).

- Government costs associated with an option mainly reflect implementation costs and have been estimated using available evidence and information from similar schemes.

- Changing levels of greenhouse gas (GHG) emissions have been valued using the social cost of carbon following BEIS guidance. This is a comprehensive estimate of the long-term damage done by a tonne of carbon dioxide (CO_2) emissions in a given year.

- Economic growth potential has been assessed qualitatively as this stage by identifying the likely short-term and long-term economic impacts (e.g. employment, demand for services) of each option.

Clean Air Zones

Clean Air Zones (CAZs) are geographically defined areas in urban environments where action is focused to improve air quality by encouraging any group of local initiatives to improve air quality. They fall into two categories, non-charging and charging. In non-charging CAZs, a range of local actions on any source of air pollution could be instigated, such as car sharing, cycling schemes, or park and ride schemes.

In addition to the actions described above, charging CAZs place additional access restrictions on vehicles that do not meet the set standards of the zone by requiring them to pay a charge to enter. Charges are not a required part of CAZ proposals, but as part of the CAZ framework a consistent approach has been established for charging zones entailing four classes of access restriction. These provide an element of flexibility to tailor the framework to the problems faced in particular areas. These different classes place constraints on different types of vehicles. To define which vehicles face a charge, standards for each type of vehicle have been set based on Euro standards. These standards define the acceptable limits for exhaust emissions of new vehicles. The latest Euro 6 standard is projected to deliver a significant reduction in NO_x emissions from vehicles[1]. Purely for the purposes of this analysis, it has been assumed that the CAZs include charging schemes – however this would only be expected where equally effective alternatives are not identified.

---

[1] It is noted that these assessments are based on the latest emission standards reflecting the recent international evidence on the performance of Euro 6 in real world conditions.

National actions to support CAZs

It is recognised that the type of changes required to deliver compliance could disproportionately impact a number of individuals. In order to mitigate these impacts and support the transition to CAZs three national supporting options have been considered: retrofit, scrappage and the support for Ultra Low Emission Vehicles (ULEVs).

The **retrofit** option would entail the installation of selective catalytic reduction (SCR) technology for buses and heavy goods vehicles (HGVs) and liquefied petroleum gas (LPG) technology for black cabs. This policy considers retrofit for around 6,000 buses, 4,400 black cabs, and 2,000 HGVs by 2020. This is considered feasible given current market capacity.

Retrofitting for buses is well established; however, there may be challenges in successfully extending retrofitting to other types of vehicles in terms of both technological capability and market capacity to meet required demand. Based on previous schemes, which have proved to be successful in promoting retrofit, it is envisaged that a retrofit grant scheme would need to be established where organisations could bid for funding to retrofit vehicles with accredited technology.

The **scrappage** option assumes a national level scheme is introduced targeting drivers of older diesel and petrol cars, which emit substantially more pollution per kilometre than newer vehicles. It is assumed that around 15,000 vehicles (9,000 diesel and 6,000 petrol vehicles) are scrapped and replaced with new Battery Electric Vehicles (BEVs) during a one-year scheme. A targeted scrappage scheme of this type would improve air quality by amplifying fleet turnover so that highly polluting vehicles are scrapped sooner than they would have been if no intervention took place.

The **promotion of Ultra Low Emission Vehicles (ULEVs)** option would seek to extend the existing plug-in car grant set up by Government which incentivises the adoption of ULEVs, comprising both battery operated vehicles and plug-in hybrid electric vehicles. By securing additional funding, it is envisaged that around 160,000 ULEVs would be purchased over a three-year period. As ULEVs have low NO_x emissions, air quality improvements stem from the assumption that each additional ULEV is replacing a conventional car.

Promotion of ULEVs is expected to support economic growth in the short term by encouraging the ULEV market and there is expected to be a substantial reduction in greenhouse gas emissions. Despite this, the additional cost of the grant to Government significantly overshadows the estimated benefits to society. However, it should be noted that there are a range of non-monetised benefits (e.g. increased public understanding, acceptance of electric vehicles) associated with the early uptake of ULEVs that have not been considered as part of this assessment.

Supplementary national options

In addition to the improvements that can be delivered through adapting the UK Air Quality Plan for tackling nitrogen dioxide (published in 2015) a range of supplementary additional measures have been assessed. This is especially important as not all areas in exceedance of NO_2 concentration limit levels can be readily addressed through Clean Air Zones. In these cases, options applied on a national scale are required to help reduce NO_2 concentrations or to reduce the period of non-compliance. The options identified in this category are: introducing speed limits on the strategic road network; improving the standard of Government vehicle purchases; and encouraging changes in driving behaviour.

Speed related emission curves suggest that vehicles travelling at high speeds emit greater levels of NO_x the faster they travel. Therefore, there may be potential to improve air quality by lowering **speed limits**. The speed limits option would seek to tackle lengths of motorway experiencing poor levels of air quality. For this option, the effect of reducing the motorway speed limit from 70 to 60mph has been simulated by modelling a reduction in the average speed (by 10mph) of affected vehicles. This change is assumed to have no impact on congestion, which is also a notable determinant of air pollution. There is uncertainty in this area and the evidence would benefit from further monitoring in real world conditions: for example, at sites where variable speed limits are used already for traffic smoothing purposes, to understand better the extent of the impact any change to speed limits might have on air quality.

The option to improve the standard of Government vehicles would involve updating the **Government Buying Standards for transport** (GBS-T) to account for NO_x and PM impacts, in order to guide the procurement process. It is anticipated that this option will gradually replace the Government fleet with cleaner vehicles with diesel vehicles only being bought as a last resort. The policy is limited by the fact that low NO_x alternatives do not exist for certain specialist vehicles (e.g. fire engines) and because it has only been applied to central Government.

Behavioural change has been considered through two indicative options: vehicle labelling, which attempts to change consumer behaviour at the point of purchase; and influencing driving styles, which could use education and technology to encourage more environmentally friendly driving techniques.

Vehicle labelling would improve air quality by encouraging a shift of purchasing behaviour away from new diesel vehicles to alternative vehicle types. This would involve an expanded labelling system, which would include information on air pollutants, in addition to already existing information on fuel consumption and carbon dioxide emissions. The modelled scenario assumes a 0.5% shift in purchasing decisions away from new diesel cars to new petrol cars annually. The cost to Government of this option is assumed to be negligible as a labelling review is already taking place.

Influencing driving styles would seek to tackle excessive speeds and harsh acceleration, which are known to increase NO_x emissions. It would teach and reinforce economical driving practices through driving style training. The option assumes that 100,000 drivers would be trained by 2019 with a percentage reduction in distance travelled used as a proxy to estimate the impacts of the option. With both options outlined to achieve behavioural change, it is important to recognise that there are notable non-quantifiable benefits, but that these come with unpredictability in the ability for Government to achieve the desired impact, as behavioural responses are uncertain.

Summary of results

From the options considered, establishing Clean Air Zones (CAZs) is the most effective way to bring the UK into compliance with NO_2 concentration levels in the shortest possible time (Table **Ex.3**).

For each option, the estimated air quality impact is presented for the first year of the anticipated implementation of the policy to show the earliest point at which each option will begin to have an impact. As the options have different implementation dates and magnitudes of impact that are felt in varying proportions over time, the total reduction in NO_x emissions arising from each option over its ten year appraisal period is also provided to enable a consistent comparison.

The ten-year appraisal period for each option is different according to their specific start dates. The appraisal period generally begins in the year where the first actions are taken to implement the policy option. However, air quality impacts may only be exhibited after the start of the appraisal period for some options due to the setup time involved with their implementation.

Table Ex.3: Summary of analysis results for each option to improve UK air quality			
Brief description of option	**First year NO_2 concentration reduction**[I]	**Total reduction in NO_x emissions**[II]	**Net present value**[III]
Clean Air Zones[IV] Expansion from 5 CAZs, plus London, to a further 21	8.6µg/m^3 in 2020	24kt over ten years	£1,100m
Retrofit Retrofitting of buses, HGVs and black cabs between now and 2020	0.09µg/m^3 in 2019	10kt over ten years	£270m
Scrappage National scrappage to electric cars and vans	0.008µg/m^3 in 2020	0.4kt over ten years	-£20m
Ultra Low Emission Vehicles (ULEVs) Provide additional support to purchasers of ULEVs	0.008µg/m^3 in 2017	2kt over ten years	-£20m
Speed Limits[V] Reduce average speeds from 70 to 60mph on sections of motorways with poor air quality	Up to 2.5µg/m^3 in 2021	Up to 0.05kt over ten years	-£25m to -£32m
Government Buying Standards Encouraging purchases of new petrol cars instead of diesel cars	0.0005µg/m^3 in 2018	0.1kt over ten years	£0.13m
Vehicle Labelling Air quality emissions information on new car labels	0.004µg/m^3 in 2018	0.7kt over ten years	£12m
Influencing Driving Style Training and telematics for 100,000 car and van drivers (<0.5% of fleet) by 2019	0.01µg/m^3 in 2019	0.35kt over ten years	£12m

[I] Reduction in average NO_2 concentrations in the first year where air quality impacts are expected to arise as a result of the implementation of the option. This is relative to the baseline projection for the option in the particular year specified.

[II] Total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period. This is in comparison to the baseline projection for the option over the same ten-year appraisal period.

[III] A discount rate is used to convert all costs and benefits to 'present values' so that they can be compared. The net present value calculates the present value of the differences between the streams of costs and benefits associated with the option.

[IV] Clean Air Zones are assumed to be implemented in 27 non-compliant areas in 2020. This represents the average reduction in the maximum concentration for these areas in 2020.

[V] Speed limit impacts are shown just for the <1% of motorway projected to be in exceedance in 2021. These impacts cannot be extrapolated to other roads. All impacts related to air quality are expressed as 'up to *x*' because there is uncertainty over the modelling approach in relation to vehicle speed. The air quality impact of this option is calculated on the assumption that traffic on failing motorway links is travelling at the same speed as the national average (for the type of motorway). It is possible that highly polluted motorway links are busier and more heavily congested, and that average speeds on them are lower. In this case, a change in the speed limit may have little impact on air quality – because cars are already travelling at speeds below the limit. Work is ongoing to improve our understanding of speeds on these links.

UK compliance with annual NO_2 limits is determined at a zonal level. Thus, the size of the reduction in NO_2 concentrations needed to bring forward compliance in non-compliant zones will differ to varying degrees according to local circumstances. Table **Ex.4** displays the lowest concentration abatement required to deliver compliance in zones estimated to have the lowest concentrations of NO_2 above the limit level in 2017 to 2021. Policy options that have impacts on air quality of this magnitude will prove to be the most effective in tackling the air quality challenge.

Table Ex.4: Reduction in NO_2 concentrations needed to bring the marginal zone[I] from non-compliance to compliance with annual NO_2 limits in each year ($\mu g/m^3$)

Year	2017	2018	2019	2020	2021
Number of non-compliant zones	37	36	34	31	22
Concentration reduction needed to bring the zone with the lowest average annual concentration above the concentration limit into compliance	1.7	2.3	1.3	<0.1	0.7

[I] The non-compliant zone that, in a given year, is closest to the compliance boundary.

It is evident that only CAZs are expected to deliver a concentration reduction of sufficient size to achieve the compliance of zones in the shortest time possible. This is with the exception of a single non-compliant zone with the lowest estimated concentration of NO_2 in 2020. This zone contains a single non-compliant motorway road link where it might be possible to achieve compliance by reducing speed limits, through targeted retrofit, scrappage, or support for Ultra Low Emission Vehicles. The results of the analysis set out in this technical report are being used to inform policy development for the final UK Air Quality Plan for tackling nitrogen dioxide.

Distribution of effects across population groups

Whilst cost-benefit analysis allows a transparent assessment of the streams of costs and benefits associated with an option, it does not show how different groups in society may be affected. There is likely to be unequal health and financial implications for diverse groups.

Studies provide evidence to suggest that the highest pollution concentrations occur disproportionately amongst the most deprived areas, with inequality generally being the greatest in urban areas with the highest levels of NO_2 and PM. However, on average, air quality is poor even in areas of London that are generally considered affluent, such as Westminster. This accords with the overall national distribution of air pollution with highest average levels in the South East and lowest in the North of England, Scotland, Wales, and Northern Ireland.

CAZs will typically be implemented in cities experiencing high concentrations of NO_2. Specific groups within these urban populations, such as those heavily reliant on the oldest cars or those who make frequent use of buses, may be impacted more by the costs associated with CAZs.

Uncertainties

Uncertainty is inherent with any assessment of the future. Acknowledging the inevitable uncertainties and its associated risks forms an important step in understanding the relative strengths and weaknesses of the approach taken to model air quality and assess the impacts of the proposed options.

The modelling uncertainties associated with the analysis undertaken can be broadly categorised as: uncertainties in the modelling of air quality and resulting future predictions, and uncertainties in the modelling of policy options to improve air quality, including their influence on behaviour. In many cases, a number of assumptions have been employed and an assessment into the robustness of these assumptions allows an identification of the limitations of the results. An amount of noise surrounds some of the measurements used to inform these assumptions, although this is unlikely to drive fundamental changes in the nature of the proposed options. It is assumed that real world emissions reflect the latest evidence on vehicle emissions. However, there is considerable uncertainty about this and if standards are less effective than predicted (as with historical real-world emissions), the impact of the options could be greater than the estimates presented here. Further, there are uncertainties surrounding the quantification and valuation of air quality impacts, particularly on human health. The Committee on the Medical Effects of Air Pollutants (COMEAP) continues to work on scientific evidence to achieve a better understanding of this relationship.

Given this range of uncertainties, the aim of this report is to use the best evidence and data sources currently available to help guide decision-making on appropriate and proportionate assessments. The net present value estimates and cost-benefit analysis aim to do this, but it should be recognised that these estimates are only as robust as the inputs used to produce them. Thus, the values presented could change substantially as new evidence emerges; including the potential to shift some currently positive net present value estimates to negative estimates.

A notable part of this uncertainty is driven by the local circumstances in each area. In order to improve this, locally led reviews to develop more specific modelling and measures will be undertaken. The results of this local level assessment and evidence will then be used to inform the national evidence base.

These inherent uncertainties provide motivation to continually develop the knowledge, evidence, and monitoring of air quality so that an expanding high-quality evidence base can be achieved. In doing so, uncertainties can be reduced in a multi-faceted way, thus gradually building confidence in the way intervention options can be implemented effectively.

Future steps

In light of the need to continually improve the air quality evidence base, a series of actions will be taken to facilitate this requirement. Primarily, for the final UK Air Quality Plan for tackling nitrogen dioxide, updated PCM modelled projections will be available and will take account of the latest evidence. Further analysis of the final package, combining different intervention scenarios, will provide greater insight into the impacts of the options.

It is important that implementation of any of the measures outlined is accompanied by a detailed system to assess performance, including comparisons to the progress in areas where no action has been undertaken. Further consideration will also be given to the more general evaluation methods, data collection requirements, and stakeholder feedback mechanisms that will be necessary to conduct effective evaluations of the package. The integration of these rigorous evaluation routes will provide an adaptive approach whereby actions can be adjusted to respond to emerging evidence appropriately.

1. Introduction

This technical report accompanies the consultation on the Draft UK Air Quality Plan for tackling nitrogen dioxide (hereafter referred to as the 'draft Plan'). It is intended to support the consultation document and the draft Plan document.

1.1 The air quality challenge

There is increasing evidence that air quality has an important effect on public health and on the environment. The Department for Health has identified air pollution as one of the biggest health risks across the UK[2]. It has greatest effects on the elderly, people with pre-existing lung and heart conditions, children, and people on lower incomes[3]. Emerging evidence is linking cognitive decline and dementia with air pollutants[4] and it is plausible that these effects are linked to longer-term exposure. There is still considerable uncertainty about the magnitude of health effects but the balance of current evidence and most emerging research tends to increase the evidence of pervasive effects of air pollution on human health.

In addition to affecting health, air quality also affects the environment. In 2013, 44% of sensitive habitats across the UK were estimated to be at risk of significant harm from acidity and 62% from nitrogen deposition[5]. It has also been found that ozone (formed by the reaction between nitrogen oxides and non-methane volatile organic compounds – see Box **1.1**) has a number of effects including on human health (respiration), ecosystems (reducing carbon uptake and biomass in sensitive plants and trees) and on agriculture (where crop production has been found to be reduced

---

[2] Department for Health, '*Public Health Outcomes Framework Impact Assessment'*, 2011 <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/485100/PHOF_IA_acc.pdf >

[3] World Health Organization, '*Review of evidence on health aspects of air pollution – REVIHAAP Project'*, 2013 <http://www.euro.who.int/__data/assets/pdf_file/0004/193108/REVIHAAP-Final>.

[4] M. C. Power et al., 'Exposure to air pollution as a potential contributor to cognitive function, cognitive decline, brain imaging, and dementia: A systematic review of epidemiological research', *Neurotoxicology*, 2016 Sep (2016), pp.235-253 <https://www.ncbi.nlm.nih.gov/pubmed/27328897>.

[5] Based on a 2012-2014 three-year average. Department for Environment, Food & Rural Affairs, 'Modelling and mapping of exceedance of critical loads and critical levels for acidification and eutrophication in the UK 2013-2016', 2016 <https://uk-air.defra.gov.uk/library/reports?report_id=925>.

by up to 9%)[6]. Further research is required to improve understanding of the human, ecosystem, and agricultural health effects of air pollution, meaning the evidence is therefore subject to change. Nevertheless, the evidence indicates that air pollution is an important public health issue.

Pollution comes from many sources and there are several different air pollutants. These pollutants behave differently when in the atmosphere and can undergo chemical reactions with each other (Box **1.1**).The main pollutants include nitrogen oxides (NO_x), particulate matter (PM_{10} and $PM_{2.5}$), sulphur dioxide (SO_2), ammonia (NH_3) and non-methane volatile organic compounds (NM-VOCs).

Box 1.1: An overview of the health effects of different pollutants

Nitrogen oxides (NO_x)

NO_x emissions are made up of both nitrogen dioxide ('primary' NO_2) and nitric oxide (NO) and are primarily formed from domestic (boilers, wood burners), industrial (manufacturing and construction) and road transport (engines) combustion processes. NO reacts with oxidants such as ozone to form NO_2 in the atmosphere ('secondary NO_2'). Short-term exposure to concentrations of NO_2 higher than 200µg/m^3 can cause inflammation of the airways. NO_2 can also increase susceptibility to respiratory infections and to allergens.

It has been difficult to identify and quantify the direct health effects of NO_2 at ambient concentrations because it is emitted from the same sources as other pollutants such as particulate matter (PM). The evidence associating NO_2 with health effects has strengthened substantially in recent years. Studies have found that both day-to-day variations and long-term exposure to NO_2 are associated with increased mortality and morbidity.

Evidence from studies that have corrected for the effects of PM is suggestive of a causal relationship, particularly for respiratory outcomes. The Committee on the Medical Effects of Air Pollutants (COMEAP) continues to consider the estimate of the health impact of NO_2.

Particulate matter (PM_{10} and $PM_{2.5}$)

Primarily from combustion in industry and road transport, particularly from diesel vehicles (PM_{10}). Also formed by the chemical reaction of other pollutants, such as NO_2 or ammonia (NH_3).

Fine particulate matter can penetrate deep into the lungs and research in recent years has strengthened the evidence that both short-term and long-term exposure to $PM_{2.5}$ are linked with a range of negative health outcomes including (but not restricted to) respiratory and cardiovascular effects. COMEAP estimated that the burden of anthropogenic particulate air pollution in the UK in 2008 was an effect on mortality equivalent to nearly 29,000 deaths. The burden can also be represented as a loss of life expectancy from birth of approximately six months.

[6] Ozone factsheets produced by the Natural Environment Research Council, Centre for ecology and Hydrology and the Science & Technology Facilities Council are available at <http://www.ozone-net.org.uk/factsheets>.

Sulphur dioxide (SO_2)

Arises primarily as a result of fuel combustion from power stations (for heat and electricity) and to a lesser extent, road transport. A respiratory irritant that can cause constriction of the airways. People with asthma are considered to be particularly sensitive. Health effects can occur very rapidly, meaning short-term exposure to peak concentrations can have significant effects.

Ozone (O_3)

A respiratory irritant formed by reactions between non-methane volatile organic compounds and nitrogen oxides in the presence of sunlight. Short-term exposure to high ambient concentrations of O_3 can cause inflammation of the respiratory tract and irritation of the eyes, nose, and throat. High levels may exacerbate asthma or trigger asthma attacks in susceptible people and some non-asthmatic individuals may also experience chest discomfort whilst breathing. Evidence is also emerging of negative health effects due to long-term exposure. In addition, O_3 is a greenhouse gas contributing to climate change.

Non-methane volatile organic compounds (NM-VOCs)

Emitted to air from the use of solvents (such as in paints, fuel and pesticides), extraction and distribution of fossil fuels and from combustion processes primarily from domestic wood burning, but are also emitted from diesel exhaust. Significantly, NM-VOCs react with NO_x in the presence of sunlight to form ground-level O_3. The health effects of volatile organic compounds themselves (putting aside their role in O_3 formation) can vary greatly according to the compound, which can range from being highly toxic to having no known health effects.

Sources: Adapted from Air pollution in the UK 2015[7] and the National Atmospheric Emissions Inventory webpages[8].

Each of these pollutants is produced in different proportions by different sources and up to 7.5% of the urban NO_x in the UK can come from outside the UK. Many normal activities contribute to poor air quality (Fig. **1.2**) and therefore tackling air quality means changing the way people have become used to living and working. Road vehicles contribute about 80% of NO_2 pollution at the roadside and growth in the number of diesel cars[9] has exacerbated this problem.

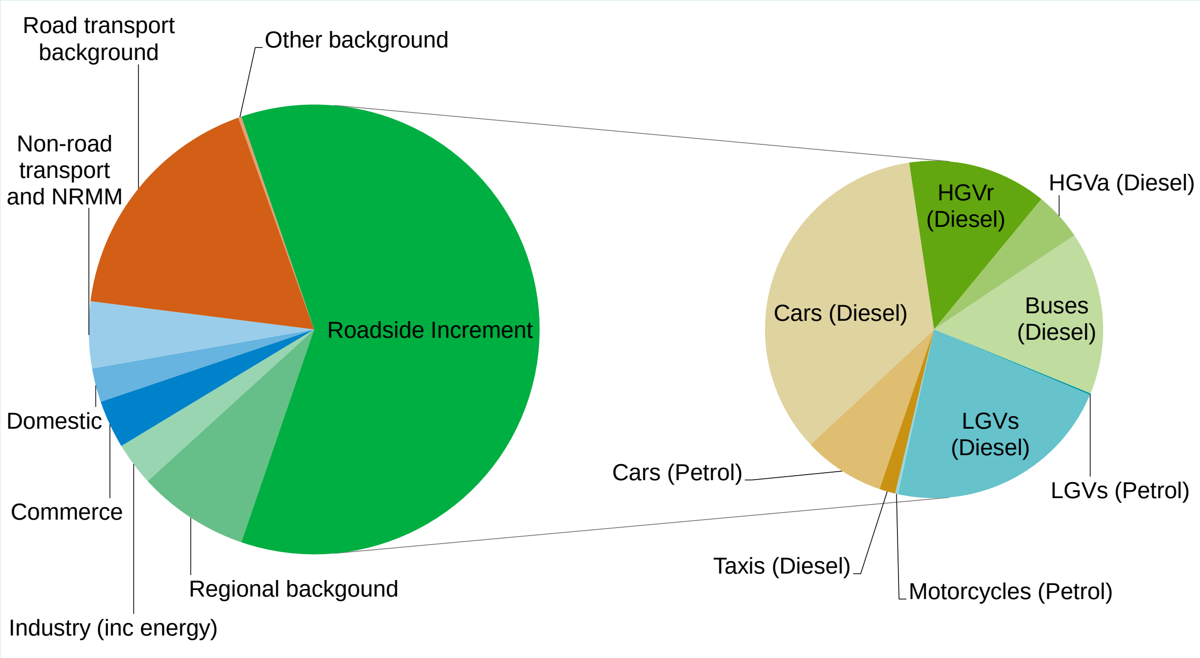
---

[7] Department for Environment, Food & Rural Affairs, *'Air pollution in the UK 2015'*, 2016 <https://uk-air.defra.gov.uk/library/annualreport/viewonline?year=2015_issue_1>.

[8] National Atmospheric Emissions Inventory, Overview of air pollutants, <http://naei.defra.gov.uk/overview/ap-overview>.

[9] Department for Transport, *'Vehicle Licensing Statistics: Quarter 4 (Oct – Dec) 2015'*, 2016 <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/516429/vehicle-licensing-statistics-2015.pdf>.

Figure 1.2: UK national average NO_x roadside concentration apportioned by source of NO_x emissions, 2015



Note: The 'Roadside Increment' in the large pie chart is the estimate of the proportion of local NO_x roadside concentrations contributed by local traffic, which is shown in greater detail in the smaller pie chart. NRMM = Non-Road Mobile Machinery; LGV = Light Goods Vehicles; HGVr = Rigid Heavy Goods Vehicles; HGVa = Articulated Heavy Goods Vehicles.

1.2 Regulatory framework

The UK has national and international obligations that require us to reduce air pollution[10]. The legal requirement for NO_2 stipulates that the annual average concentration of NO_2 needs to be less than 40μg/m^3 across a whole year within all 43 reporting zones of the UK (Fig. **1.3**)[11].

[10] For UK legislation see the Air Quality Standards Regulations 2010 (SI 2010/1001), the Air Quality Standards (Scotland) Regulations (SSI 2010/204), the Air Quality Standards (Wales) Regulations 2010 (SI 2010/1433) and the Air Quality Standards Regulations (Northern Ireland) 2010 (SR 2010 No 188), as amended.

[11] This limit value of 40μg/m^3 is based on WHO air quality guidelines.

Figure 1.3: UK air quality reporting zones; for monitoring and reporting air pollution the UK is divided into agglomeration zones (major urban areas) and non-agglomeration zones

The system currently used to report air quality information and to assess legal compliance has been approved by the European Commission. In many other European countries, compliance is measured using denser networks of monitoring stations than are used in the UK, as these countries choose not to use supplementary modelling for compliance reporting. Consequently, those countries report empirical data whereas the UK reports the outputs of models alongside monitoring data. The modelling approach is used in the UK because it provides a more complete assessment of air quality and consistency for modelling future scenarios of air quality integral to assessing the proposed measures presented in this draft Plan.

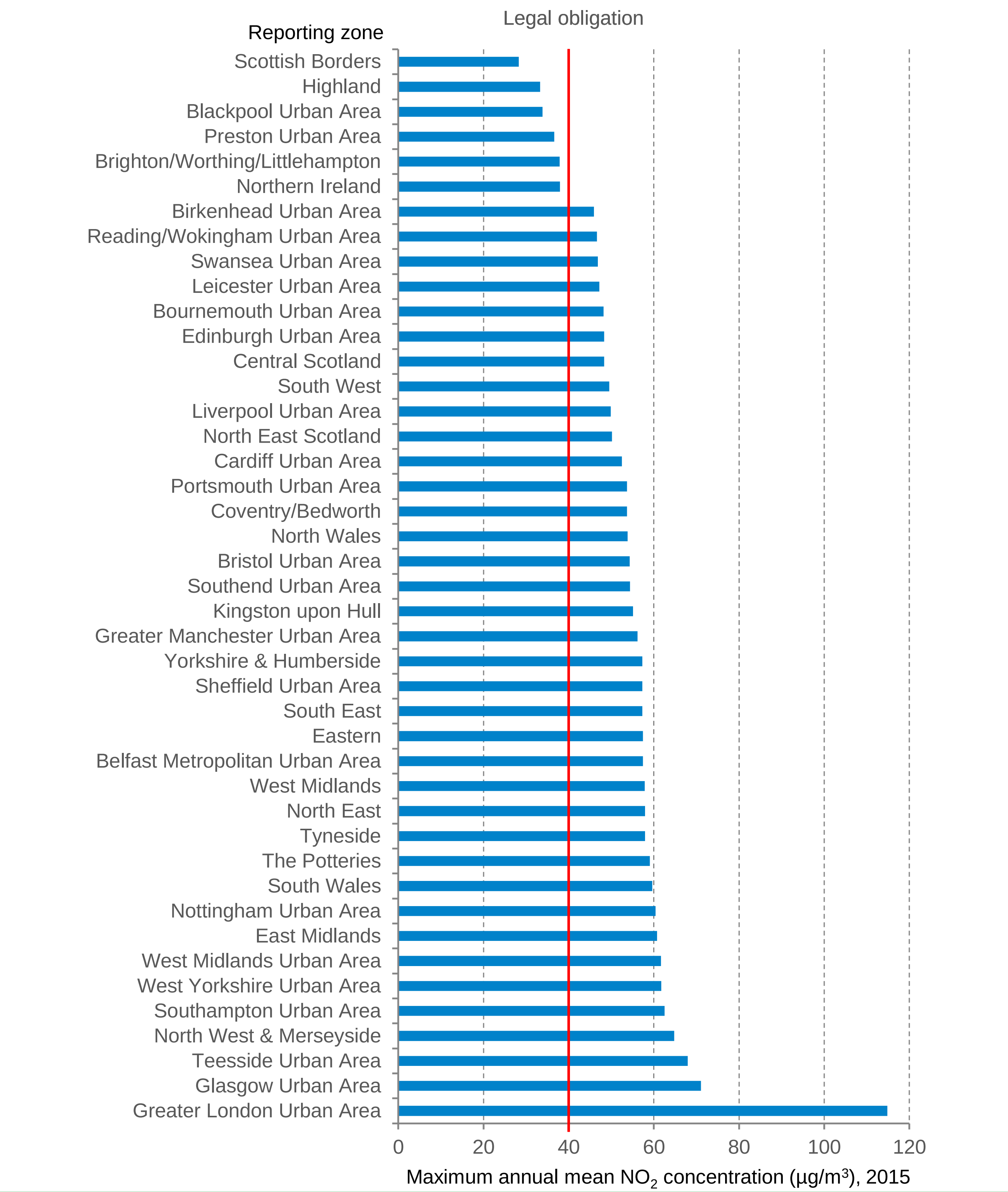
The UK Government and its counterparts in Scotland, Wales, and Northern Ireland have policy responsibility for air quality in England, Scotland, Wales, and Northern Ireland respectively. However, air quality evidence remains UK-wide. In particular, for compliance reporting a single assessment of air quality across the UK is made. The devolved administrations and Local Authorities may supplement UK evidence with evidence of their own. Modelling of options in the Technical Report is UK-wide. Ultimately, the UK Government, the Scottish Government, the Welsh Government and the Department of Agriculture, Environment and Rural Affairs in Northern Ireland will each decide on the policies to introduce for exceedances in their areas.

In 2015 (the latest year for which a compliance assessment is available), 37 of the 43 air quality reporting zones exceeded the statutory annual mean limit for NO_2 (Fig. **1.4**).

1.3 Goal

The consultation, supported by this technical report, focuses on how to reduce concentrations of NO_2 quickly in those areas currently exceeding the limit so as to meet legal limits in the shortest time possible. However, it is recognised that this represents only a first step towards reducing air pollution because, for some pollutants like NO_2, there is currently no known lower limit to the adverse effects on human health. Consequently, this technical report is structured to ensure that evidence-based solutions are established quickly and that, by establishing these solutions, data gathered is used continuously to refine the regulatory interventions used to improve air quality. By improving concentrations of NO_2, this draft Plan will also help to reduce particulate matter (PM_{10} and $PM_{2.5}$).

Figure 1.4: Maximum annual mean NO_2 concentration (µg/m^3) for each UK reporting zone, 2015



1.4 Uncertainty

This document supports the draft Plan. In doing so, it is making explicit the uncertainties that exist in the evidence about the measurement of air quality and its impacts on human health. The identification of these uncertainties is not a justification for inaction but a rationale for swift implementation and ongoing evaluation of policies. There are areas of high uncertainty around certain inputs and assumptions, and for many of these it will take years of research to reduce the uncertainties. For some the uncertainties can only be reduced by implementing the final UK Air Quality Plan for tackling nitrogen dioxide (hereafter referred to as the 'final Plan'), measuring the outcomes and then, where necessary, adapting the final Plan in the future based on increased knowledge of how well the final Plan has performed against expectation.

An Air Quality Review Group has been established by the Defra Chief Scientist to provide wider assurance of the evidence as it is developed for the final Plan. A particular consideration has been how to take account of and communicate the uncertainties related to the technical report. The Air Quality Review group has recommended that for the final Plan the assessment of uncertainties should be aligned with guidance[12] from the Intergovernmental Panel on Climate Change (IPCC). This will ensure consistent communication of how different sources of uncertainty compare. The uncertainties in this document have not been assessed or presented in this way at this point; as outlined in Section **9.1.3**, this will be developed and incorporated in the final Plan.

This technical report is an important step towards building greater understanding of the impacts of different policy options on air pollution and the most effective ways of managing air quality. Systematic measurement of the performance of interventions to control air quality will be used to adjust and improve the range of controls and thereby incrementally build confidence in which methods are most effective.

In order to design policies that have the highest likelihood of being effective, given what is currently known, Defra has used its air quality model to make projections about future levels of NO_2. The model was designed to assess compliance and not to provide projections of future air quality, but its outputs have been adapted for this purpose.

[12] Intergovernmental Panel on Climate Change, *'Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties'*, 2010 <https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf>.

1.5 Actions to improve air quality

Road transport measures are likely to result in the most effective way of improving NO_2 concentrations. This could include three types of change:

- Removal of vehicles from the road by investing in public transport and alternative modes of transport such as walking or cycling.
- Reducing emissions from existing vehicles by fitting abatement equipment or encouraging better driving styles.
- Replacing vehicles with cleaner alternatives.

Policy options include regulation, subsidies, taxation, information provision, market creation, and direct supply. This report presents the rationale for the choices of options proposed to improve air quality across the UK.

2 Air quality assessment

This section of the report describes the methods used to monitor and model air quality.

2.1 Methods

Air quality in the UK is assessed using a combination of direct measurements and modelling of how different chemical pollutants are transported and transformed in the atmosphere. This provides an estimate of the historic and projected annual average levels of pollution on a 1 km grid scale across the whole of the UK, and for around 9,000 individual roads. This estimation system is designed to provide the information needed to assess whether the UK is complying with the need to maintain the concentration of pollutants below specified levels (known as limit values) within 43 reporting zones.

This estimation system is built on a four-step process involving data collection, modelling and analysis, calibration, and validation:

(1) Data is collected regarding the distribution, abundance, and magnitude of sources. These are compiled into the National Atmospheric Emissions Inventory (NAEI)[13]. Many of the industrial sources are fixed and the owners of these assets provide information about their latest emissions to the relevant inventory agency[14] under the statutory terms of their licences. This includes industrial plants and power stations. Other emissions, for example from households, are estimated based on the Digest of UK Energy Statistics (DUKES) provided by the Department for Business, Energy and Industrial Strategy (BEIS)[15]. Emissions from vehicles are estimated using a combination of the traffic model used by the Department for Transport (DfT)[16] and

---

[13] National Atmospheric Emissions Inventory <http://naei.defra.gov.uk/>.

[14] The agencies are the Environment Agency (England), Natural Resources Wales, Scottish Environment Protection Agency and Northern Ireland Environment Agency.

[15] Digest of UK Energy Statistics <https://www.gov.uk/government/organisations/department-of-energy-climate-change/series/digest-of-uk-energy-statistics-dukes>.

[16] Department for Transport, Transport appraisal and modelling tools, 2012 <https://www.gov.uk/government/collections/transport-appraisal-and-modelling-tools>.

emissions from individual vehicle types from the Computer Programme to calculate Emissions from Road Transport (COPERT – see Box **2.1**). The latest version, COPERT 5, is used for this assessment and this takes into account the newest real-world emissions standards developed after the Volkswagen emissions issue[17]. Projections of future emissions are built on this historical assessment based on the projected change in the number and type of vehicles using the road (provided by a simplified road traffic emissions model, from DfT[18]), and COPERT emission factors. Future activity data for the energy sector is provided by BEIS[19].

(2) Emission sources are distributed within Geographical Information System (GIS) layers. Deterministic dispersion models specific to each pollutant are used to simulate atmospheric mixing and to generate background concentrations for different pollutants. The climatology is obtained from the UK Meteorological Office annual average metrology for the relevant year, based on the data from the Met Station at RAF Waddington. This modelling provides an un-calibrated estimate of the distribution of atmospheric pollutants including NO_2 on a 1km x 1km grid and for individual roads. Collectively, this is known as the Pollution Climate Mapping (PCM) model and is operated on behalf of Defra by Ricardo Energy & Environment (see Annex **A** for quality assurance information).

An additional GIS layer is used to model the local roadside concentration of pollutants at a finer scale for urban major road links (n=~9,000), as defined by DfT's road classifications[20]. The model assesses concentrations along the stretch of road between junctions with other major roads (A-roads or motorways), consistent with the legislative requirements. Individual traffic counts[21] for each of the modelled road links provide the fine-scaled input data.

---

[17] In 2015, it was found that many Volkswagen cars being sold had software in diesel engines that could detect when they were being tested, changing the performance accordingly to improve emission testing results.

[18] Department for Transport, Transport appraisal and modelling tools, 2012 <https://www.gov.uk/government/collections/transport-appraisal-and-modelling-tools>.

[19] Department for Business, Energy & Industrial Strategy, 2015 energy and emissions projections, 2015<https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2015>.

[20] Department for Transport, Road traffic statistics, 2017 <https://www.gov.uk/government/collections/road-traffic-statistics>.

[21] Department for Transport, Traffic counts <www.dft.gov.uk/traffic-counts/>.

This estimate of roadside concentrations is designed to simulate a receptor at approximately 4m from the kerbside. The roadside modelling is carried out using the Atmospheric Dispersion Modelling System (ADMS) Roads dispersion model, taking into account road geometry, meteorology, and traffic behaviour[22].

(3) The modelled estimates are then compared with the direct measurements made at 147 Automatic Urban and Rural Network (AURN) measurement stations across the UK (Fig. **2.2**)[23]. These data are available online through the UK Air Information Resource (UK-AIR). The data from each station are aggregated to an annual mean concentration for each site. The location and density of monitoring stations is greatest within areas where the highest NO_2 concentrations occur to which the population is likely to be exposed for a period which is significant in relation to the limit values[24]. Calibrated measurements are made of nitrogen oxides (NO_x) comprising nitric oxide (NO) and nitrogen dioxide (NO_2); PM_{10} and $PM_{2.5}$ particles; sulphur dioxide (SO_2); benzene; 1,3-butadiene; carbon monoxide (CO); metallic pollutants: arsenic (As), cadmium (Cd), lead (Pb) and nickel (Ni); polycyclic aromatic hydrocarbons (PAH); and ozone (O_3). The un-calibrated modelled outputs are adjusted to provide the best fit to these measurements.

(4) Validation of these calibrated results is then carried out using data from independent air quality monitoring stations operated independently throughout the UK. These data are taken from 'verification sites', which are selected on

[22] Cambridge Environmental Research Consultants, ADMS-Roads <http://www.cerc.co.uk/environmental-software/ADMS-Roads-model.html>.

[23] The methods used to measure gaseous pollutants within the AURN are defined in the relevant legislation. Standard methods of a known certainty (in this case ±15% or better) are required to ensure comparability across the whole network. The measurement methods for NO_2 were EN 14211:2012, *'Ambient air – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence'*, 2012, <http://shop.bsigroup.com/ProductDetail/?pid=000000000030210748>. The number of monitoring sites is subject to a five yearly review.

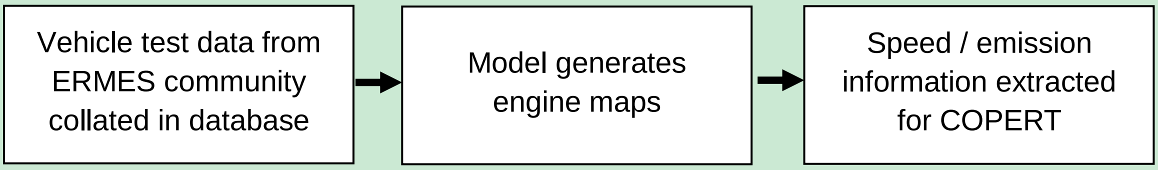
[24] Department for Environment, Food & Rural Affairs, *'Air Quality Assessment Regime Review for the Ambient Air Quality Directive 2008/50/EC'*, 2013 <https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1312171445_UK_Air_Quality_Assessment_Regime_Review_for_AQD.pdf>.

the basis that the data are known to be of good quality and are readily available from public websites[25].

This estimation process provides a historical and projected assessment of air quality (most recently for 2015) but has two significant limitations. First, it takes approximately three months to complete a full model assessment and, second, this means the model cannot be operated over several runs to test the impact of varying individual inputs. Together, these mean that the uncertainty around the modelled estimates is not available.

Box 2.1: COPERT Emission Factors

The air quality modelling in this report is based on the latest 'Computer Program to calculate Emissions from Road Transport' NO_x emission factors (COPERT 5). COPERT emission factors are developed by Emisia - one of the partners of the European Research group for Mobile Emission Sources (ERMES). They are the recommended method for emissions inventory compilation according to international guidelines[26] and are used by the majority of European countries. COPERT emission factors are routinely updated based on the latest vehicle test data, via the following process:



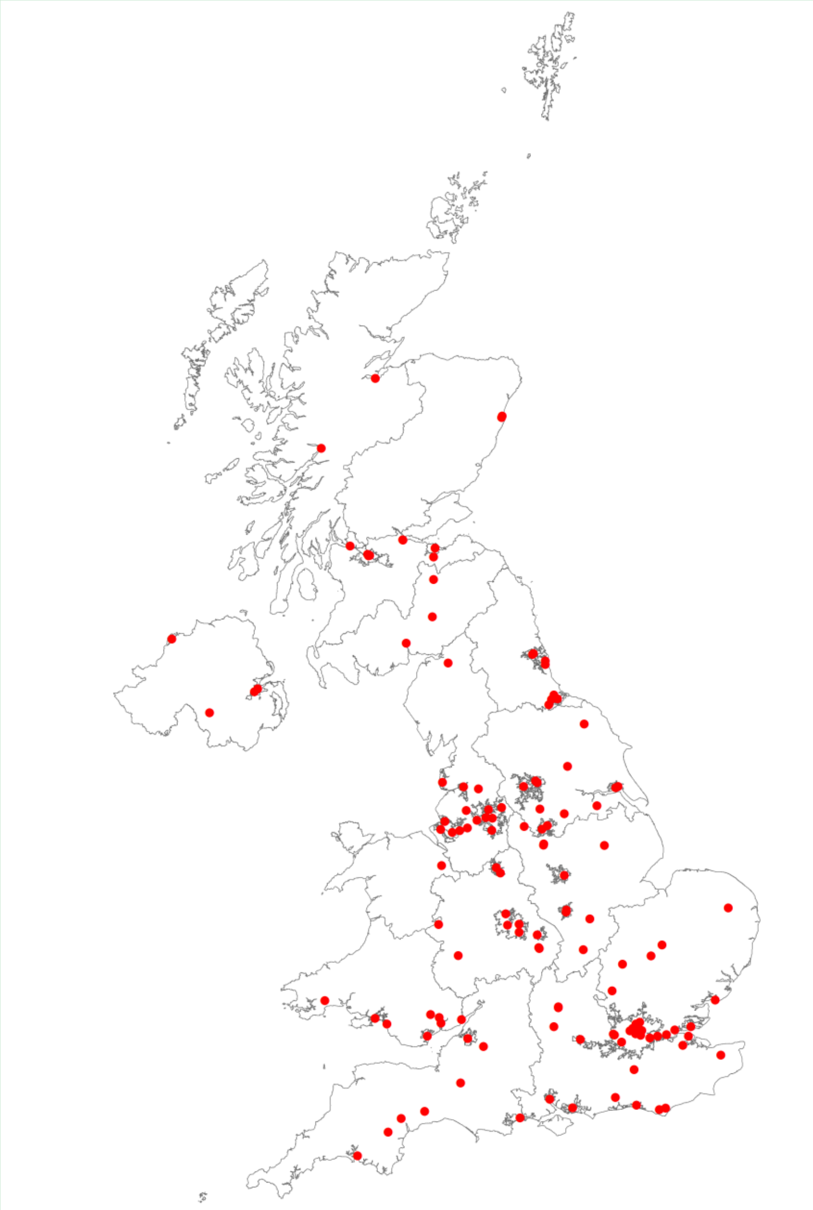
During late 2015 and 2016 widespread vehicle emission testing took place resulting in a body of new evidence (including official vehicle testing programmes of several countries, including France, Germany, and the UK). Results from the UK vehicle emissions testing programme were presented to ERMES and the UK has engaged in ongoing discussions with Emisia.

In light of this new evidence, COPERT 5 was published in September 2016 and included updated NO_x emission factors for Euro 5 diesel LGVs, Euro 6 diesel LGVs and Euro 6 diesel cars.

[25] Local authority monitoring sites that meet the strict siting and methodological requirements of the Directive may be incorporated into the national network and used for model calibration. In other instances, they may be used for verification purposes.

[26] European Environment Agency, '*EMEP/EEA air pollutant emission inventory guidebook – 2016*' 2016 <http://www.eea.europa.eu/publications/emep-eea-guidebook-2016>.

Figure 2.2: UK NO_2 monitoring sites (red dots) with reporting zones, 2015



Source: Ricardo Energy & Environment

The PCM model produces an estimate of the distribution of air quality under a single scenario. This design reflects its original purpose as a tool to provide information about regulatory compliance and not, as here, a tool to support decision making.

However, the Streamlined Pollution Climate Mapping (SL-PCM)[27] model, developed from the full PCM model, may be used to model NO_2 annual mean concentrations for the same ~9,000 urban major roads under a number of different scenarios. The SL-PCM model is a simplified version of the full PCM model and as a result has a substantially reduced analysis time. These faster analysis times are possible since the SL-PCM relies on information previously prepared for and by the full PCM model and does not require dispersion modelling for each scenario. This makes it practical to use the SL-PCM model outputs to investigate the sensitivity of the modelled concentrations to different policy interventions and transport solutions. While the SL-PCM model only calculates the impacts on concentrations of NO_2 as a result of changes in road traffic, it also contains estimates of background concentration levels and does not allow the modelled concentrations to fall below these values. See Annex **A** for quality assurance information regarding the SL-PCM model.

The effects that different policy options are expected to have on the number, type[28], size, age, type of usage and distribution of vehicles are then included within this projection using the SL-PCM model, to arrive at an estimate of the effects of particular policy scenarios[29].

The UK is divided into 43 areas or "reporting zones" for air quality reporting. There are two types of reporting zone: 28 agglomeration zones (large urban areas) and 15 non-agglomeration zones (Fig. **1.3**). Compliance is assessed against an annual mean concentration of 40μg/m^3 and 1-hourly average concentration of 200μg/m^3, with 18 permitted exceedances of the latter each year. The annual assessment uses information from the UK national monitoring networks and the results of the modelling assessment for that year.

The final air quality compliance statement for each pollutant in each zone is derived from a combination of measured and modelled concentrations. The assessment of compliance for each zone is based on the highest concentration of the modelling and measurements in each zone.

---

[27] Ricardo Energy & Environment, *'Streamlined PCM Technical Report'*, Report for Department for Environment, Food & Rural Affairs (project AQ0959), 2015 <https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1511260938_AQ0959_Streamlined_PCM_Technical_Report_(Nov_2015).pdf>.

[28] European Commission, Transport Emissions: Air pollutants from road transports <http://ec.europa.eu/environment/air/transport/road.htm>.

[29] Note that the latest available SL-PCM model in March 2017 uses projections from 2013. An updated SL-PCM model based on projections from 2015 (and fully consistent with the latest PCM modelling) is under development and will be used for analysis published in the final Plan.

Although modelling projections may predict that zones will exceed the limit in a certain future year (year *n*), the compliance status only becomes official once both the monitoring and historical modelling assessment are combined and the overall assessment is completed (in year *n*+1). Hence, the latest compliance assessment, published in September 2016, is for 2015.

2.2 Results

2.2.1 Model validation

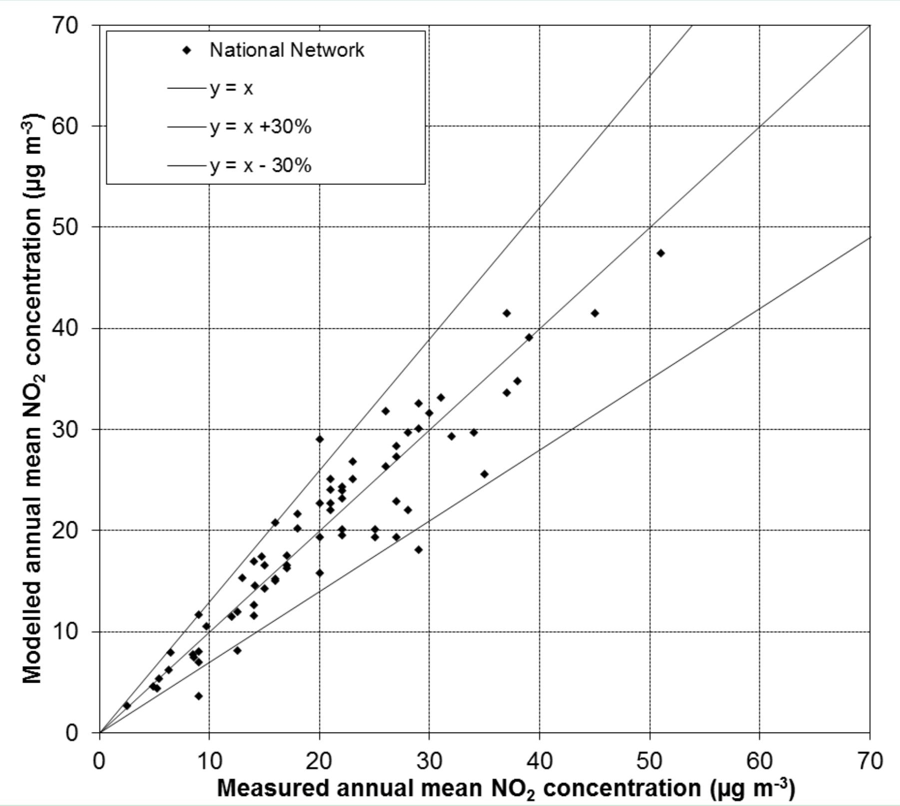
The relationship between the results from modelling air quality and those from independent measuring sites (Fig. **2.3**) shows that the level of accuracy of modelling was normally within ±30% of the measured value and there was no evidence of significant non-linearity in the modelled data. This suggests that modelled data has validity as a method for estimating actual NO_2 concentrations but with the caveat that estimates based on models will have additional uncertainty.

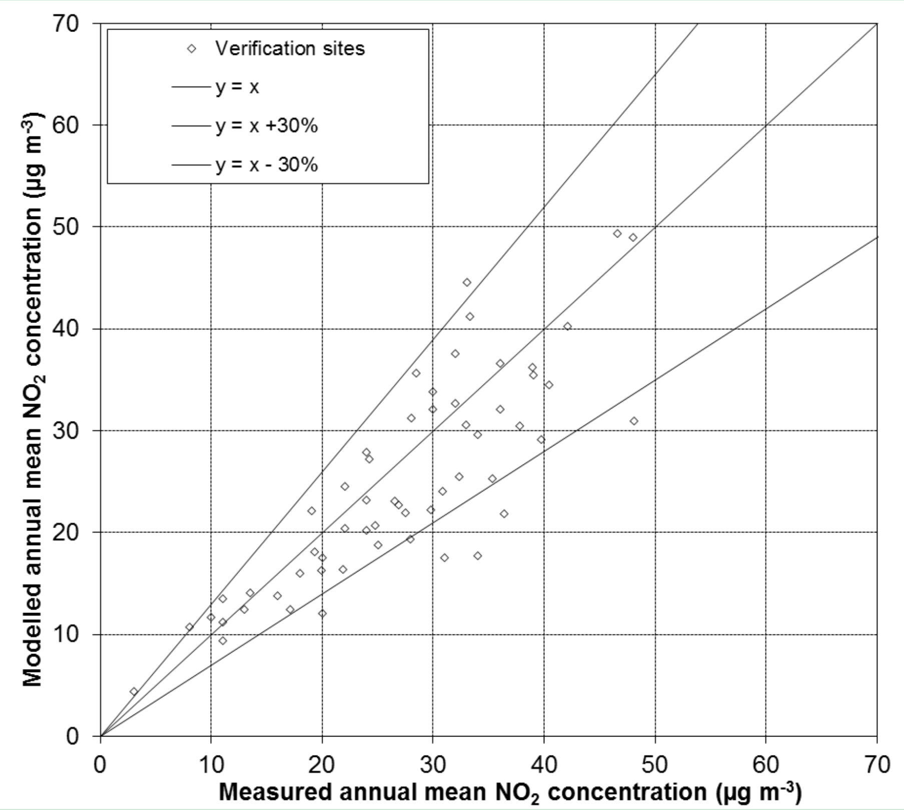
Figure 2.3: The relationship between modelled NO_2 concentration and the NO_2 concentrations measured in 2013 using the wider national network (a) and validation sites within the local authority network (b)

(a)

Based on measurement data from national background monitoring sites.

R^2 = 0.88; number of data points = 71.



(b) Based on measurement data from independent verification sites. R^2 = 0.71; number of data points = 57.	
Note: R^2 provides a measure of how well observed outcomes are replicated by a model, based on the proportion of total variation of outcomes explained by the model. Values range from 0 to 1, with 1 representing a perfect correlation.	

2.2.2 Compliance

Past compliance data and results for the UK can be found online[30] [31]. As well as these official reports on air quality data, information is made available to the public via annual 'Air Pollution in the UK' reports[32].

Table **2.4** summarises the NO_2 assessment in the latest version of this report and provides a comparison with the results of the assessments carried out in previous years since 2008 when the limits came into force.

---

[30] EIONET Central Data Repository, Information on the attainment of environmental objectives (Article 12) <http://cdr.eionet.europa.eu/gb/eu/aqd/g/>.

[31] EIONET Central Data Repository, Annual report (questionnaire) on air quality (2004/461/EC) <http://cdr.eionet.europa.eu/gb/eu/annualair>.

[32] Department for Environment, Food & Rural Affairs, Air Pollution in the UK report <https://uk-air.defra.gov.uk/library/annualreport/>.

Table 2.4: Number of non-compliant UK reporting zones for NO_2 concentration limit values for 1-hourly and annual assessments, 2008-2015

Limit value	2008	2009	2010	2011	2012	2013	2014	2015
NO_2 1-hour[I]	3	2	3	3	2	1	2	2
NO_2 Annual[II]	40	40	40	35	34	31	30	37

[I] An hourly average concentration of 200μg/m^3, with 18 permitted exceedances each year. No modelling for 1-hour LV.

[II] Between four and eight additional zones exceeded the annual mean NO_2 limit value each year from 2011-14 but were covered by time extensions and within the limit value plus margin of tolerance, therefore compliant. 2015 was the first year with no time extensions for NO_2: this is the reason for the apparent increase in zones exceeding between 2014 and 2015.

Recent revisions to COPERT emission factors were discussed in Section **2.1**. These changes have been incorporated into the revised 2015 base year compliance modelling of NO_2 presented in the draft Plan. As there are no requirements to back-correct previous assessments, historical compliance results prior to 2015 will not be updated retrospectively.

2.2.3 Air quality projections

Projections based on the historical 2013 assessment estimated the annual average NO_2 concentrations across the UK up until 2030 (Table **2.5**). While the 2013 assessment itself has not been retrospectively updated in light of the revised COPERT emission factors, the corresponding projections have been updated to reflect the latest estimates data. These projections represent what may happen if no further action is taken to control air quality. These projections include the impact of policy interventions that have already been taken or for which there is a firm commitment to implement[33]. They show that, in the absence of further interventions, all regions apart from one (London) will be compliant by 2027. This is because continual vehicle fleet turnover means older more polluting vehicles are replaced with newer cleaner vehicles.

[33] New policies set out in the 2015 Air Quality Plan, including Clean Air Zones in five English cities, have not been included in the baseline projections because they are expected to materially change as a result of the new Plan.

Table 2.5: Number of zones projected to be non-compliant with the limit value for NO_2 assuming no additional policy interventions to those currently in place

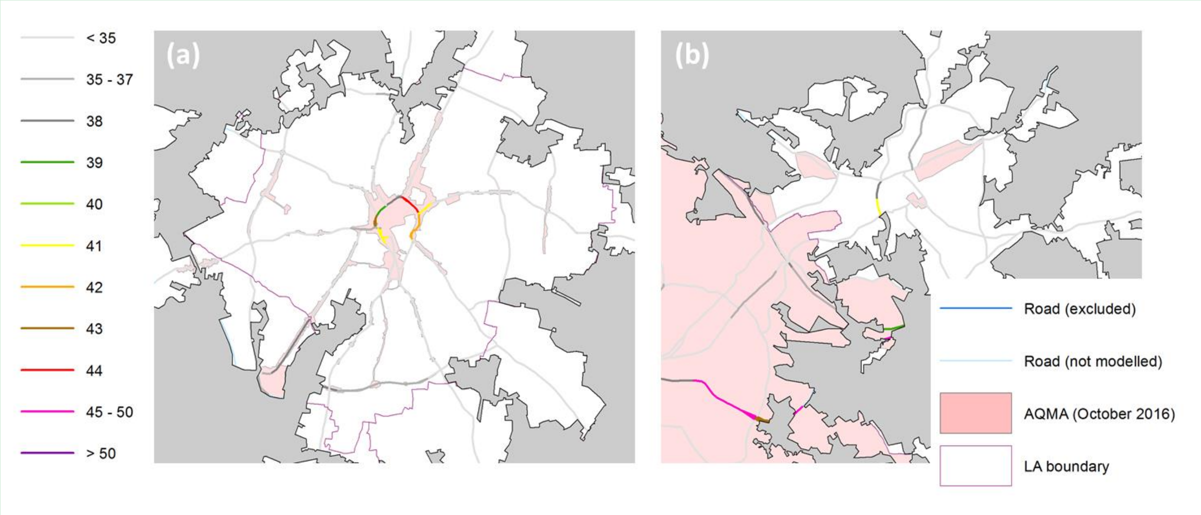
Year	2017	2018	2019	2020	2021	2022	2023
No. of zones	37	36	34	31	22	18	9
Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
No. of zones	3	3	3	1	1	1	1

Under the previous projections published in 2015[34], 8 zones were expected to remain non-compliant by 2020 without further action. These latest projections (Table **2.5**) indicate that this has now increased to 31 zones. This difference is the result of developments in the evidence base, most notably around increased NO_x emissions from Euro 5 LGVs, Euro 6 LGVs and Euro 6 diesel cars.

Figure **2.6** demonstrates that roads projected to exceed the NO_2 limit value occur in different orientations. In some situations, these roads are contained within an urban centre where it might be feasible to implement a Clean Air Zone to control emissions (Fig. **2.6a**). There are also instances where an individual road outside an urban centre (e.g. a bypass, Fig. **2.6b**) is projected to exceed the limit value, where a Clean Air Zone would not be appropriate, and an alternative solution is required.

[34] Department for Environment, Food & Rural Affairs, Air Quality in the UK: plan to reduce nitrogen dioxide emissions, 2015 <https://www.gov.uk/government/publications/air-quality-in-the-uk-plan-to-reduce-nitrogen-dioxide-emissions>.

Figure 2.6: Examples of orientation of roadside exceedances; showing exceedances contained within an urban centre (a), and exceedances located on routes into the city and on a bypass (b)



Note: The roads are coloured according to the NO_2 concentration in µg/m^3 (see scale to the left). AQMA = Air Quality Management Area; LA boundary = local authority boundary.

Section **9** describes in more detail the work that is underway to provide updated PCM modelling in time for the final Plan.

2.3 Discussion

The PCM and SL-PCM models combine to provide a picture of how air pollution may change in future. The accuracy of the models means that there is a need to consider that the estimates of future air pollution will contain a level of uncertainty in addition to uncertainty associated with the expected number and distribution of sources and their characteristics. For example, if vehicle technology does not deliver the anticipated NO_x emission reductions then the number of zones not compliant with air quality standards for NO_2 in future years would be greater than the numbers shown Table **2.5**.

3. Option assessment

3.1 Introduction

Given the scale of the challenge set out in Section **2,** this section looks at what policy options might be undertaken to improve air quality. In particular, it describes the process by which the options considered in the draft Plan were identified, as well as how the different options have been assessed against each other. Following this, the results of a high-level assessment of the theoretical maximum technical potential of the proposed measures is given. Exploration of the theoretical maximum technical potential acts as a catalyst to explore the scope of options that could feasibly be implemented as a measure to control air quality.

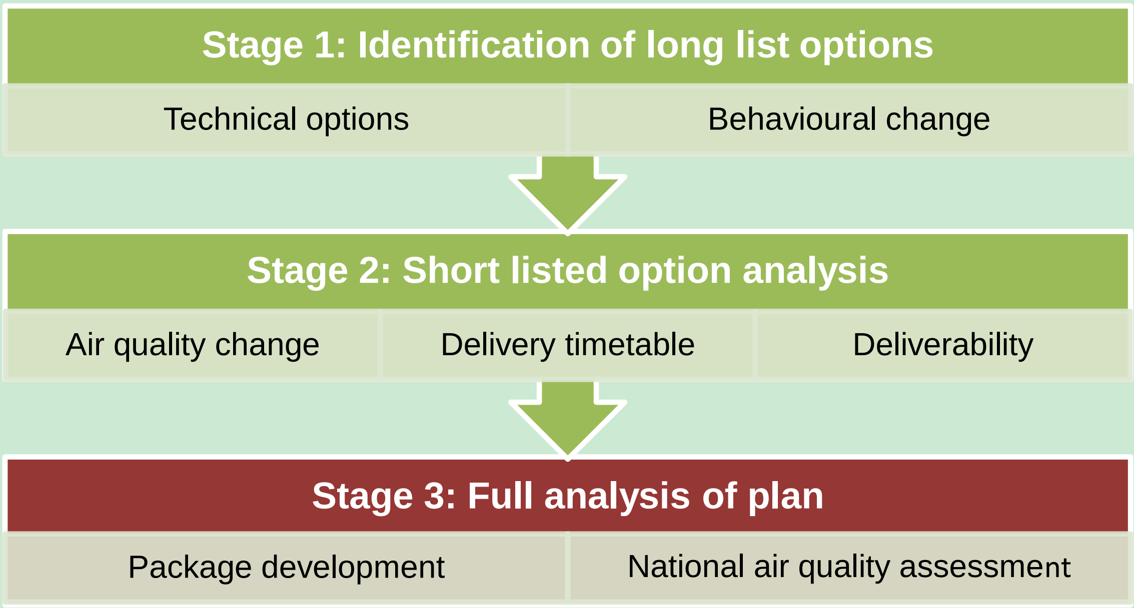
While policy related to air quality in the UK is devolved, air quality evidence is not. In particular, for compliance reporting a single assessment of air quality across the UK is made. Therefore, during the development of this technical report the modelling of different options has been conducted on a UK wide basis. Ultimately, the UK Government, the Scottish Government, the Welsh Government and the Department of Agriculture, Environment and Rural Affairs in Northern Ireland will each decide on the policies to introduce for exceedances in their areas.

The selection and assessment of options to improve air quality has been conducted based on the central appraisal guidance 'Public Sector Business Cases Using the Five Case Model (2013)'[35]. It has been necessary to adapt the approach for this consultation to address two particular challenges. First, the analysis needed to be completed in less than five months to allow the consultation to be published by the court deadline. Second, the final Plan is not intended to complete all the stages of the five case model through to implementation and evaluation.

A three-stage method has been developed to enable these challenges to be addressed (Fig. **3.1**).

[35] HM Treasury, The Green Book: appraisal and evaluation in central government, <https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent>.

Figure 3.1: A three-stage method adapted from the ‘Public Sector Business Cases Using the Five Case Model’ to suit the plan-specific challenges

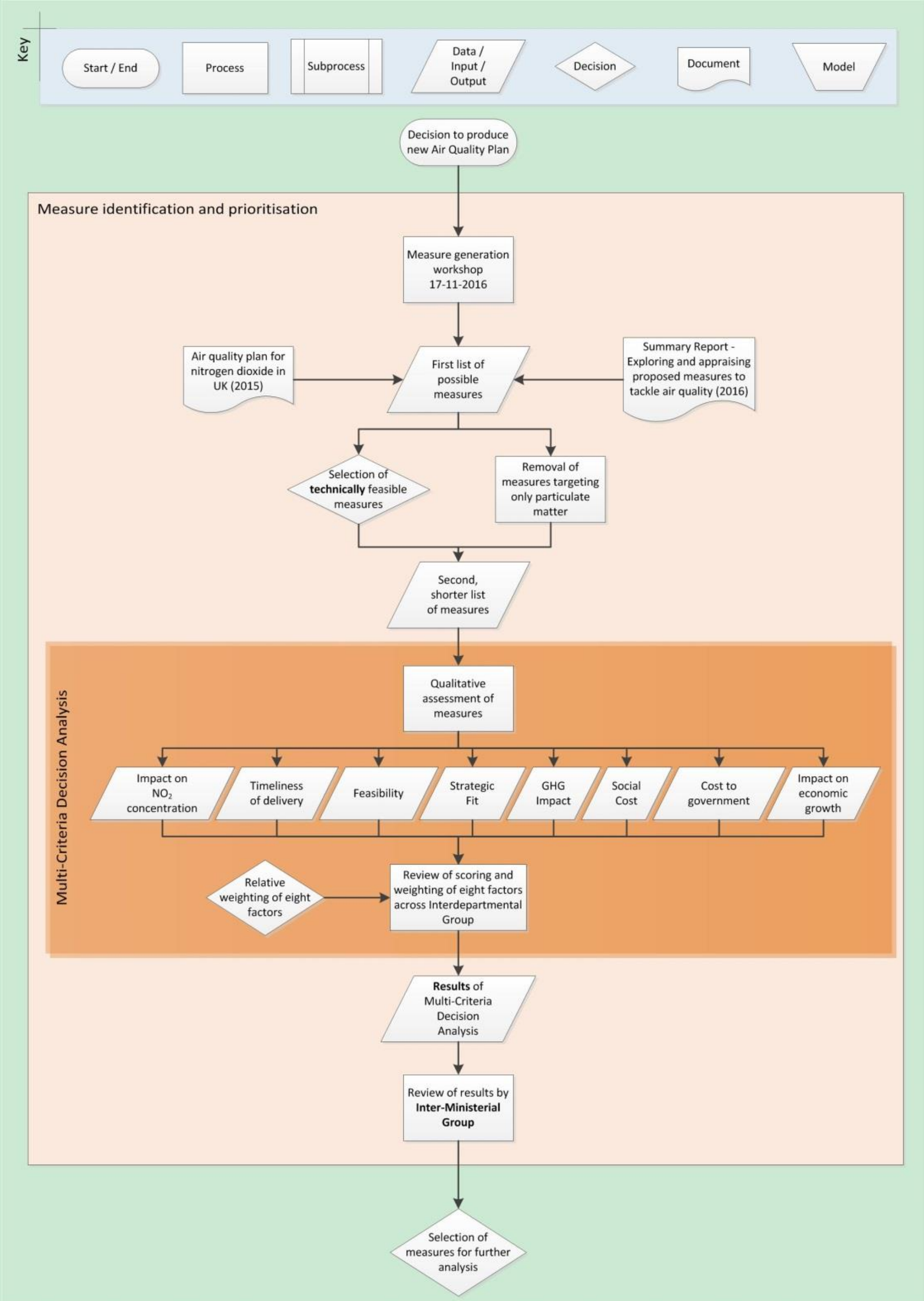


Section **3.2** and Section **3.3** address how stages 1 and 2 were conducted respectively, whilst the details of how stage 3 will be conducted, following the consultation, is described in Section **9.2**.

3.2 Identification of options for emission reduction

A range of techniques were used to identify a long list of different options to improve air quality in the first stage of the approach to identifying and assessing potential options for reducing emissions of NO_x (Fig. **3.2**).

Figure 3.2: A process flow diagram displaying the range of techniques used to identify the long list of air quality improvement options



3.2.1 Sources of NO_x

The compliance assessments and baseline projections described in Section **2** show when and where modelling indicates there are nitrogen dioxide (NO_2) exceedances in the UK. To reduce concentrations of NO_2, it is important to understand where it comes from so that the sources can be tackled. This is done by looking at emissions of nitrogen oxides (NO_x) made up of NO_2 and nitric oxide (NO), because NO can be oxidised into NO_2 in the atmosphere.

One output of the PCM model is detailed information on the sources of NO_x (source apportionment) that go on to influence annual mean NO_2 concentrations, which helps target options for improvement. The source apportionment of NO_x emissions can be divided into regional, urban, and local scales. The regional scale includes within country, trans-boundary[36], and shipping sources; the urban scale includes sectors such as road traffic, industry, and domestic; and the local scale includes a split into different vehicle classes, such as cars, buses, and HGVs.

The national average categorisation of NO_x coming from different sources for the UK in 2015 was shown in Figure **1.2**. Apportionment of NO_x to sources is used as a proxy for the apportionment of NO_2 to sources. This allocation of the average annual NO_2 concentration to different sources is complicated by the fact that NO_2 can be derived indirectly from some sources because of the oxidation of the NO portion of NO_x. This complexity is set out in more detail in Box **3.3**.

The analysis of sources of NO_x emissions shows that the road transport sector is the single largest contributor to the NO_2 challenge, accounting for some 80% of NO_x emissions in 2015 at the roadside. Thus, it is evident that tackling NO_2 exceedances requires addressing road transport emissions. Actions to tackle other sources are summarised in the draft UK overview document.

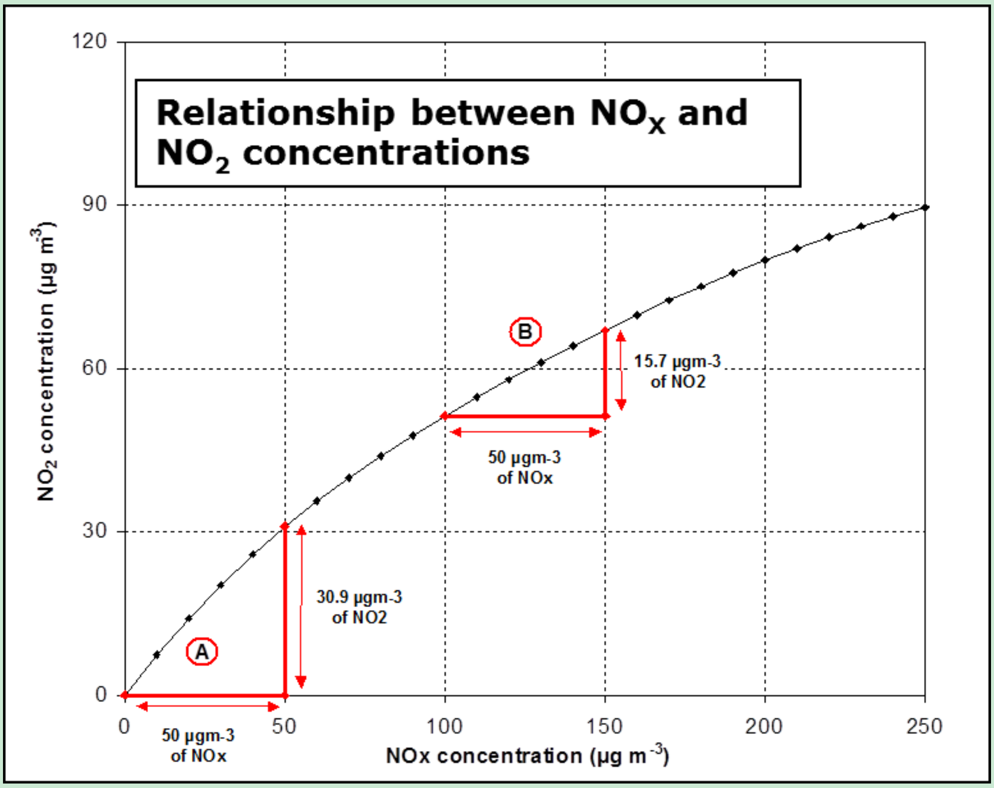
[36] Including pollution transported in to a region from another region and also from another country to the UK.

Box 3.3: Relationship between NO_x emissions and NO_2 concentrations

The relationship between NO_x emissions and NO_2 concentrations is complex. For a given reduction in NO_x concentration, the corresponding reduction in NO_2 is dependent upon the initial NO_x concentration, as illustrated in the figure below. Factors such as the presence of other pollutants, temperature and wind speed can also have an impact.

This can be demonstrated by observing points A and B, which reside in locations of low and high pollution concentrations respectively. A reduction of 50µg/m^3 NO_x results in a reduction of over 30µg/m^3 NO_2 for locations of low pollution concentrations. In contrast, the same reduction in NO_x concentration at a second more highly polluted location only results in a reduction of just under 16µg/m^3 in NO_2 concentration.

As this shows, where the starting concentration of NO_2 is already high, a higher reduction in NO_x will be required to deliver the same reduction in NO_2 concentrations. The complexity is further increased by the variation in primary NO_2 emissions from one location to another, meaning the curves can be different for different locations.



3.2.2 Identification of options for emission reduction

In order to identify policy options for consideration, the measures in the 'Air quality plan for nitrogen dioxide (NO_2) in UK (2015)'[37] were collated with options from an evidence review that explored the effectiveness of road transport policy measures to improve air quality[38].

This was supplemented by a workshop undertaken with a mix of Defra and Department for Transport (DfT) officials with experience in air quality.

This session was separated into three parts identifying:

- Potential performance criteria;
- Technological abatement options; and
- Actions to deliver behavioural changes.

Following the session, a list of 60 measures was drawn up, which was brought down to 49 by removing technically infeasible options or options only targeting particulate matter. The list included a wide range of potential options, from promoting ultra low emission vehicles and diesel scrappage schemes to planting trees and banning diesel vehicles from town centres on certain days. The options were then assessed with a formal multi-criteria analysis to narrow them down to those that would be considered in detail.

Within this process, eight criteria were used to assess each option. These criteria were split into critical success factors and other considerations. Three critical success factors were identified: air quality impact, timing to impact and deliverability. These critical success factors came directly from the legal obligation for the final Plan to contain actions that are likely to deliver compliance as soon as possible. Consequently, options that deliver benefits over a short time horizon have been prioritised.

Five other considerations were identified as the best indicators that would allow an appropriate comparison of the different options identified, reflecting their wider impacts. These were:

---

[37] Department for Environment, Food & Rural Affairs, Air quality plan for nitrogen dioxide (NO_2) in UK (2015), <www.gov.uk/government/collections/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2015>.

[38] Department for Environment, Food & Rural Affairs, *'Exploring and appraising proposed measures to tackle air quality: Project summary report for contract AQ0959'*, 2016 < https://uk-air.defra.gov.uk/library/reports?report_id=901>

- The cost incurred by central Government in implementing the option;
- The costs and benefits of wider societal impacts associated with the option;
- Changes in the level of greenhouse gas (GHG) emissions as a result of the implementation of the option;
- The extent to which the option aligns with wider Government objectives (the strategic fit); and
- The potential impact of the option in supporting future economic growth.

The options were assessed against these criteria by members of the Defra/DfT Joint Air Quality Unit, using their working understanding and available evidence. The assessment scores were subsequently weighted, with each critical success factor given triple the weighting of the other factors. The results of this exercise were then tested with key individuals in DfT and Defra.

Table **3.4** is a shortlist of policies developed from the most suitable options in the analysis.The shortlist was derived based on the scores in Table **3.5**, with additional options added for completeness, and some policies merged where they work well together. More detail on each option in Table **3.4**, including a full analysis of their air quality impact and costs and benefits follows in Sections **4**, **5** and **6**.

Table 3.4: Short-listed options to reduce NO_x emissions	
Option	**Description**
Clean Air Zones (CAZs)[39]	A geographically defined area bringing together immediate action to improve air quality. CAZs can include a charging element for vehicles that enter that do not meet the required standard.
Clean Air Fund (CAF)	A clean air fund could provide financial support for Local Authorities to fund local measures such as implementing sustainable transport strategies.
Scrappage	National targeted car and van scrappage scheme that would incentivise the move to a cleaner fleet; increasing turnover by targeting the removal of the oldest and dirtiest vehicles.
Retrofit	Providing national support for the installation and operation of abatement equipment on existing buses, taxis, and heavy goods vehicles.
Ultra Low Emission Vehicles (ULEV)	Providing additional support to purchasers of Ultra Low Emission Vehicles (ULEV).
Tax	Adjusting vehicle excise duty, fuel duty and company car tax to create incentives towards less polluting vehicles. This is a reserved matter for the Treasury and will be assessed independently of this exercise.
Speed limits	Reducing speed limits on motorway links that are not complying with the legal air quality obligations.
Government buying standards for transport (GBS-T)	Expanding the use of GBS-T[40] to include emissions of NO_x and PM.
Vehicle labelling	Reflect air quality performance of vehicles on their labelling to allow consumers to make decisions that are more informed.
Influencing driving style	Encouraging less polluting driving styles through reducing aggressive driving.
Government independent assurance	Establishing a body to review and support the delivery of air quality improvements. This is not a measure that would in itself deliver air quality improvements and so is not analysed in this report.

[39] Department for Environment, Food & Rural Affairs, Implementation of Clean Air Zones in England, <www.gov.uk/government/consultations/implementation-of-clean-air-zones-in-england>.

[40] Department for Environment, Food & Rural Affairs, Sustainable procurement: the Government Buying Standards (GBS), <www.gov.uk/government/collections/sustainable-procurement-the-government-buying-standards-gbs>.

Table 3.5: Scores from a multi-criteria analysis of the relative suitability of different emission reduction options, options were rated on a range from 1-3 and key criteria weighted by a factor of 3, a higher score indicates a more positive assessment

Emission reduction option	Key criteria			Secondary criteria					Total scores
	Timing	Impact on NO_x	Deliver-ability	Cost to Gov.	Cost to consumer	Strategic fit	Economic growth	GHG emissions	
Expand Clean Air Zones	9	9	9	2	1	3	1	3	37
Expanded retrofit programme	9	6	6	2	3	2	3	3	34
Drive down shorter journeys	9	3	9	3	3	2	2	3	34
Reduce speed limits	9	6	9	3	1	1	1	3	33
Promote ultra-low emission vehicles	9	3	9	1	3	3	2	3	33
Carpool lanes	9	3	9	2	3	2	1	3	32
Promote alternative fuels	9	3	9	3	1	3	2	2	32
Promote better driving	9	3	9	3	2	2	1	3	32
Ban dirtiest cars on high pollution days	9	6	6	3	1	2	1	3	31
Wider policies to discourage diesel purchase	9	3	9	3	2	1	2	2	31
Reduce Government's use of diesel vehicles	9	3	9	3	3	2	1	1	31
Use VED[ii] and/or CCT[iii] to promote low NO_x vehicles	6	6	9	3	1	3	1	1	30
Introduce vehicle labelling system	6	3	6	3	1	3	1	2	25

[I] Vehicle Excise Duty.

[II] Company Car Tax.

3.3 Impact assessment methods

This section describes the methods used to assess the impacts to the UK of the shortlisted options in Table **3.4**. As explained in Section **3.1**, the assessment covers all of the UK even though ultimately different policy decisions may be made for England, Scotland, Wales, and Northern Ireland. An assessment of these options was conducted according to the process laid out in Figure **3.6**.

In addition to reducing NO_2 concentrations, the measures taken will have a range of other impacts. The assessment therefore attempts to reflect these impacts through cost-benefit analysis. It is not possible to assess all the impacts and so this analysis focused on the most significant direct impacts as required by the best practice appraisal guidance (the Green Book[41]). Uncertainties inherent in all appraisals of future events mean there are risks to delivery of the assessed impacts. How these are dealt with and the steps taken to ensure that options are continually assessed against their desired affects are discussed in Sections **8** and **9**.

The options were assessed at this stage against the two quantifiable critical success factors (CSFs) in Section **3.2.2**: the scale of the improvement (the concentration reduction) and the time until the improvement begins to be realised. These critical success factors were directly derived from the legal obligation for the final Plan to contain measures that are likely to deliver compliance as soon as possible; consequently, options offering the highest abatement in the shortest time were seen to be most desirable.

Following this, a cost-benefit analysis was undertaken to consider the wider implications of the measures over a ten-year appraisal period. The monetised impacts include the health benefits from reduced exposure to NO_2, impacts from changes to greenhouse gas emissions, cost to Government and cost to the public. A ten-year appraisal period for assessment was chosen as this was considered the time horizon over which most of the impacts of options were expected to be observed, whilst being consistent with the Green Book guidance. The impacts were then discounted[42] and summed to calculate the net present value (NPV) of the options. Throughout this analysis, 2017 was used as the price base year as well as

---

[41] HM Treasury, The Green Book: appraisal and evaluation in central government, <https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent>.

[42] See Section **3.3.3** for more information.

the present value base year. As a result, the NPV indicates a policy options monetised net value in terms of 2017 prices.

The starting year of the ten-year appraisal period for each policy option was different depending on the specific nature of the option. The appraisal period of each option begins in the year when the first costs associated with the option are assumed to be incurred (e.g. setup and implementation costs). However, air quality impacts may only be exhibited after the start of the appraisal period for some options due to the setup time involved.

Finally, the strategic fit was assessed to understand how well the policy is likely to fit with national priorities and other Government policies. This considered what impact the options would have on different demographic groups within the population, and the impacts on economic growth. Figure **3.6** provides a visual representation of the option assessment process.

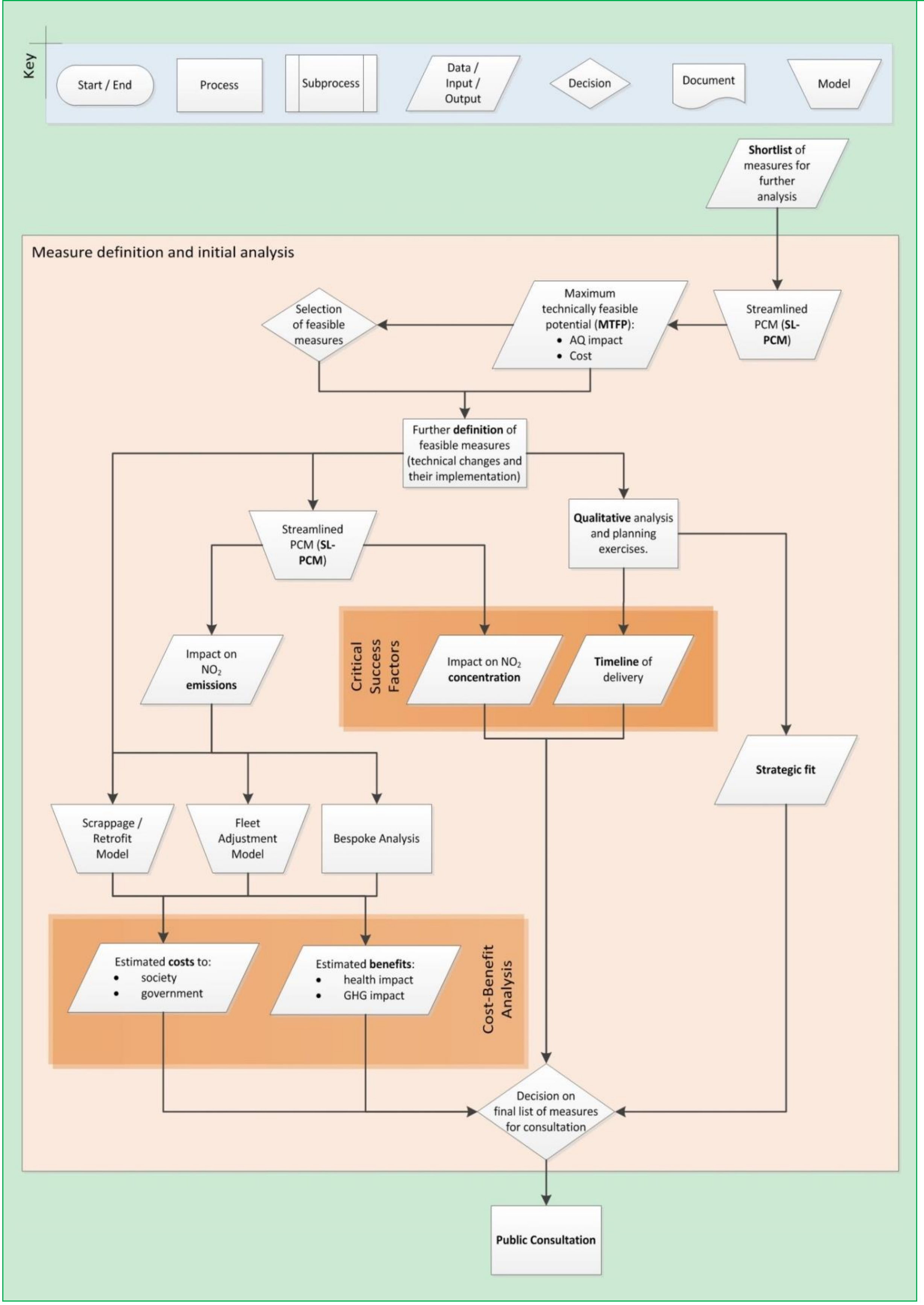
For the consultation, the most significant impacts have been assessed and, as far as possible, quantified. At this stage, five such impacts have been assessed:

- Health benefits – reflecting the reduced cost of health problems linked to NO_2
- Social cost – reflecting the costs of the given action to society
- Benefits from traffic flow improvements – monetised using the value of time saving
- Government cost – including implementation and setup costs
- Change in greenhouse gas emissions – valued using the social cost of carbon.

For the final Plan, a cost-benefit analysis of the impacts of the proposal will be undertaken to provide a transparent assessment of the impacts of the final package of measures. More detail on how analysis will be developed for the final Plan is set out in Section **9.1**.

The remainder of this section describes how each of the criteria set out above have been assessed.

Figure 3.6: A flowchart showing the process for assessing the net impacts of different emission reduction options.



3.3.1 Interim year air quality assessment

For this draft plan, full modelling of air quality impacts is only available for the years 2020, 2025, and 2030. In order to assess the impact of the policy options on air quality in the interim years, the data from these three modelling assessments has been interpolated. For policies that start prior to 2020, the 2020 SL-PCM modelling outputs have been interpolated with the 2015 full PCM modelling outputs.

Interpolation is a method of estimating values between a known set of data points. A linear interpolation method between the two closest modelled data points has been employed for this report (i.e. for the 2023 baseline, a linear interpolation between 2020 and 2025 baseline outputs has been calculated).

Alternative interpolation methodologies, including a linear function, a square polynomial function, and a cubic polynomial function, have been compared to the linear interpolation methodology (Annex **H**) in order to determine which produced the most accurate results. The analysis concluded that the interpolation methodology used in this report produced results that were extremely close to actual projected values (with a correlation coefficient of 0.998). It also found the method produced slightly conservative results in the years 2020-2025. In this period, the interpolated values were higher than the actual values, meaning that areas were more likely to be considered non-compliant with NO_2 limits. Therefore, this methodology would lead to a slight overestimation of the expected number of NO_2 limit exceedances in these years.

It should be noted that interpolating the concentration values in interim years will not be necessary for the final Plan because the SL-PCM model will be updated to generate additional outputs for these years (see Section **9.1**).

3.3.2 Health impacts valuation

Much of the evidence linking health impacts with long-term average NO_2 concentrations has been gathered using observational epidemiological studies. These studies use statistical methods to identify associations between outcomes, such as mortality or ill health, with external factors, such as modelled or measured pollutants levels, whilst taking into account other variables such as sex and age. Observational epidemiological studies are only able to provide evidence of effects based on a statistical relationship between risk factors and health outcomes.

Concentrations of NO_2 and some other pollutants such as $PM_{2.5}$ are closely correlated because they are emitted from the same sources (for example traffic). Although the statistical procedures attempt to disaggregate the effects of the individual pollutants, this correlation means that some of the statistical association found with NO_2 may represent effects caused by other correlated pollutants. There is, therefore, uncertainty in the extent to which the association between long-term average concentrations of NO_2 and mortality is causal. The Committee on the Medical Effects of Air Pollutants (COMEAP) has noted that:

> "…*it is possible that, to some extent, NO_2 acts as a marker of the effects of other traffic-related pollutants*…"

COMEAP considered the evidence linking long-term average NO_2 concentrations with effects on mortality, with a view to recommending methods for quantifying this association and estimating the mortality effect in the UK. In their advice to Defra in July 2015[43] they recommended that a coefficient of 1.025 (95 percent confidence interval 1.01–1.04) per 10µg/m^3 NO_2 could be used in cost-benefit analysis to reflect associations between long-term average concentrations of NO_2 and all-cause mortality. This means that for every 10µg/m^3 increase or decrease in concentrations, there will be a 1% to 4% increase or decrease in mortality. For the central analysis in this technical report, the central 2.5% coefficient has been applied. In order to ascertain how varying the coefficient may impact mortality, the 1% and 4% sensitivities have been tested and presented in Section **8.3**.

COMEAP explained that the uncertainty in applying a coefficient to assess the health benefit of measures to reducing NO_2 would depend on the extent to which the policy option is specific to NO_2, or also reduces concentrations of other co-emitted pollutants. There is likely to be more uncertainty when the option is specific for a reduction in NO_2, compared to when an intervention aims to reduce the whole mixture of pollutants. None of the interventions assessed in this report are expected to increase emissions of other air pollutants.

In December 2015, COMEAP published an interim statement explaining that there was potentially considerable overlap between the increased mortality risks found to be associated with concentrations of NO_2 and $PM_{2.5}$[44]. COMEAP continues to develop their advice on this as the scientific evidence develops. The uncertainty surrounding these effects can have potentially large impacts on the cost-benefit assessments.

Defra has calculated interim NO_x damage costs by applying the coefficients recommended by COMEAP to all types of intervention that reduce NO_x emissions.

---

[43] Appended to Committee on the Medical Effects of Air Pollutants, *'Interim statement on quantifying the association of long-term average concentrations of nitrogen dioxide and mortality'*, 2015 <www.gov.uk/government/uploads/system/uploads/attachment_data/file/485373/COMEAP_NO2_Mortality_Interim_Statement.pdf>.

[44] Ibid.

Damage costs are a simple way to value changes in air pollution. They estimate the cost to society of a change in emissions of different pollutants. Damage costs are provided by pollutant, source, and location[45]; health outcomes have been valued using these in accordance with Defra guidance[46]. In due course, this guidance will be updated as new evidence and scientific advice becomes available.

In order to monetise the health impacts arising from a change in NO_2 concentrations, the location-specific damage costs were multiplied by the total tonnage change in emissions in that area. These were then totalled for each year to provide an overview for the whole UK.

As laid out in Section **2** the tonnage change in NO_x emissions for each of the short-listed policy options has been calculated using the PCM and Streamlined PCM models. The health impacts from these changes in NO_x emissions have been valued using NO_x damage costs for all of the options assessed in this report. For the charging CAZ option, the damage costs used are based upon the proportion of emissions falling within each type of urban location: transport central London, transport inner London, transport outer London, inner conurbation, urban big and urban large. For the other policies assessed in this report, the transport average damage cost is used as these policies do not target a certain geographic area[47].

These total annual values are then uplifted by 2% per annum, from the base year of 2015 in line with best practice (Green Book) guidance[48], to take into account the assumption that the willingness to pay for improvements in health will rise in line with economic growth.

---

[45] Further information on damage costs is available at <https://www.gov.uk/guidance/air-quality-economic-analysis>.

[46] Department for Environment, Food & Rural Affairs, Air quality: economic analysis, <https://www.gov.uk/guidance/air-quality-economic-analysis#damage-costs-approach>.

[47] The geographical definitions used for damage costs are based on the definitions provided for transport modelling. Department for Transport's transport appraisal guidance (WebTAG) provides more information on each of these areas. This guidance is available at <www.gov.uk/guidance/transport-analysis-guidance-webtag>.

[48] Department for Environment, Food & Rural Affairs, 'Valuing impacts on air quality: Supplementary Green Book guidance', <www.gov.uk/government/publications/green-book-supplementary-guidance-air-quality>.

3.3.3 Other societal impacts valuation

Where possible, each of the shortlisted measures has been assessed for any other significant societal costs and benefits using consistent valuation approaches. For example, the benefits of reducing congestion in CAZs or the costs of increased journey times by reducing speed limits.

The most sophisticated of these valuation processes is the Fleet Adjustment Model (FAM), which is used for assessing charging CAZs. Further, the Scrappage/Retrofit Model, which uses many of the same inputs and valuations as the FAM, has been used to assess both the scrappage and retrofit proposals. Finally, other measures have been assessed using simpler bespoke, but consistent, approaches that are described alongside the results in Sections **5** and **6**.

There follows brief descriptions of the main two models: the FAM and Scrappage/Retrofit Model.

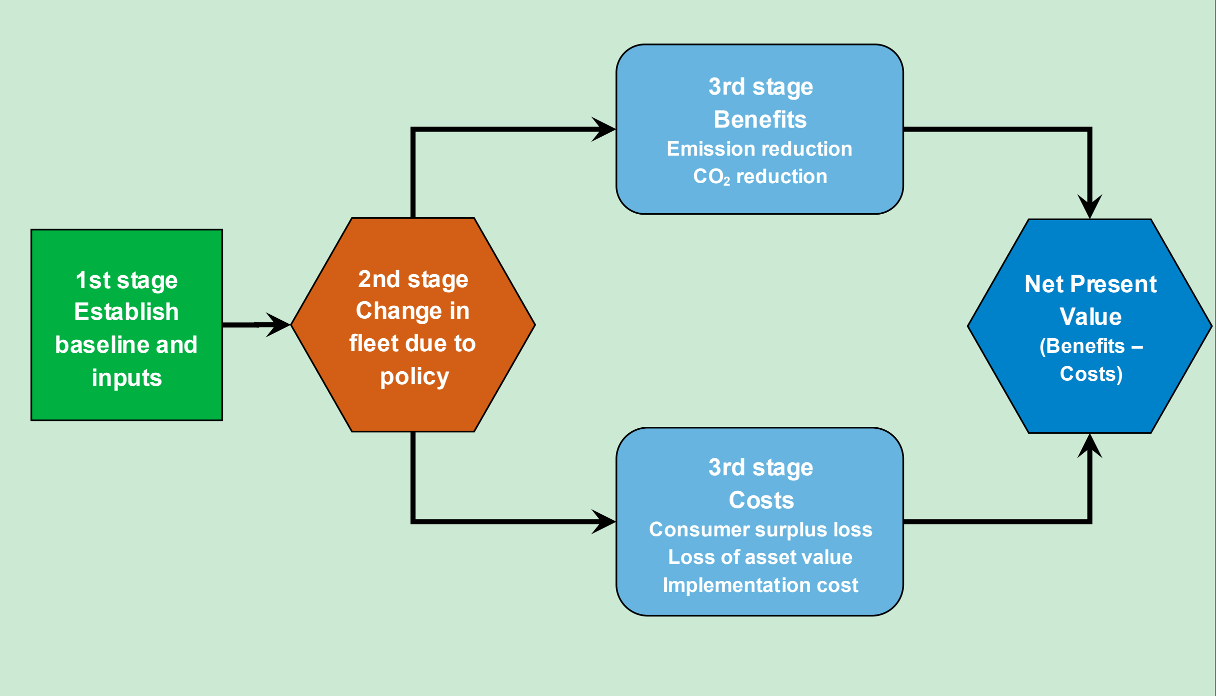
Fleet Adjustment Model

The FAM quantifies the societal costs and benefits associated with changes in the UK's vehicle fleet. This fleet change may be triggered by many different policies, but the model has been used here for the charging CAZ assessment.

The FAM was developed and published[49] alongside the 2015 UK Air Quality Plan for tackling nitrogen dioxide, and the latest technical documentation is attached in Annex **B**. Figure **3.7** outlines a brief overview of the sequential stages within this model.

[49] See Annex D of
<www.gov.uk/government/uploads/system/uploads/attachment_data/file/492901/aq-plan-2015-technical-report.pdf>.

Figure 3.7: A flow chart to illustrate the process by which the Fleet Adjustment Model evaluates an option



In the first stage, the baseline scenario establishes the vehicle fleet in different years before the implementation of any policy adjustments. The baseline is established via two key inputs:

- the fleet composition (number of vehicles by age and vehicle type - buses, coaches, taxis, HGVs, LGVs and cars); and
- the number of vehicle kilometres driven by each type of vehicle, inside and outside of the proposed CAZ and their location.

The second stage introduces measures that have an impact on the vehicle fleet. It models individual owners' specific responses to the options introduced. The responses will depend on the costs of different options available and the specific nature of the option. In relation to CAZs, some vehicle owners may choose to upgrade vehicles or avoid the restricted zone, triggering changes in the fleet composition and to the proportion of time older vehicles spend driving in different locations.

The third stage then quantifies and values the main societal impacts of the changes in fleet relative to the baseline. These impacts, in order of significance, include:

- **Health benefits:**

  The CAZ option will lead to vehicle owners changing their behaviour, for example by upgrading to a cleaner vehicle, cancelling a journey, avoiding zones or redeploying vehicles to less polluted areas. These behavioural responses will result in overall reductions in vehicle trips and in the replacement of older dirtier vehicles with newer less polluting ones, both of which result in lower emissions and therefore benefits to health.

- **Social costs:**

  Owners of vehicles below the required Euro standard will have to change their behaviour in one of the ways listed above. The new action is favoured less than their baseline behaviour (otherwise they would have been doing it already); hence these vehicle owners will incur an additional cost, termed welfare loss in economics.

- **Traffic flow improvements:**

  Alongside changes in the fleet, additional impacts may be felt from changes in the behaviour of vehicle owners. Vehicle owners who choose not to make their journey will be reducing the number of vehicles on roads within each of the CAZs. While it is assumed that business journeys using non-compliant vehicles will be replaced by equivalent businesses with a compliant vehicle, affected private car journeys are assumed not to be replaced. Consequently, less traffic on roads would lead to faster journey times for other users.

- **Government costs:**

  There will be both set up and ongoing costs to deliver improvements in air quality. Such costs could include scoping studies, infrastructure including installation costs and IT equipment and ongoing running costs such as communication, enforcement and staff costs.

- **Change in greenhouse gas emissions:**

  Modelling results show that overall charging CAZs are likely to reduce CO_2 emissions slightly. Reductions in the level of CO_2 emissions have been valued for vehicle scrappage and foregone trips. Where owners replace vehicles with a compliant vehicle a CO_2 emission saving is not expected, as the vehicle is sold to another user who will continue to use it (unless it is scrapped). Where vehicles are scrapped there will be a CO_2 saving. These savings have been valued using an average CO_2 non-traded central carbon price for the appraisal[50].

Finally, all the impacts are discounted and the total costs are subtracted from the total benefits providing a net present value (NPV).

Scrappage / Retrofit Model

This model has been developed from the FAM to provide an assessment of the impacts of a scrappage and retrofit scheme. It allows the assessment of different potential scrappage scheme policy options around the type of replacement vehicle and the levels of grant required to ensure a given level of take up. This model has also been used to assess different potential retrofit policy options (further detail on the assumptions is provided in Section **8**). The scrappage model is comprised of four key stages, which have been outlined below.

Stage one establishes the baseline vehicle fleet in different years prior to any policy adjustments. The key inputs are: the national fleet composition by vehicle type, Euro standard, fuel type, mileage, and average NO_x and CO_2 emissions for vehicle types by Euro standard, and fuel type. These inputs are consistent with the inputs in the FAM already outlined.

Stage two introduces the policy option and estimates the emission savings associated with the policy measure. Specifically, it estimates emissions of new vehicles purchased from a scrappage scheme, and compares these to vehicles in the baseline. The key simplifying assumption in the model is that the average mileage of the replacement (or retrofitted) vehicle and the vehicle that is scrapped (or retrofitted) is equivalent.

In stage three, the model estimates the number of vehicles that are expected to be scrapped. The estimated number of vehicles scrapped and replaced with conventional vehicles is estimated based on the residual value of vehicles. Where the value of the scrappage scheme payment is higher than the residual (second hand) value of vehicles, it is assumed that these vehicles are scrapped. For a policy of scrappage to Ultra Low Emission Vehicles, a top down estimate has been produced based on benchmarking using similar schemes and existing evidence. The adoption of retrofit has been estimated based on assessments of market capacity for

---

[50] Table 3: Carbon prices and sensitivities 2010-2100 for appraisal, 2015 £/tCO_2e <www.gov.uk/government/uploads/system/uploads/attachment_data/file/483282/Data_tables_1-20_supporting_the_toolkit_and_the_guidance.xlsx>.

retrofit. It is assumed that the offer of free retrofit will incentivise its uptake, particularly if there are access restrictions on non-compliant vehicles.

Finally, stage four quantifies and values the main societal impacts of the changes in fleet relative to the baseline. At this stage the most significant impacts that have been assessed and as far as possible quantified, are:

- Health benefits – reflecting the cost of health problems linked to NO_2;
- Welfare cost – reflecting the lost residual asset value to society, operating cost savings to the consumer and any deadweight loss;
- Government cost – including the level of compensation for the grants;
- Change in greenhouse gas emissions – valued using the social cost of carbon.

Finally, all the impacts are then discounted and total costs are subtracted from the total benefits providing a net present value (NPV).

3.3.4 Net present value and discounting

The net present value (NPV) of an option is calculated by summing the present values of the costs and benefits attributed to the option. Present values are obtained by discounting costs and benefits over time to account for people's time preferences. People tend to place a higher value on immediate impacts rather than those incurred in the future. This is because future events are less certain and because people expect to be financially better off in the future. In this analysis, the Treasury recommended discount rate of 3.5% per annum has been used to calculate the present value of the monetised costs and benefits for each option[51].

The net present value provides a broad indicator of the performance of an option. The primary advantage of the NPV is that it provides a transparent assessment of the different policy options by using the best available evidence and a systematic approach to the valuation of the impacts arising from the implementation of a particular option. Positive net present values indicate that the monetised stream of benefits of the option over the appraisal period outweigh the corresponding costs. In

[51] HM Treasury, The Green Book: appraisal and evaluation in central government, <https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-govenent>.

contrast, negative net present values highlight that the monetised cost of the option outweighs the benefits over the appraisal period.

Given the range of uncertainties associated with the evidence used to value impacts (see Section **8.4**) it should be recognised that the net present value estimates are only as robust as the inputs used to produce them. Thus, the values presented could change substantially as new evidence emerges; including the potential to shift some positive net present value estimates to negative estimates.

3.3.5 Analysis of effects among social groups

Groups in society will be affected differentially by NO_x emission reduction options. This will include how the health and financial impacts are distributed. Section **7** of this report provides an initial summary of findings in both these areas. Specifically, it reviews existing national-scale evidence (in the form of published articles) and outlines the likely effect of the proposed emissions reduction options. It also provides analysis based on information available from the National Travel Survey and other similar sources.

Further analysis has been conducted on the financial impact of the options on specific groups in society, such as those on lower incomes. This is based on the emission reduction options most likely to have specific geographic impacts, as distinct from the national picture. In particular, it focuses on charging CAZs, which have both the greatest overall impact and most localised financial impacts. This analysis has been carried out using both existing survey data and modelling from the FAM (Section **3.3.3**).

3.3.6 Economic growth

The impact on economic growth has been assessed qualitatively for each of the options.

3.3.7 Quality assurance of analysis

All analysis presented in this technical report has been quality assured by other analysts in order to check for calculation errors and to test the credibility and appropriateness of any assumptions used. Checks have also been made on the inputs and model runs which use the established SL-PCM and FAM models to mitigate against any data entry errors.

For the bespoke pieces of analysis created for assessing the impacts of all except the CAZ option, thorough checks of all calculations and assumptions have been completed. These checks have included testing the logic of assumptions in relation to the policy descriptions set out in this document as well as checking the model formulae and coding for computational errors. The reviewers have also rerun modelling scenarios where necessary and performed sense checks of the outputs produced. All analysis has been checked iteratively with all changes from one iteration to the next quality assured, and all identified issues addressed, before final sign-off.

The FAM and SL-PCM models have both been extensively reviewed by multiple analysts in advance of this report (see Annex **A** for details of SL-PCM model quality assurance). The quality assurance process as described here focused on the changes made to these models for the purposes of this analysis and to the inputs used for each of the options modelled.

Another aspect of the quality assurance process has been to check that the assumptions and data sources used are consistent across all analysis wherever possible. These common assumptions are set out in Section **8**. All options have used the SL-PCM model to calculate the expected changes in emissions and concentrations and the same source data has been used for each. The monetisation of air quality and carbon impacts follow standard supplementary Green Book appraisal guidance.

3.4 Theoretical maximum technical potential of options

Sections **4**, **5** and **6** present the results of a full assessment of each policy option conducted with the methods described so far. To help prioritise and shape the options considered in this full analysis, first a high level assessment was undertaken of the theoretical maximum technical potential (MTP). The MTP indicates the maximum reduction in NO_2 concentrations that could theoretically be delivered, in the absence of real-world implementation or deliverability challenges. **Therefore, this assessment does not reflect the technical and implementation challenges in delivering such an outcome**, nor does it provide a full financial impact analysis, but it does give an indication of the full potential of different policies to improve NO_2 concentrations. To make such an assessment meaningful it also uses the same indicative assumptions to calculate the potential costs to Government of such an outcome.

In this way, the MTP assessment can be used to prioritise and shape the options considered, so that a more feasible scale of implementation can be ascertained.

Table 3.8: Summary of results of theoretical maximum technical potential assessment for each of the shortlisted options[I]

Option	Scope	NO_2 concentration impact (mean µg/m^3 reduction in 2020)[II]	Cost to central Government (£m)[III]
Clean Air Zones[IV]	Targeted	11.0	600
Retrofit	National	1.5	4,500
Scrappage[V]	National	6.3	60,000
Ultra Low Emissions Vehicles	National	3.0	90,000
Speed limits[VI]	Targeted	Up to 4.5	60
Government vehicles	National	0.004	5.6
Vehicle labelling	National	0.13	Negligible
Influencing driving style	National	4.2	5,300

[I] Numbers subject to change following finalisation of analysis methods and policy design assumptions. Numbers rounded to two significant figures.

[II] Air quality impacts are presented as the national mean reduction in NO_2 in 2020 except for CAZs and Speed Limits, which are targeted. 2020 is used for comparison because this is the earliest year of data in the SL-PCM model, which has been used to estimate these impacts. Earlier impacts are modelled where policy implementation is possible before this.

[III] All monetised values are net present values over a ten-year appraisal period.

[IV] CAZ impacts are presented only for areas where CAZs will be implemented. It has been modelled that CAZs will be implemented covering all vehicles in 27 areas. The costs to central government reflect the costs of setting up and running CAZs but do not capture the costs of upgrading vehicles or welfare losses for vehicle owners, which are likely to be significant.

[V] National scrappage scheme assumed to scrap all pre-Euro 6 diesel cars and vans in the UK in 2019 (8 million cars and 2 million vans, with grant levels of £6,000 and £6,500 respectively)

[VI] Speed limit impacts are shown just for the motorway projected to be in exceedance in 2020. These impacts cannot be extrapolated to other roads. The impact of this measure is calculated on the assumption that traffic on failing motorway links is travelling at the same speed as the national average (for the type of motorway). It is possible that failing motorway links tend to be busier and more heavily congested, and that average speeds on them are lower. In this case, a change in the speed limit may have little impact on air quality - because cars are already travelling at speeds below the limit. Work is ongoing to improve our understanding of speeds on these links. Air quality impacts related to speed limits are expressed as 'up to *x*' because there is uncertainty over the modelling approach in relation to vehicle speed. Highways England's approach would not give a reduction in NO_2 concentrations or congestion following speed limit reduction.

The assessment of the theoretical MTP is presented and explained for each policy in greater detail in Annex **C,** which includes:

- A brief description of the scenario considered as the maximum technical potential;

- An outline of key assumptions;
- The projected air quality impact; and
- The estimated cost to Government.

3.5 Conclusion

Source apportionment analysis shows that the road transport sector is the single largest contributor to the NO_2 challenge. Using this as a starting point, policy options have been shortlisted for assessment using the methods described in Section **3.2**. Subsequently, to help prioritise and shape the options, an initial theoretical maximum technical potential analysis has been conducted with the results summarised in Table **3.8**.

It is important to note that because only two impacts have been considered at the MTP stage rather than the full range of costs and benefits, options should not be discounted purely on the basis of this analysis. This analysis does not represent a complete value for money assessment of these options but merely indicates options that have the potential to deliver high air quality improvements.

The results suggest that implementation of Clean Air Zones (CAZs) is likely to be key to achieving Government's air quality objectives. This is based on the fact that CAZs can potentially have significant impacts on NO_2 concentrations without disproportionate public cost; for example, the targeted nature of CAZs avoids restricting the use of vehicles that would never operate within the areas of high pollution. However, implementation of CAZs could potentially have notable impacts on individuals and businesses needing to comply with the CAZ requirements. A number of the other actions could, if scaled appropriately, help reduce the negative impacts on those affected by CAZs. These measures include scrappage, retrofit, and grants for Ultra Low Emission Vehicles.

Further, the investigation of CAZs revealed that not all areas with NO_2 exceedances could be effectively addressed by introducing a CAZ. For instance, exceedances include areas of the Strategic Road Network and roads without viable alternative routes (Fig. **2.5**). National measures are likely to be needed in order to address the air quality problems in these locations. Such measures could include speed limits on the Strategic Road Network, Government Buying Standards for transport and behaviour change measures such as improved driving and vehicle labelling.

The following three sections present the analysis for the shortlisted measures following the methods outlined in Section **3.3**.

4. Clean Air Zones

4.1 Introduction

Section **3.4** (Theoretical maximum technical potential of options) outlined eight policies to tackle poor air quality designed without any constraints. The next three sections of this technical report assess a feasible version of each of these options. This step looks to reflect the real world constraints on these measures such as the supply constraints on technologies and the process required to implement such options.

CAZs were one of the options investigated in Section **3.4** and it is evident that this option will be a key part of reducing NO_2 concentrations**.** CAZs are areas where action is focused in a particular geographical location to improve air quality and only the use of the most polluting vehicles is discouraged.

CAZs fall into two categories:

- Non-charging CAZs – These are defined geographic areas used as a focus for action to improve air quality. This action can take a range of forms such as facilitating the use of ULEVs and encouraging businesses to clean up their vehicle fleets[52], but does not include the use of charge based access restrictions.

- Charging CAZs – These are zones where, in addition to the above, vehicle owners are required to pay a charge to enter or to move within the zone, if they are driving a vehicle that does not meet the particular standard for their type of vehicle in that zone. Charging CAZs would only be expected where equally effective non-charging approaches are not identified.

The following section outlines the possible impact of local measures that could be implemented as part of non-charging CAZs. The subsequent section details the assessment of impacts that charging CAZs could have on society.

In the areas where CAZs are introduced there are further suggestions for complementary options which would help support their implementation or to support broader Government objectives such as aiding the transition for those least able to manage such a change. These options have been considered in Section **5**.

---

[52] See the Clean Air Zone Framework.

It is also recognised that CAZs are not suitable for all the areas exceeding NO_2 limits. For instance, it would not be reasonable to establish a CAZ on a single link of motorway, or on sections of the local road network outside towns and cities. Therefore, Section **6** reviews a range of national options that may be required in addition to CAZs.

4.2 Local measures

There are a variety of actions that could be taken locally as part of a non-charging CAZ that would improve air quality. Local Authorities could introduce a range of measures such as, but not limited to:

- Encouraging the uptake of Ultra Low Emission Vehicles;
- Infrastructure changes;
- Retrofitting the most polluting vehicles; or
- Promoting public transport, cycling and walking.

These, and other, measures could be introduced in different packages, varying in style and scope according to the local air quality problem. The effect of each project will depend on these factors as well as characteristics of the local area, such as the willingness of residents to change transport mode. These initiatives could have a range of impacts in addition to improving air quality, which could range from improved traffic flows to health improvements from additional cycling.

Due to the variability in the type of projects implemented and the associated uncertainty in their effect on reducing NO_2 concentrations a formal modelling has not been undertaken. To illustrate the possible impacts, Box **4.1** presents a case study looking at the effectiveness and value for money of these kinds of options. The box draws upon evidence from a scheme targeting car usage in three urban areas, operated by DfT.

Analysis of national level schemes for scrappage and retrofit has been presented in Section **5**. This analysis can act as a guide to the potential impacts of a scrappage or retrofit scheme at a local level. However, as noted above the local situation will influence their effectiveness, as will the design of specific schemes.

Box 4.1: Case study on promoting alternatives to car use

Between 2004 and 2009, DfT supported three 'Sustainable Transport Towns' where £15m was spent on initiatives to reduce car use. Evaluation results show the initiatives achieved an 8% reduction in journeys compared to similar unfunded towns.

For simplicity, an 8% reduction in the distance travelled by car has been modelled (it is not possible currently to model reductions in numbers of trips) and shown to produce a reduction in concentrations of NO_2 of approximately 3% or 1.4µg/m^3 in areas of exceedance.

The eventual costs amounted to 3.6p per car km removed, and conservative estimates of the benefit-cost ratio (BCR), taking only decongestion into account, were in the order of 4.5. That is, for every £1 spent on these projects society derived £4.50 worth of benefit. It has been estimated that adding the health benefits of more active travel and improved air quality, along with the reduction in carbon, could double this BCR[53].

Following on from these demonstrators, DfT's Local Sustainable Transport Fund ran from 2011-15 and provided £600m towards projects that met twin objectives of supporting the local economy and facilitating economic development, and reducing carbon emissions.

Example projects included smart ticketing, the promotion of infrastructure for electric vehicles, bus, rail and ferry improvement measures, the promotion of car clubs, and infrastructure improvements for cycling and walking.

An early evaluation of the fund's effects by DfT shows that after just one year of the scheme there was a 7% reduction in distance travelled by cars in comparison to other parts of the country. These results are not statistically significant due to the small sample size, but further analysis once more time has elapsed should give more confidence.

---

[53] Report to the Department for Transport, *'The Effects of Smarter Choice Programmes in the Sustainable Travel Towns: Summary Report'*, 2010 <www.toolsofchange.com/userfiles/STT%20final%20evaluation%20summary.pdf>.

Bids of more than £5m were required to submit a proportionate appraisal of the costs and benefits of the project. Based on the forecasts provided by 12 such projects, receiving a total of £225m, they delivered a collective BCR of 5:1[54]. This conclusion demonstrates that investment in local sustainable transport projects represents very high value for money. The value for money assessment of the smaller bids worth less than £5m suggested that, as a package, these also represented high value for money.

These studies show that, as well as offering air quality relief, reducing the need to travel by car has the potential for significant decongestion benefits – and where cycling and walking form part of the proposal significant health benefits can be expected too.

A fund specifically targeted at local air quality improvement would expect to deliver notable air quality benefits. These benefits cannot be quantified with the evidence provided but the BCRs achieved by these local schemes indicate the kind of outcomes a competitive bid scheme can achieve. They also highlight that these kinds of funds can be successful at facilitating flexible local solutions to local problems, which are particularly useful for the current NO_2 problem.

4.3 Charging zones

4.3.1 Overview

The second category of CAZ, as set out in Section **4.1**, is a charging CAZ. The key feature of this is an access restriction, where vehicles that do not meet the standards of the zone are required pay a charge to enter. This restriction could be introduced in addition to a range of supporting options targeting an improvement in air quality, as outlined in Section **4.2**.

Charging CAZs are just one of a number of tools local authorities could consider using in the development of their plans and charging is not a required element of CAZs. Charging would only be expected where equally effective alternatives are not identified. For this assessment of CAZs, it has been assumed that charging CAZs are implemented at the level required to bring the affected roads into compliance. This is purely for the modelling – Government will only mandate the measures that

---

[54] Department for Transport, *'Value for Money Assessment for the Local Sustainable Transport Fund'*, 2014 <www.gov.uk/government/uploads/system/uploads/attachment_data/file/347894/vfm-assessment-of-lstf.pdf>.

are identified by LAs as leading to compliance at the earliest point. Only the access restriction related impacts of a charging CAZ have been modelled as the potential effects of the supporting measures are too varied to allow a meaningful analysis.

The Clean Air Zone Framework defines four classes of access restriction based upon the vehicle type, as set out in Table **4.2**. These classes define the group of vehicles that would face access restrictions. The sequence in which the types of vehicle enter the different classes has been selected to target the most polluting vehicles first. However, the class of entry restriction will need to be decided locally.

Table 4.2: Charging Clean Air Zone classes set out in the 2015 Plan for NO_2

Clean Air Zone class	Vehicles included
A	Buses, coaches and taxis
B	Buses, coaches, taxis and heavy goods vehicles (HGVs)
C	Buses, coaches, taxis, HGVs and light goods vehicles (LGVs)
D	Buses, coaches, taxis, HGVs, LGVs, cars, motorcycles and mopeds[I]

[I] The impact of including motorcycles and mopeds in CAZs have not been modelled. These vehicles only represent a small proportion of total NO_x emissions so it is not expected that they will be included in the access restrictions for the majority of zones.

Charging CAZs are expected to lead to a change in the composition of the fleet entering the zone, resulting in high polluting vehicles operating within the zone largely being replaced with cleaner vehicles. This will result in less NO_x emitted within the zone. As a result of the lower emissions, concentrations of NO_2 will be reduced at both roadside and background locations.

Taking into account the minimum time it will take to implement this policy, modelling of charging CAZs suggests that compliance could be brought forward in around 27 cities in the UK, so for the purposes of the modelling this is the number that have been assumed. In London, the previous Mayor agreed to introduce a range of actions including the Ultra Low Emission Zone (ULEZ), which is analogous to a Class D Clean Air Zone, and the new Mayor has signalled his commitment to do more than this.

In applying these actions, it is necessary to set a specific standard for each type of vehicle. As Euro standards currently perform this function across the EU, these have been used in setting the framework. The Euro standards required for the different vehicle types are based on expected emissions. The proposed Euro standard requirements for each vehicle type are set out in Table **4.3**. The Euro standards chosen when setting the framework for this option are generally the most stringent currently available across different fuel types.

Table 4.3: Compliant Euro standards for charging CAZs by vehicle type	
Vehicle type	**Compliant Euro standards**
Cars and taxis	Euro 6 diesel / Euro 4-6 petrol
LGVs	Euro 6 diesel / Euro 4-6 petrol
HGVs / buses / coaches	Euro VI diesel
Motorcycles and mopeds [I]	Euro 3 diesel / petrol
[I] The impact of including motorcycles and mopeds in CAZs have not been modelled. These vehicles only represent a small proportion of total NO_x emissions so it is not expected that they will be included in the access restrictions for the majority of zones.	

This analysis has assumed that the compliance criteria for charging CAZs will not change over time. Government has committed in the CAZ Framework to set out a full process and timetable for the long term updating and tightening of the standards by the end of 2018.

Until the full PCM air quality modelling is completed, there is uncertainty around the number of CAZs that might be needed, which creates uncertainty around the number of vehicles affected. Annex **D** provides some preliminary estimates of the number of cars affected. As stated in Section **3.1,** modelling of the options in this Technical Report has been conducted on a UK-wide basis. To maintain consistency with the other options, areas of exceedance in the devolved administrations that could potentially be addressed through CAZs or a similar policy have been considered when determining how many CAZs to assume in the modelling.

Using the SL-PCM model the NO_2 concentration impacts of different classes of CAZ were modelled nationally, to understand what class of charging CAZ would be required to ensure compliance is reached in all zones. Non-compliant road links were plotted on a map to provide an indication of where CAZs might be a suitable approach to address an exceedance. Through this exercise, 27 possible CAZ areas were identified and this is the number assumed in the modelling. This number may change for the final Plan based on the results of the full PCM modelling.

In order to estimate the possible classes of these CAZs, the different classes of CAZ were modelled for all areas and the class that brought each area into compliance was assumed to be the one that was implemented. Four, three, five and fifteen cities were identified as requiring a Class A, Class B, Class C and Class D CAZ respectively.

An adaptive approach will be taken to the implementation of CAZs, and the effectiveness of the zones will be assessed through impact and process evaluation. Consideration will be given to conducting a process evaluation that will identify any implementation lessons that can be learned. For example, process evaluation techniques could be used to identify good practice in implementing CAZs effectively. Impact evaluation will be used to gain an understanding of the impact of CAZs on relevant outcomes. The specific impact evaluation techniques might include interrupted time series and difference-in-difference approaches[55].

All evaluation will need to be underpinned by new and detailed data collection to provide information about how the atmospheric concentrations of NO_2 have responded to the introduction of CAZs in various forms. This will require the establishment of similar measurement in control zones where no CAZ has been established to provide a comparison with the CAZs (see Section **9.2**).

Estimating changes in emissions

For the 2015 Plan, indicative zone perimeters were mapped for five cities in order to calculate the area in which emissions changes would be measured[56]. Emissions changes on road links within these zones were then estimated using the PCM model.

For this technical report, the average area of these five zones was assumed to be representative of the average area of the additional zones, and therefore the size of the zones covered (and therefore the corresponding emissions change within these zones) could be scaled up to provide an estimate of the emissions change within these zones.

Impacts on emissions from changing behaviour

Emissions within zones will be affected by the behavioural change of owners in response to the charging CAZ. There will also be a number of knock-on impacts on emissions outside the zone.

The total change in emissions was calculated based on the following elements:

- Emissions reduction within zone from changing behaviour;
- Emissions increase outside zone from changing behaviour; and

---

[55] Difference in differences is a statistical technique used in quantitative research in social sciences that attempts to mimic an experimental research design using observation study data, by studying the differential effect of a treatment on a 'treatment group' versus a 'control group' in a natural experiment.

[56] The actual perimeters of the zones will be decided via in-depth scoping studies and those chosen for this assessment are indicative only.

- National emission reductions from scrappage of oldest vehicles.

It is expected that CAZs would lead to affected vehicle owners changing their behaviour, leading to a reduction in kilometres travelled by non-compliant vehicles inside the zone. Separate assumptions are used in terms of behaviour change for vehicle kilometres used to estimate air quality impacts, and behaviour change in terms of vehicles, which is used to understand the costs falling on vehicle owners.

Charging CAZs are assumed to lead to one of the following behavioural responses by drivers of affected vehicles:

- **Upgrade to an exempt vehicle:**

This is expected to be the most common response and therefore to have the largest impact on emissions within the zones. The most frequent travellers to the zone will have a strong incentive to upgrade vehicles, as this will be cheaper over time than paying the charge every time they travel in. This will result in a large shift from non-compliant vehicle kilometres to compliant vehicle kilometres within the zone. However, there will be an increase in non-compliant vehicle kilometres outside the zone as some vehicle owners will choose to divert their journeys to avoid the CAZ area. This is not expected to be as large as the in-zone reduction, given the impacts of vehicle disposal (see Section **4.2.5**).

- **Avoid driving into the Clean Air Zone:**

Vehicle owners may choose to drive around the zone, change their mode of transport, or not make the journey. For those who take a diverted route to avoid the CAZ, there will be reductions in distance travelled and emissions within the zone and an increase outside the zone. Emissions outside the zone are assumed to be partially offset by reduced emissions inside the zone. It is assumed that if businesses choose not to make journeys, an equivalent business with a compliant vehicle will enter the zone to replace it (e.g. a plumber who cannot afford to upgrade chooses not to take a job in the zone and is replaced by another plumber who uses a compliant vehicle). This assumption applies to all vehicles except for privately owned cars. Therefore this response will replace non-compliant vehicle kilometres with compliant vehicle kilometres, though there will be no change in overall distance travelled. Consultation responses from industry representatives have suggested that some HGV operators impacted in Class B CAZs may switch to LGVs to avoid the charge. However, the impact of this on emissions is difficult to determine and likely to be negligible, and is not considered further here. Private car journeys not taken are assumed not to be replaced because there is no incentive for private citizens to replace the journeys of others. There will be a resulting reduction in vehicle kilometres within the zone. While this may lead to increased use of other modes of transport, increasing overall emissions, this is likely to be a negligible impact because the major shift of trips is likely to be towards public transport, which is assumed to have sufficient capacity to absorb these trips without needing to run greater numbers of services. Local authority feasibility studies will explore this impact in more detail.

- **Continue and pay charge:**

There will be no impact on kilometres travelled for the vehicles that choose to continue to enter. Drivers who continue into the zone in a non-compliant vehicle are likely to be the more infrequent zone visitors.

- **Redeploy vehicles subject to the charge outside the Clean Air Zone:**

The change in emissions from this is modelled in a similar way to upgrading vehicles discussed previously.

Table **4.4** sets out the behavioural assumptions for the percentage of vehicle trips that are used to calculate the air quality impacts of the scheme. These are based on unpublished evidence from the Ultra Low Emission Zone stated preference research alongside Transport for London (TfL) response modelling[57] modified to the characteristics of CAZs. They are consistent with the assumptions used to model the impacts of five CAZs in the unpublished Committed Clean Air Zone Impact Assessment.

It is assumed that the percentage of trips that respond in a given way will be proportional to the percentage of vehicle kilometres that respond in a given way. This change in the fleet, in terms of vehicle kilometres, has been input into the SL-PCM model to understand the impacts on emissions and concentrations within the zones.

[57] These are based on results from a stated preference survey of 1,200 participants. While stated preference surveys have limitations, this is considered to be the best available data.

Table 4.4: Proportions of non-compliant trips by response to the presence of a CAZ					
	Cars	LGVs	HGVs	Buses	Coaches
Pay charge	7%	20%	9%	0%	16%
Avoid zone	7%	8%	0%	0%	0%
Cancel journey / change mode	21%	8%	9%	6%	13%
Replace vehicle	64%	64%	83%	94%	72%

Table **4.5** shows the behavioural assumptions by proportion of vehicles, which are used to estimate the costs of charging CAZs to the public. These are estimated based on the Ultra Low Emission Zones stated preference survey combined with Global Positioning System (GPS) trip data to identify the number of vehicles that will have to trade up to meet the change in trip rates identified in the TfL research. It is based on the assumption that vehicles that enter a zone more often are more likely to be replaced; as the cost of paying charges increases they are incentivised to trade up to a compliant vehicle. Therefore, the proportion of vehicles that are replaced is lower than the proportion of vehicle kilometres that are replaced, because a small amount of vehicles account for a large proportion of vehicle kilometres inside a zone.

These assumptions are an input into the Fleet Adjustment Model in order to estimate the expected costs to the public as a result of charging CAZs. Vehicles that do not replace a vehicle may exhibit more than one behaviour change, so these represent the typical choice of that vehicle type – e.g. other non-compliant vehicle owners may pay the charge for some journeys, but cancel trips on some journeys.

Table 4.5: Proportions of non-compliant vehicles by response to presence of a CAZ					
	Cars	LGVs	HGVs	Buses	Coaches
Pay charge	17%	48%	34%	0%	23%
Avoid zone	26%	24%	0%	0%	0%
Cancel journey / change mode	43%	14%	34%	41%	18%
Replace vehicle	14%	14%	33%	59%	59%

While the majority of trips are expected to shift to compliant vehicles, this translates to a smaller proportion of total vehicles because there are a large number of vehicles that only enter the zones once or twice a year and are unlikely to upgrade. There are a relatively small number of vehicles which make up the majority of trips and these are expected to be the most likely to replace their vehicles in response to the CAZ charges.

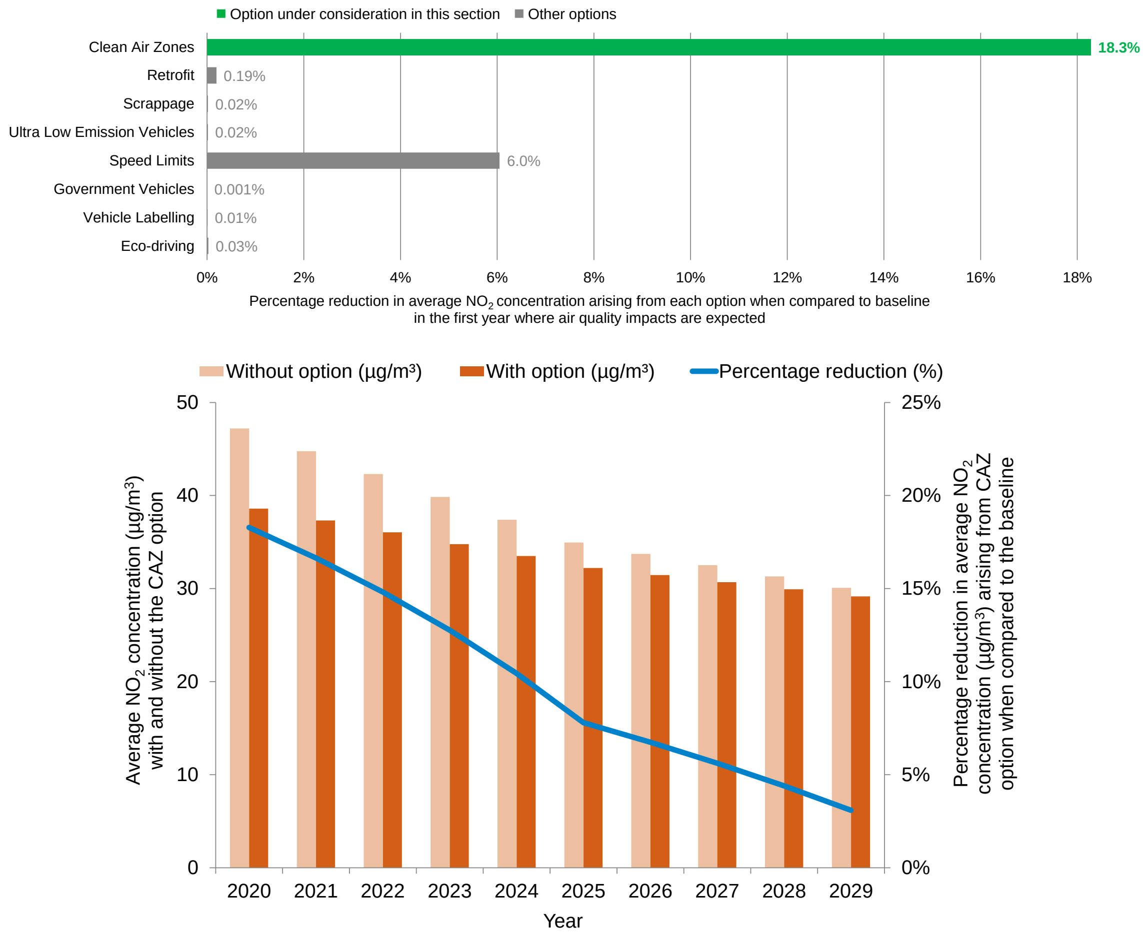
The SL-PCM model is run accounting for the reduction in non-compliant vehicle kilometres, and resultant increases in compliant vehicle kilometres inside the zone. From this change, the SL-PCM model is able to estimate the impact on emissions within the zones due to the upgrade of vehicles.

Of the drivers within the zone who are upgrading, the modelling assumes they purchase the cheapest available compliant vehicle, a second hand vehicle, and sell their non-compliant vehicle. This means that a proportion of vehicle owners who do not enter the zone will switch their less polluting vehicle and purchase a more polluting one given the increased demand placed on low emission vehicles. This will have an upward impact on total emissions outside the zone.

4.3.2 Air quality impacts

A profile of the changes in NO_2 concentration associated with the implementation of the charging CAZs is provided in Figure **4.6**.

Figure 4.6: Reduction in average NO_2 concentrations arising from the implementation of the charging CAZ option



The light and dark shaded orange bars show the projected mean NO_2 concentration with and without the implementation of the CAZ option. The blue line shows the percentage reduction in mean NO_2 concentration attributable to the implementation of CAZs (i.e. the percentage difference between the 'with' and 'without' option bars). CAZs are predicted to have their greatest impact on air quality in the year of implementation (2020), leading to an 18% reduction in NO_2 concentrations. This impact will gradually decrease over the appraisal period, with the percentage reduction decreasing to 3% by 2029.

The absolute reduction in NO_2 concentration assumes the baseline scenario is dependent on the effectiveness of the Euro standard. If the Euro standards are less effective than predicted (as with historical real-world operations), the impact of charging CAZs will differ from the projections presented here.

These projections have been produced from the SL-PCM model. It is not feasible to obtain uncertainty ranges for these estimates. Uncertainty estimates surrounding input data are also limited, but the SL-PCM modelling incorporates the latest assumptions around emissions from each source, to reflect the best range of evidence available. See Section 8.2 for further details.

There is a large percentage reduction in NO_2 in the early phase of implementation, followed by a lower reduction over time (Fig. **4.6**). This is because over time in the absence of CAZs, the older non-compliant vehicles come to the end of their lifetimes and are naturally replaced meaning that the fleet eventually becomes cleaner over time (assuming that the Euro standards deliver the expected emission reductions). CAZs are therefore bringing forward this behaviour to improve air quality more quickly.

4.3.3 Timing

Delivery of the full programme of CAZs is anticipated to take 2 to 3 years. Where local authorities have already done some preparatory work and are able to move more swiftly, Government will support earlier implementation.

There are a number of stages involved in the implementation of CAZs and these can broadly be categorised into the following:

- Feasibility studies – covering data collection, transport and air quality modelling of the local situation, options assessment, local consultation and production and approval by the Secretary of State of a final business case (for a scheme). Timings will vary but may take up to 18 months.

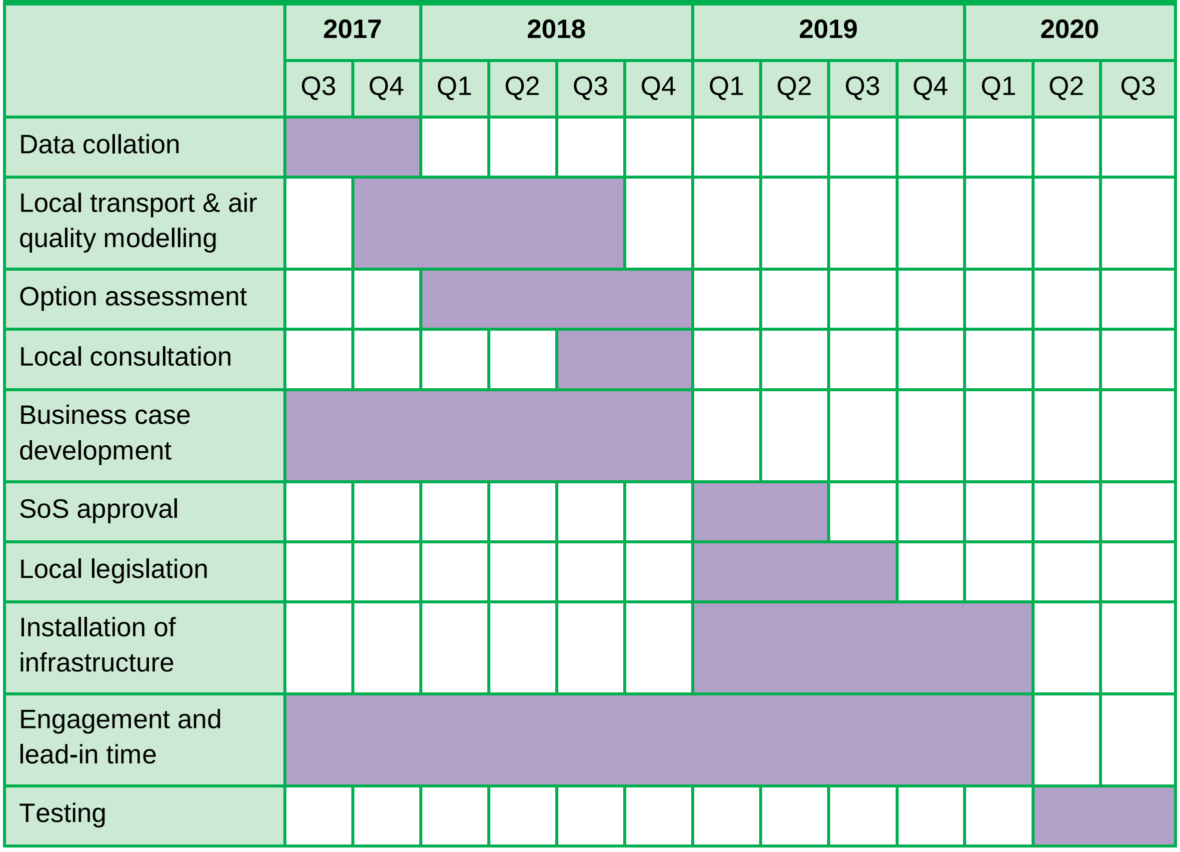
- Local scheme legislation – local legislation will be required to establish the scheme following Secretary of State approval. This may take up to six months.

- Procurement and installation of infrastructure – this primarily relates to signs and cameras and management systems e.g. for charging. This is expected to take up to a further six months.

- Lead-in time – a period before the scheme takes effect to allow for testing of systems and local engagement and communications to raise awareness of the scheme and enable businesses and individuals to adjust. This is likely to take a further six months.

Figure **4.7** provides an indicative timeline and sets out where the various elements involved with the implementation of a charging CAZ could be progressed in parallel.

Figure 4.7: Indicative timeline of CAZ measure implementation



4.3.4 Government cost

These costs cover the setup and running costs of the assumed 27 charging zones. It is expected that costs are independent of class of CAZ implemented. The costs presented in Table **4.8** have the following attributed:

- Costs are discounted values. The undiscounted setup costs are assumed to be £270m. In the modelling, setup costs are assumed to be spent in the earliest year all of the zones are expected to be operational (2020) and discounted to 2017 prices, leading to a present value of £244m. In reality much of the capital expenditure will happen prior to zones being operational; however this simplification has been made for modelling the ten-year appraisal period of 2020-2029.

- Costs do not account for the revenues local authorities are expected to receive from charges (these are a transfer from the public to government and therefore are not counted in this assessment). These represent a proportion of the running costs. Further research is underway to improve the evidence on what this proportion is.

Table 4.8: Costs to government of implementing the CAZs (£m, discounted)											
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Total
Capital	244	-	-	-	-	-	-	-	-	-	244
Running	41	39	38	37	36	34	33	32	31	30	351
Total	284	39	38	37	36	34	33	32	31	30	595

4.3.5 Public cost

The costs to the public were calculated using the Fleet Adjustment Model. For more details on the model and methodology employed, see Section **3.3.3** and Annex **B**. This cost is separated into two parts:

- Welfare cost – reflecting the cost to the public of meeting CAZ requirements
- Loss of asset value – including the disposal of the dirtiest vehicles.

In addition to these costs, there are expected to be some traffic flow benefits to the public as a result of the reduced number of trips taken within the zones by private vehicles. These impacts are explained in more detail below.

Welfare loss

There will be a loss of welfare for those who own a non-compliant vehicle switching to a more costly compliant vehicle, from foregoing the trip completely or from diverting to avoid the zone (for more details see Section **3.3.3**). The impacts of foregoing the trip completely would only apply in areas with a Class D CAZ, given that with other vehicles it is assumed other businesses will make the foregone journeys of those that cannot, and gain a corresponding benefit (so the impact on business journeys is neutral).

The cost of foregone and diverted trips is valued by estimating the number of days within the zone that are cancelled or diverted and multiplying this by half of the value of the charge to enter the zone. This is based on the fact that the cost of changing behaviour must be less than the charge. For some drivers the cost will be close to zero (those where the alternative diverted route does not add a meaningful cost), for some the cost will be just under the full value of the charge. Therefore, dividing the charge by two is a good approximation of the likely welfare cost.

Table 4.9: Welfare cost to society of CAZs (£m, discounted)											
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Total
Upgrade cost	403	312	166	117	66	41	24	14	8	5	1,157
Foregone trip cost	61	49	38	29	22	16	10	7	4	3	238
Diverted trip cost	237	188	146	111	82	59	39	26	16	10	914
Total welfare cost	700	549	349	257	170	115	74	47	29	18	2,309

Loss of asset value

Encouraging the shift towards cleaner vehicles will reduce the value of the older, more polluting vehicles, incurring a loss of asset value for the owners of such vehicles. This impact is assumed to be a one-off cost in the first year of implementation, as this is when a proportion of vehicles are upgraded. The lost value of the vehicles that will be scrapped will total an estimated £341m in present values.

Traffic flow improvement benefits

As a result of the behavioural changes brought about by the CAZs, there is expected to be a reduction in the total number of vehicle kilometres driven due to some journeys being cancelled or individuals switching to public transport. This will lead to less congestion, which will bring benefits to those who are still using the roads. The total value of these benefits is estimated to be £718m in present values. It is possible that the improvements in traffic flow will create a rebound effect by making travelling on these roads more appealing and thus encouraging more vehicles to use these roads. However, this effect is assumed to be negligible compared to the effects of the CAZ charges. As a result, it has not been monetised.

4.3.6 Health benefit

Air quality is projected to improve over time as the vehicle fleet renews, controls on emissions from industrial sources become tighter, and domestic combustion becomes cleaner. Therefore, the health benefits incurred each year from CAZs will diminish over the period because the air quality is expected to improve anyway without this intervention. The positive impacts from reduced NO_2 exposure total £3.6bn in present value terms over the ten-year appraisal period, due to the dirtiest vehicles being removed from the roads. This value is calculated using the damage cost approach as outlined in Section **3.3**, and covers mortality impacts only.

There will be a reduction of 24kt of NO_x emissions across the UK over the ten-year period assessed. This has been calculated using the SL-PCM model (see Section **2.1**). Table **4.10** demonstrates the emission changes experienced in the UK as a result of CAZs being implemented.

Table 4.10: Changes in national NO_x emissions resulting from CAZs (kt/year)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Total
Inside zone	-9.2	-7.8	-6.5	-5.2	-3.8	-2.5	-2.1	-1.7	-1.2	-0.8	-40.8
Outside zone	2.4	3.2	2.9	2.5	1.9	1.3	1.1	0.9	0.7	0.4	17.3
Total	-6.7	-4.7	-3.6	-2.7	-2.0	-1.3	-1.0	-0.8	-0.6	-0.4	-23.6

There is expected to be a reduction in emissions in the area just outside the zone, due to lower emission vehicles replacing high emission vehicles when entering the zone. However, in the wider area outside the zone in the UK as a whole there will be an increase in emissions from the dirty vehicles being sold to those unaffected by the zone. The impact is a net increase of NO_x emissions outside the zone of approximately 17,300 tonnes (Table **4.10**).

However, exposure to NO_2 will be lower outside the zone as a result of the policy. This is because emissions are likely to increase in areas of low population density but fall just outside the zone where the population density is high. As a result, there is expected to be a positive impact on health across the entire outside zone area overall.

Table 4.11: Valuation of NO_x emissions change from CAZs (£m, discounted)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Total
Inside zone	725	610	498	389	283	180	146	114	82	51	3,076
Outside zone	167	110	83	61	42	26	19	14	10	5	536
Total	892	720	580	449	325	205	165	128	91	56	3,612

4.3.7 Greenhouse gas emissions

The implementation of CAZs is expected to lead to a reduction in greenhouse gas (GHG) emissions, as the oldest, most polluting vehicles are expected to leave the fleet and be replaced with cleaner vehicles, and some car journeys will be cancelled and not replaced. This is because the new vehicles purchased as a result of the CAZs will push down the prices of older cars across the national market leading to many people trading up and only the oldest vehicles being scrapped. However, most of these impacts will only be felt in the early years of the policy.

By removing these vehicles from the fleet and reducing non-compliant vehicle journeys, there will likely be a reduction in CO_2 emissions – this will fall by an estimated 339kt over the appraisal period when compared to the baseline. As with NO_x emissions, the annual emissions reductions will likely be greater in earlier years when there are a greater number of non-compliant vehicles on the road, which are expected to be affected by the policy. This is estimated to provide a £19.0m benefit to society.

Table 4.12: Reductions in CO_2 emissions (kt) resulting from the implementation of charging CAZs (£m, discounted)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Total
CO_2 emissions (kt)	-128	-70	-48	-34	-24	-16	-8	-6	-4	-2	-339
Present value cost (£m)	7.4	4.0	2.7	1.8	1.3	0.8	0.4	0.3	0.2	0.1	19.0

4.3.8 Economic growth

The implementation of CAZs is likely to have a significant effect on businesses, which may have an impact on economic growth, as indicative analysis suggests that CAZs will target buses, coaches and taxis in 27 cities, HGVs in 23 cities and LGVs in 20. These vehicles are principally owned by businesses (for more detail on ownership profile see Annex **B**). It should be noted that personal cars would only be affected in Class D CAZs.

More specifically, the CAZ charge will primarily affect businesses who own older vehicles that would be subject to the charge, and who enter the proposed CAZs on a relatively frequent basis.

Businesses' ability to respond will depend on a number of circumstances. The main factors are the availability of funds to upgrade their non-compliant vehicle or pay the charge; flexibility to change behaviour in another way such as switching to an alternative mode of transport (e.g. train); rerouting to travel outside the CAZ; or redeploying their older vehicles to other areas of the country. In general, larger businesses would be expected to have more capacity to manage the impacts both financially and operationally. In contrast, smaller businesses, particularly sole traders who are dependent on using their vehicle within a CAZ, may be less able to adjust behaviour and continue into the zone.

There is a scarcity of available evidence on the proportion and characteristics of businesses that would absorb costs, those that would pass these on to customers, and those that may go out of business as a result. This information will be collected during implementation of the policy.

The TfL feasibility study for the London Low Emission Zone (2006) provided an overview of the impacts on different sectors of the economy that are most likely to be affected financially by the implementation of the LEZ[58]. Whilst much of this information is relevant to the assessment of the zones where CAZs will be implemented, London is unique in size, fleet composition, and business demographics. Therefore, it is important to bear in mind that the information derived from the TfL findings may have some limitations.

TfL found that the transport and storage, construction sectors and commuter services were those likely to be most impacted. It was anticipated that the necessary costs of compliance (which would vary for different operators depending on their fleets) will be largely absorbed by vehicle owners within these sectors because of the very competitive markets in which they operate.

CAZs should also deliver benefits to economic growth through improved air quality. This would reduce the number of absences from work, distracted performance or employee deaths, which all impact on business productivity (for more details see Section **8** on sensitivities). The policy would also stimulate demand for new vehicles, which will have a positive impact on vehicle manufacturers and therefore encourage economic growth.

4.3.9 Conclusion

Table **4.13** summarises the results of the analysis of charging CAZs. It shows the expected average reduction in concentrations in 2020 (which is the modelled start year of the scheme) and the present values of impacts on Government, the public, and the benefits to society as a result of improved air quality and reduced greenhouse gas emissions. These impacts have been appraised over a ten-year period.

---

[58] Report for Transport for London, *'Proposed London Low Emission Zone Economic And Business Impact Assessment: Non-Technical Summary'*, 2006 <http://content.tfl.gov.uk/economic-impact-assessment-non-technical-summary.pdf>

Table 4.13: Summary of impacts of the charging CAZ assessment[I]			
	Results	**Confidence in assessment**	**Comments**
First year air quality improvement[II]	8.6µg/m^3 in 2020	Established (preliminary assumptions)	This is the average reduction in the maximum concentration for non-compliant areas
Total reduction in NO_x emission[III]	24kt over ten years		
Timing to impact[IV]	1-3 years	N/A	Time taken dependent on the state of LA preparation as well as procurement timing
Health impact	£3,600m	Established (preliminary assumptions)	The net monetised impact of the change in NO_x emissions resulting from this measure
Government impact	-£600m	Established (preliminary assumptions)	The cost to Government of setting up and administering the CAZs over the ten year period
Public impact	-£1,900m	Established (preliminary assumptions)	The net of the costs of both lost welfare and the loss of asset value with the benefits of improvements in traffic flows
Greenhouse gas emissions impact	£19m	Established (preliminary assumptions)	The net monetised impact of the change in CO_2e emissions resulting from this measure
Economic growth impact	Positive and negative impacts	N/A	Positive impacts through improved air quality and higher new vehicle purchases. Negative impacts through increased costs to businesses.

[I] All monetised impacts are present values, discounted to 2017 prices, appraised over 2020-29.

[II] This is the reduction in average NO_2 concentrations, in the first year where air quality impacts are expected to arise as a result of the implementation of the option. This is relative to the baseline projection for the option in the particular year specified.

[III] This is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period. This is in comparison to the baseline projection for the option over the same ten-year appraisal period.

[IV] Indicative timings are provided for all options as either <1, 1-3 or >3 years.

5. Measures to support Clean Air Zones

5.1 Introduction

While local action through CAZs is one of the most effective measures to reduce NO_2 emissions, they could affect many individuals and businesses. This section analyses measures that could be introduced to support the transition to CAZs. They would do so by reducing the costs of compliance for individuals or businesses, or by lowering the level of charging required, or possibly removing it entirely. These measures are:

- Retrofit
- Scrappage
- Support for Ultra Low Emission Vehicles (ULEVs)

Each of these has been assessed in turn, using the same criteria applied to the CAZ assessment and as outlined in Section **3.3**.

5.2 Retrofit

5.2.1 Introduction

Retrofitting vehicles can reduce the amount of NO_x emitted. This policy considers retrofit schemes for buses, HGVs, and black taxis. Retrofit installs two technologies: selective catalytic reduction (SCR) for buses and HGVs, and liquefied petroleum gas (LPG) retrofit for black taxis. SCR is the technology used in the latest Euro 6 buses and HGVs to minimise NO_2 emissions. LPG retrofit for black taxis has been undertaken within the Clean Vehicle Technology Fund, and evaluation evidence showed emissions after retrofit equivalent to a petrol engine.

The theoretical maximum potential scheme assumed that all pre-Euro 6 buses, HGVs, and black taxis are retrofitted. The scheme considered in this section scales the measure to what is considered a more feasible level of retrofitting. The chief constraint on retrofit is market capacity. Policy experts have estimated that it may be possible to retrofit up to 6,000 buses, 4,400 black taxis, and 2,000 HGVs over a three-year period. This is based on an assessment of market capacity, based on working with retrofit suppliers.

The most significant uncertainty is likely to be market capacity. Retrofit of buses is well established. Retrofit of HGVs uses the same technology; however, there may be design issues with installing retrofit technology within the design of existing vehicles. Retrofit of taxis has been undertaken to date, but only at limited scale.

5.2.2 Air quality impacts

The impact of retrofitting 6,000 buses, 4,400 taxis, and 2,000 HGVs (around 12,400 vehicles in total) has been estimated. This would result nationally in 6% of taxis, 0.4% of HGVs, and 19% of buses being retrofitted. The policy is designed so that retrofitted vehicles are targeted at those delivering highest value for money. That is Euro 3-5 buses; Euro 5 HGVs and Euro 5 taxis. The assessment for the retrofit option is made using the scrappage/retrofit model described in Section **3.3.3**.

A profile of the changes in NO_2 concentration associated with the implementation of the retrofit option is provided in Figure **5.1**.

5.2.3 Timing

A retrofit accreditation scheme is currently being developed to test, validate, and certify retrofitted vehicles to ensure that when retrofit solutions are rolled out all suppliers are in a position to deliver solutions that reach the required standard. The scheme is expected to be in place by the end of 2017 to early 2018.

A retrofit grant scheme would need to be established where organisations could bid in for funding to retrofit vehicles with accredited technology – it is estimated to take between one and three years to deliver retrofitted vehicles.

Previous retrofit grant schemes, such as the Clean Bus Technology Fund (CBTF) and Clean Vehicle Technology Fund (CVTF), have successfully implemented some technologies and in particular have focused on buses. There may be challenges to extending retrofitting to other types of vehicle successfully. In addition, retrofitting companies will need to have the capacity to meet the demand. Any grant funding could be staggered across the funding period.

5.2.4 Government cost

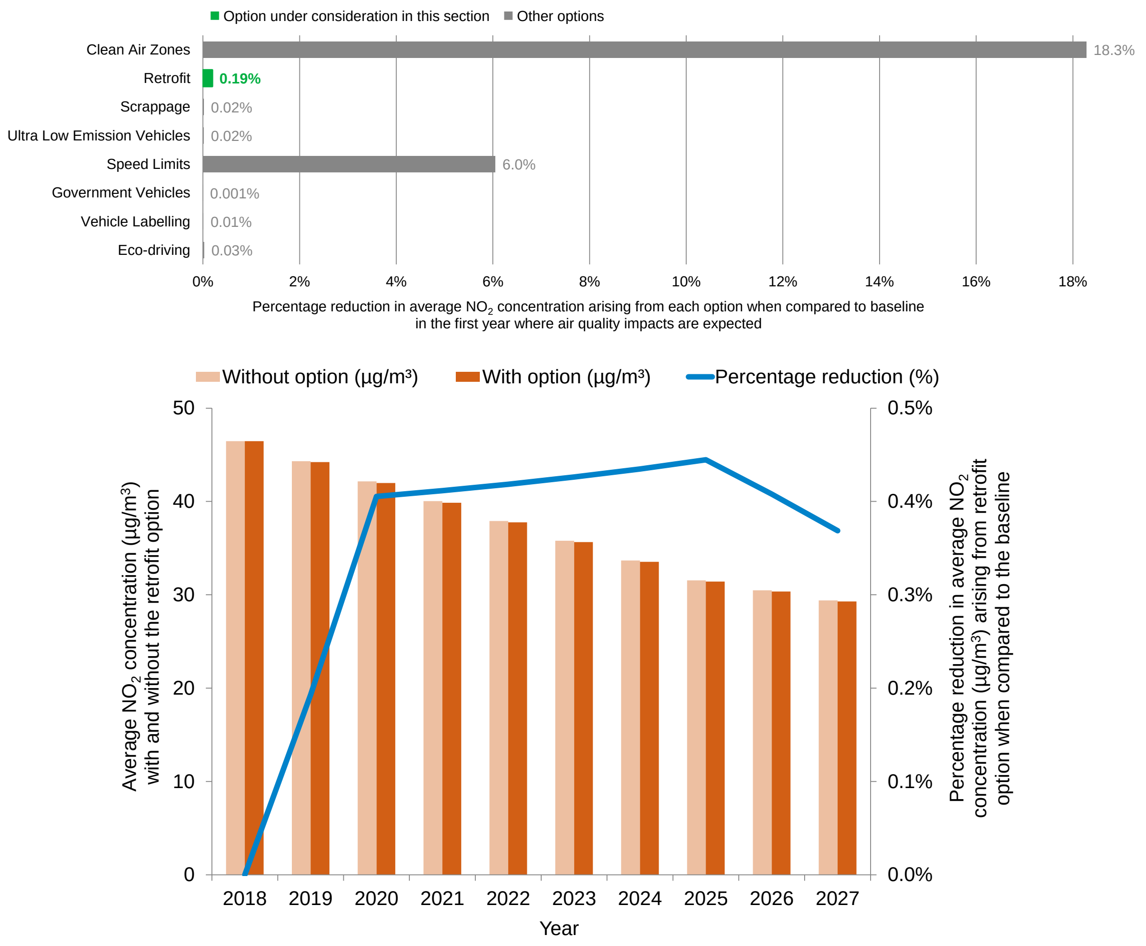
The costs to administer the proposed options have not been estimated at this stage. These costs are unlikely to be significant in comparison to the costs of retrofitting vehicles, and therefore excluding these is unlikely to materially affect the conclusions.

Government is assumed to incur the full cost of retrofit, estimated at £170m. The assumed costs of retrofit are as follows:

- Cost of SCR: £17,000
- Cost of LPG: £8,000

These have been estimated based on existing retrofit schemes undertaken by Government. The cost of retrofitting HGVs is assumed to be the same as the cost for retrofitting buses. Total costs were estimated by multiplying the retrofit cost by the number of vehicles retrofitted. In the modelled option, retrofit is assumed to take place in 2018.

Figure 5.1: Reduction in average NO_2 concentrations arising from the implementation of the retrofit option



The light and dark shaded orange bars show the projected mean NO_2 concentration with and without the implementation of the retrofit option. The blue line shows the percentage reduction in mean NO_2 concentration attributable to the implementation of the retrofit option (i.e. the percentage difference between the 'with' and 'without' option bars). The retrofit option is assumed to be implemented in 2018 and is projected to have its greatest impact on air quality from 2020-2025, contributing a reduction in NO_2 concentrations of around 0.4-0.45% each year. From 2026 onwards, the size of percentage reduction begins to decrease and is predicted to be around 0.35% at the end of the appraisal period.

The absolute reduction in NO_2 concentration assumes the baseline scenario is dependent on the effectiveness of the Euro standard. If the Euro standards are less effective than predicted (as with historical real-world operations), the impact of retrofitting will differ from the projections presented here.

These projections have been produced from the SL-PCM model. It is not feasible to obtain uncertainty ranges for these estimates. Uncertainty estimates surrounding input data are also limited, but the SL-PCM modelling incorporates the latest assumptions around emissions from each source, to reflect the best range of evidence available. See Section **8.2** for further details.

5.2.5 Public cost

As the full cost of retrofit is paid for by Government, there are no direct costs to society. It is assumed that the costs to companies of taking vehicles out of service are mitigated by getting vehicles retrofitted when they are out of circulation or in the case of taxis on days when the vehicle is not being used. It has been assumed that vehicle owners do not face a cost when retrofitting vehicles as they can manage fleets and use vehicles not in service.

5.2.6 Health benefit

NO_x emissions are expected to fall as a result of retrofit. The difference in NO_x before and after retrofit is estimated over the lifetime of the vehicle over the period to 2027. The estimated reduction in NO_x over the appraisal period is estimated to be around 10kt.

As noted, for buses and taxis the damage cost for large urban areas was applied to total emission savings, and for HGVs the transport average damage cost was applied, and discounted to provide an estimate of the health impacts of the options.

It is estimated that the retrofit option could result in a present value health benefit of around £440m.

5.2.7 Greenhouse gas emissions

Evidence from bus retrofit schemes has shown they have had no impact on CO_2 emissions. Evidence from LPG suggests that it has a similar CO_2 content to diesel on a per kilometre basis. Therefore, it is assumed there would be no CO_2 impacts as a result of implementing this option.

5.2.9 Economic growth

There are likely to be some benefits from an expansion of retrofit. The retrofitting procedure has to be undertaken in the UK and is relatively labour intensive, thus this option is likely to lead to increased demand for the skills and services to perform retrofitting. Therefore, it is likely to contribution to UK jobs and employment in the short term, as well as promoting overall growth in the retrofit market.

5.2.10 Conclusion

Table **5.2** summarises the results for this option.

Table 5.2: Summary of impacts of the retrofit assessment[I]			
	Results	**Confidence in assessment**	**Comments**
First year air quality improvement[II]	0.09µg/m^3 in 2019	Established (preliminary assumptions)	This is the average reduction in the maximum concentration for all UK reporting zones
Total reduction in NO_x emissions[III]	10kt over ten years		
Timing to impact[IV]	1-3 years	N/A	Time taken dependent on ability of market to deliver mass retrofit and desire from vehicle owners
Health impact	£440m	Established (preliminary assumptions)	The net monetised impact of the change in NO_x emissions resulting from this measure
Government impact	-£170m	Established (preliminary assumptions)	The cost to Government of this measure assuming it covers full cost of retrofit
Public impact	Negligible	Established (preliminary assumptions)	Government covers cost of retrofit, so no cost accrued
Greenhouse gas emissions impact	Negligible	Established (preliminary assumptions)	Impact assumed to be zero as LPG and diesel have similar CO_2e emissions
Economic growth impact	Benefits through expansion of retrofit industry	N/A	Retrofitting vehicles is a labour intensive process. Thus increases in demand for these transformations will increase employment and so growth

[I] All monetised values are present values, discounted to 2017 prices, appraised over 2018-27.

[II] This is the reduction in average NO_2 concentrations, in the first year where air quality impacts are expected to arise as a result of the implementation of the option. This is relative to the baseline projection for the option in the particular year specified.

[III] This is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period. This is in comparison to the baseline projection for the option over the same ten-year appraisal period.

[IV] Indicative timings are provided for all options as either <1, 1-3 or >3 years.

5.3 Scrappage

5.3.1 Introduction

Older vehicles associated with previous Euro standards emit substantially more pollution per kilometre than newer vehicles. Consequently, Government intervention in the form of a vehicle scrappage scheme could reduce emissions by increasing the turnover in the fleet.

The maximum potential of this measure explored in Section **3.4** illustrated that the cost associated with scrapping all pre-Euro 6 diesel cars and vans (around 10 million vehicles) could be around £60 billion. However, this cost is likely to be an underestimate as consumers would likely need to be offered even higher grant levels to incentivise 100% take-up of the scheme.

This section considers a smaller scale option, assumed for the analysis to be a national scrappage scheme open to drivers of diesel Euro 1-5 cars and drivers of petrol Euro 1-3 cars. It is assumed to be open to all drivers of such vehicles, so is not targeted at particular geographic areas or characteristics of the drivers. It is also assumed that vehicles would have to be replaced with a new Battery Electric Vehicle (BEV), which would enable greater emissions savings per vehicle than if plug-in car hybrid vehicles (PHEVs) or Euro 6 conventional vehicles were offered as replacements. This option was selected as it aligns with wider Government ambition to support Ultra Low Emission Vehicles (ULEVs), can be tied in with the existing Plug-In Car Grant scheme, and does not involve replacing diesel with petrol, which could have an impact on greenhouse gas emissions. The modelling assumes that 15,000 vehicles (9,000 diesel vehicles and 6,000 petrol vehicles) are scrapped and replaced with BEVs.

This is just one way in which a scrappage scheme could be designed, and is for illustrative purposes only. Other approaches include targeting vehicles from a specific sector, targeting by geography, or narrowing the individuals eligible to apply for a scrappage scheme.

The market for vans is currently dominated by conventional internal combustion engines (ICEs). Although it is expected that the market share of low emission vans (both battery electric and plug-in hybrids) will increase in the future, vans have been excluded from this analysis because the expected take up of BEVs, especially amongst owners of pre-Euro 6 vans, is expected to be low.

The way the scrappage proposal outlined might be expected to improve air quality is by increasing fleet turnover and therefore reducing the average age of the vehicle fleet. Assuming other factors that influence emissions remain unchanged (e.g. distance travelled) this will result in reduced emissions.

The NPV for this option is estimated to be -£20 million. It is negative because the estimated costs of offering grants to the participants of the scheme significantly outweigh the benefits that it has been possible to quantify.

It should be noted that there are a range of non-monetised benefits associated with the promotion and early uptake of ULEVs to ensure that Government can stay on a path consistent with its targets. These benefits are likely to be significant – indeed cost-benefit analysis over a period to 2050 shows electric vehicle support to be cost effective. However, it has not been possible to monetise this as part of the analysis presented in this report due to the relatively short appraisal period.

The key assumptions underpinning the modelling are as follows:

- The start year of the scheme is assumed to be 2019;
- The impacts of the scheme start to feed through in 2020;
- The scheme duration is for one year only; and
- Impacts are appraised over ten years from the start of the scheme (2019-2028).

The most significant uncertainty relating to this option is the likely take up of the scheme presented. A key assumption underpinning the analysis is that the assumed grant levels are sufficiently high to:

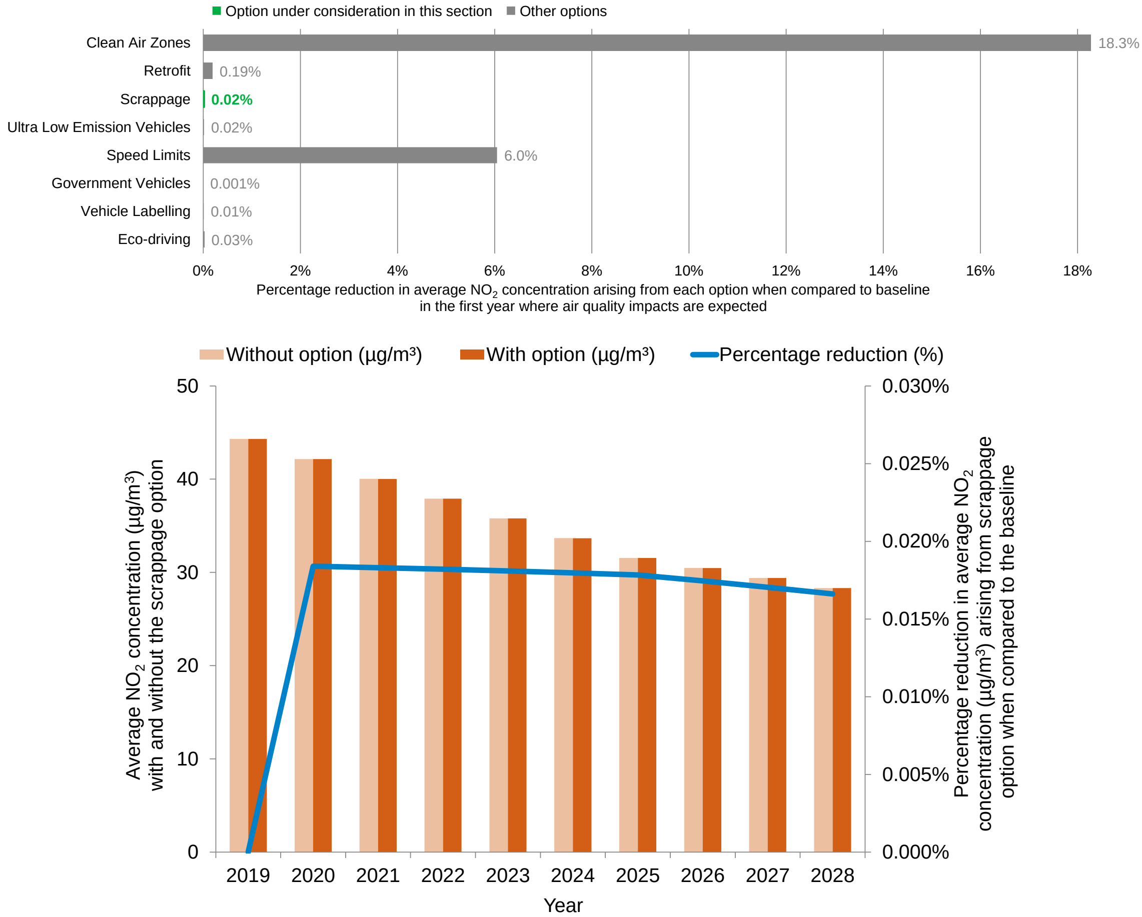
- Incentivise vehicle owners to scrap their vehicles earlier than they otherwise would have done; and
- Incentivise these vehicle owners to participate in the scheme and buy new vehicles with the scrappage payment instead of used vehicles; and/or
- Incentivise around 15,000 Euro 1-5 diesel/Euro 1-3 petrol car owners to buy a BEV if they are also offered an additional grant incentive from this scheme of £6,000 alongside £2,000 to cover the residual value of their vehicle. These estimates (on take-up and grant levels) have been benchmarked using similar schemes/existing evidence.

However, these assumptions may not be reasonable. It has not been possible to quantify the premium that vehicle owners are likely to need (over and above the residual asset value of their vehicle) to incentivise them to change behaviour (scrap their car, buy a new car and/or buy a BEV). This means the uptake of the scheme could be higher or lower than assumed.

5.3.2 Air quality impacts

The impact of scrapping 15,000 older petrol and diesel vehicles and replacing them with BEVs was estimated to deliver a 0.008μg/m^3 reduction in average NO_2 concentrations in 2020 (the first year in which air quality impacts from the scheme have been assumed). This would result in around 0.05% of the total stock of conventionally fuelled vehicles (ICEs) in 2019 being scrapped. A profile of the changes in NO_2 concentration associated with the implementation of the scrappage option is provided in Figure **5.4**.

Figure 5.4: Reduction in average NO_2 concentrations following the implementation of the scrappage option



The light and dark shaded orange bars show the projected mean NO_2 concentration with and without the implementation of the scrappage option. The blue line shows the percentage reduction in mean NO_2 concentration attributable to the implementation of the scrappage option (i.e. the percentage difference between the 'with' and 'without' option bars). This option is assumed to be implemented in 2019 and is predicted to have a low but stable impact on air quality throughout the appraisal period, contributing a reduction in NO_2 concentrations of around 0.02% each year from 2020 to 2028.

The absolute reduction in NO_2 concentration assumes the baseline scenario is dependent on the effectiveness of the Euro standard. If the Euro standards are less effective than predicted (as with historical real-world operations), the impact of scrappage will differ from the projections presented here.

These projections have been produced from the SL-PCM model. It is not feasible to obtain uncertainty ranges for these estimates. Uncertainty estimates surrounding input data are also limited, but the SL-PCM modelling incorporates the latest assumptions around emissions from each source, to reflect the best range of evidence available. See Section **8.2** for further details.

5.3.3 Timing

The design of any scrappage scheme will determine the exact processes required to implement it. There are a number of factors that would drive the timescale including potential need for new legislation, getting major project assurances in place, addressing any state aid challenges, developing contracts and agreements with industry and identifying organisations to set up and administer the scheme.

It is anticipated that it would take at a minimum 18 to 24 months before any scrappage scheme could be launched.

5.3.4 Government cost

The main cost to Government that has been quantified is the cost of the grants paid to participants of the scheme. The discounted cost to Government is estimated to be around £110m (2017 prices and base year).

Under this scheme, 15,000 Euro 1-5 diesel cars/Euro 1-3 petrol cars are replaced with electric cars. The grant level that has been assumed for this option is £8,000. This is based on the size of the grant awarded in a similar scrappage scheme in France, which achieved a similar level of take-up. £8,000 is significantly higher than the £2,000 residual value of the vehicle that would be scrapped, which reflects the fact that additional incentives are likely to be needed to incentivise people to change their cars earlier and move to a BEV.

The costs to administer any scrappage scheme have not been estimated at this stage. The costs will be dependent on how any scheme is delivered. If industry were to participate (in line with the previous UK scrappage scheme in 2009), this could lower the costs of operating a scheme for central government as the costs could be shared with industry. To illustrate the magnitude of these costs, the annual administrative costs associated with the previous scheme were estimated to be around £450,000[59] (2009 prices); this estimate includes staff and consulting costs plus other fees. The impact on taxes has not been assessed at this stage.

5.3.5 Public cost

The key assumption underpinning the scrappage analysis is that vehicles are scrapped sooner than they would have been had there been no scrappage scheme. Consequently, society loses the residual value of vehicles that are scrapped sooner. This welfare cost has been valued by quantifying the residual value of the vehicles

---

[59] The estimate above has been scaled up to cover one whole year. Actual estimate was £331,000 (2009 prices over 9 months).

by Euro standard and multiplying these by the expected number of vehicles that will be scrapped. The discounted costs to society associated with the lost residual value of the vehicles scrapped are estimated to be around £10m over the appraisal period.

In general economic terms, any form of subsidy offered results in a deadweight loss (reduction in net economic benefits) to society. Economic inefficiency (loss to society) could arise as a result of some consumers taking up the scheme even though the benefit to them of the BEV is less than the real cost of the BEV. The discounted costs to society associated with the deadweight loss are estimated to be around £40m over the appraisal period.

Given rational consumer choice, it has been assumed that the additional cost to consumers of purchasing a BEV is offset by the operating cost savings and the additional utility gained by the consumer. This means that the first three years (based on the assumed average length of ownership) of operating costs are assumed to be accounted for in the original decision to purchase. The operating cost savings to society (after the assumed three year ownership period) have been quantified and are estimated to be around £10m (2017 price and base year) over the appraisal period. The measure will also result in a transfer to consumers (the grant that the government pays out to those that take up the scheme). The discounted benefits to society associated with the transfer are estimated to be around £110m over the appraisal period.

The total discounted net benefit (costs of lost residual value and deadweight and benefits of the transfer to consumers and benefits of operating cost savings) to society associated with this measure are estimated to be around £70m over the appraisal period.

5.3.6 Health benefit

NO_x emissions would be expected to fall as a result of the change in the fleet composition. NO_x emission factors by Euro standard from the NAEI were used for the different vehicle types to assess the impact. The estimated reduction in NO_x over the appraisal period is estimated to be around 0.4kt for this option.

The transport average damage costs were then applied to the total emissions savings and discounted to provide an estimate of the health impacts. It is estimated that the measure could result in a health benefit of around £10m.

5.3.7 Greenhouse gas emissions

Greenhouse gas (GHG) emissions would be expected to fall as a result of the change in the fleet composition. CO_2 emission factors from the NAEI split by Euro standard and vehicle type were used to assess the impact of the measure. The estimated reduction in CO_2 is estimated to be around 0.2MtCO_2.

The social costs of carbon were then applied to the total emissions saving and discounted to provide an estimate of the GHG impacts of the options. It is estimated that the measure could result in around £10m in benefits from GHG emission savings over the ten-year appraisal period.

The current assessment does not consider the impact of GHG emissions from the additional electricity consumed by the BEVs, as these are included in the cost of electricity through its inclusion in the EU emissions trading scheme.

5.3.8 Economic growth

In the short term, scrappage schemes could have a small positive impact on economic growth, although this will depend on the size of any scheme and rates of uptake. This is because they may lead to an increase in demand for new cars. The primary objective of the previous national scrappage scheme was to provide a boost to the UK car industry by attempting to offset the dramatic decline in car sales at the time (as a result of the recession). The longer-term impacts of scrappage schemes on economic growth are more uncertain.

5.3.9 Conclusion

Table **5.6** summarises the results for this option.

Table 5.6: Summary of impacts of the scrappage assessment[I]

	Results	Confidence in assessment	Comments
First year air quality improvement[II]	0.008µg/m^3 in 2020	Established (preliminary assumptions)	This is the average reduction in the maximum concentration for all UK reporting zones.
Total reduction in NO_x emissions[III]	0.4kt over ten years		
Timing to impact[IV]	1-3 years	N/A	Assumed year of scrappage is 2019, impacts assumed to feed through in 2020.
Health impact	£10m	Indicative	The health benefit of the reduction in NO_x emissions.
Government impact	-£110m	Indicative	Includes the cost of the grant payments, excludes the costs to administer the scheme and any impacts on changes in tax revenues.
Public impact	£70m	Indicative	The net of the value of the grant, deadweight loss, operating cost savings and lost residual value of the asset to society.
Greenhouse gas emissions impact	£10m	Indicative	The benefit of the change in CO_2e emissions.
Economic growth impact	Short term small positive, longer term uncertain	N/A	Increased demand for new cars may boost growth in the short term but the longer-term impacts are more uncertain.

[I] All monetised values are present values, discounted to 2017 prices, appraised over 2019-28

[II] This is the reduction in average NO_2 concentrations, in the first year where air quality impacts are expected to arise as a result of the implementation of the option. This is relative to the baseline projection for the option in the particular year specified.

[III] This is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period. This is in comparison to the baseline projection for the option over the same ten-year appraisal period.

[IV] Indicative timings are provided for all options as either <1, 1-3 or >3 years.

5.4 Ultra Low Emission Vehicles

5.4.1 Introduction

The plug-in car grant is an existing scheme set up by Government to incentivise the take-up of both battery operated electric vehicles and plug-in hybrid electric vehicles (collectively referred to as Ultra Low Emission Vehicles (ULEVs) from this point forward) through a subsidy on the purchase price of new ULEVs. Section **3.4** explores the theoretical maximum potential of motorists switching to battery electric vehicles. This section considers the impact of a more feasible proposal of extending the length of the existing scheme at current grant levels. For the purposes of the modelling scenario, it is assumed the criteria of the current scheme will continue to apply only to cars. Thus, the impact of this measure on both vans and motorcycles has not been measured.

For illustrative purposes, this option assumes an additional funding pot of £300m over the next three years, to the end of this parliament. The costs to administer this proposed option have been assumed as marginal as this builds on an existing scheme, therefore the modelling assumes that the full funding pot will be utilised through the scheme and that demand perfectly fits annual budgets. This would mean a total of around 160,000 ULEVs being purchased over the next three years. Of these, the funding is assessed to provide an additional 60,000 ULEVs being purchased as a result of this measure (the other 100,000 ULEVs would have been purchased anyway).

The grant will be lower, on average, than the additional cost to the consumer of purchasing an ULEV over a convention vehicle. However, consumers continue to buy new ULEVs, in part due to the cost savings that occur in tax and operating costs. The modelling therefore looks at both the cost to Government of the scheme, but also the wider consumer benefits, operating costs and the deadweight loss associated with a subsidy type scheme.

The emission reductions and health impacts from these additional ULEVs have been modelled against a baseline scenario that they would otherwise have been newly purchased conventional cars (Euro 6 standard), split equally between petrol and diesel variants (based on existing evidence of purchasing decisions). Consequently, the reduction in NO_2 concentrations results from this switch from conventional cars to ULEVs. There is not a complete reduction in NO_x emissions, as some will continue to be released from the plug-in hybrid vehicles when they are running on their conventional engines. In addition, the impact on emissions is reduced, as newer conventional cars tend to emit relatively lower levels of NO_x than their older counterparts do.

Initial modelling of these proposals shows that the net present value of this measure is negative. This is mainly because the additional cost of the grants to Government outweighs the estimated benefits to society over the course of the ten-year appraisal. However, the modelling considers the impact of additional funding for the plug-in car grant in isolation, without the other parts of the Government's wider programme of support for ULEVs and associated benefits.

As with other policies outlined in this report, it should be noted that there are a range of non-monetised benefits associated with promoting early uptake of ULEVs, which it has not been possible to quantify in this modelling. The short appraisal period used fails to capture the full lifespan of the cars bought using the grant. Thus the potential associated long-term benefits of increased ULEV adoption, such as greater public understanding, acceptance, and uptake of ULEVs, are not accounted for at this early stage. Increased acceptance and uptake of ULEVs should ensure that we stay on a path consistent with our carbon budgets. These benefits are likely to be significant; cost-benefit analysis over a period to 2050 shows ULEV support to be cost effective.

5.4.2 Air quality impacts

As ULEVs have low NO_x emissions (and Battery Electric Vehicles have none), the air quality improvements stem from the assumption that each additional ULEV is replacing a conventional car. The vehicles being replaced are assumed to be new Euro 6 cars (i.e. that consumers would have bought a new car without the policy), split equally between petrol and diesel. As Euro 6 standard vehicles emit significantly less NO_x compared to older variants, replacing these newer vehicles with ULEVs has a correspondingly lower air quality impact than replacing older conventional vehicles.

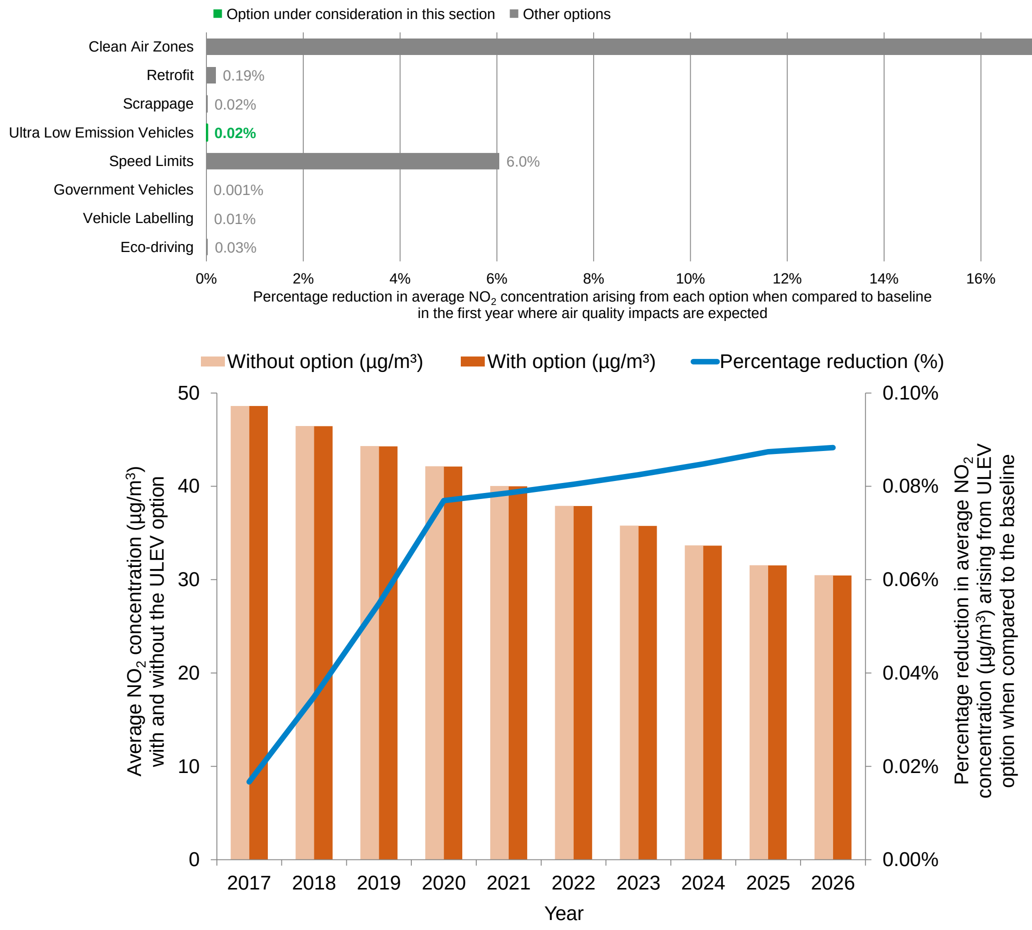
A profile of the changes in NO_2 concentration associated with the support for ULEVs option is provided in Figure **5.7**.

5.4.3 Timings

The plug-in car grant is already established and it is envisaged that this proposal would supplement existing funding, allowing the current grant rates to be maintained for a longer period. This is expected to lead to increased ULEV uptake. Any extension of the PICG could be implemented with minimal delay.

The key assumption on timing is that the integration of the additional ULEVs into the general fleet of cars will be complete by the end of 2019. If the measure is implemented in 2017, the air quality benefits of this proposal would begin as soon as additional ULEVs are introduced into the fleet. However, the full effects of the policy only become evident once the full integration of the new vehicles into the fleet is complete.

Figure 5.7: Reduction in average NO_2 concentrations following the implementation of the support for Ultra Low Emission Vehicles (ULEVs) option



The light and dark shaded orange bars show the projected mean NO_2 concentration with and without the implementation of the promotion of Ultra Low Emission Vehicles (ULEV) option. The blue line shows the percentage reduction in mean NO_2 concentration attributable to the implementation of the ULEV option (i.e. the percentage difference between the 'with' and 'without' option bars). The promotion of ULEVs option is assumed to be implemented in 2017. Its impact on NO_2 concentrations over the appraisal period is estimated to be relatively low in magnitude overall, increasing in the first few years from a reduction of 0.02% in the implementation year to around 0.08% in 2020. From then onwards, the increase in impact is more gradual, starting to level off at around 0.09% by the end of the appraisal period.

The absolute reduction in NO_2 concentration assumes the baseline scenario is dependent on the effectiveness of the Euro standard. If the Euro standards are less effective than predicted (as with historical real-world operations), the impact of ULEVs will differ from the projections presented here.

These projections have been produced from the SL-PCM model. It is not feasible to obtain uncertainty ranges for these estimates. Uncertainty estimates surrounding input data are also limited, but the SL-PCM modelling incorporates the latest assumptions around emissions from each source, to reflect the best range of evidence available. See Section **8.2** for further details.

5.4.4 Government cost

The assumed cost to Government of this option is the funding pot of £300m to fund the expansion and extension of the plug-in car grant. This would fund the purchase of around 60,000 additional ULEVs, above the baseline, over the next three years. As the cost will occur over a number of years, the discounted impact to Government is a cost of around £290m.

It should also be noted that at this stage project running costs and complementary infrastructure costs, such as additional charging stations if needed, have not been quantified or accounted for.

5.4.5 Public cost

The measure will result in a transfer to consumers in the form of the grant that the Government pays out to those that take up the scheme. The discounted impact to society associated with the transfer is estimated to be around £140m over the appraisal period.

Given rational consumer choice, it has been assumed that the additional cost to consumers of purchasing a ULEV (above the grant level) is offset by the operating cost savings and the additional personal satisfaction gained by the consumer from owning a ULEV. There are further benefits, from reductions in operating cost calculated as a result of moving to a ULEV, which have been calculated from year four onwards. This means that the first three years (based on assumed average length of ownership) operating costs are assumed to be accounted for in the original decision to purchase. The operating cost savings to society (after the assumed three-year ownership period) have been quantified and are estimated to be around £30m over the appraisal period.

Other factors such as requiring a longer charging time on long distance journeys and less noise pollution compared to conventional cars have not been quantified in this assessment.

Therefore, the total discounted impact on society associated with this option is estimated to be around £170m over the appraisal period.

5.4.6 Health benefit

NO_x emissions are expected to reduce as a result of this measure due to additional ULEVs entering the fleet and replacing conventional cars. Over the ten-year appraisal period, this results in around 2kt of reduced NO_x emissions.

The average transport damage costs are then applied in order to quantify the health impacts of this reduction in emissions. Over this period the discounted health benefits from this measure is estimated to be around £50m.

5.4.7 Greenhouse gas emissions

In addition to reducing emissions of NO_x and other particulate matter, this measure is also likely to impact upon the level of CO_2 and greenhouse gas (GHG) emissions. As ULEVs replace conventional cars, which emit more CO_2 on average, the option will reduce emissions overall. The total amount of CO_2 reduction was estimated using the average emission levels of the replaced vehicles, per km, and the average vehicle kilometres travelled. This was then offset by the CO_2 generated by the additional plug-in hybrid cars.

The social cost of carbon was then applied to the net emission reductions and discounted to provide an estimate of the GHG impacts of this option. The discounted benefits from this reduction in GHG emissions are estimated be around £50m.

The current assessment does not consider the impact of GHG emissions from the additional electricity consumed by the ULEVs, as these are included in the cost of electricity through its inclusion in the EU emissions trading scheme.

5.4.8 Economic growth

In the short term, this support for increased take up of ULEVs should have a positive impact on economic growth, especially in terms of growth in the ULEV market. There is also the potential for increased jobs and growth linked to the design, development, and manufacture of ULEVs in the UK as a result of increased ULEV uptake.

The ULEV market is still relatively small compared to the more established conventional car industry and the relatively high marginal costs mean this grant scheme should have a positive impact in helping to establish the consumer market for ULEVs. The increased demand for ULEVs generated by this scheme should have a positive short term impact and could lead to increased economic activity than otherwise would have been the case.

5.4.9 Conclusion

Table **5.8** summarises the results for this option. Under the current modelling assumptions, this policy is estimated to lead to a reduction in NO_x emissions and have positive health impacts. However, the current level of technology and production means the initial cost of purchasing an ULEV is, on average, greater than that of a conventional vehicle. Over the course of the appraisal period used this higher initial cost and the government grant used to reduce this cost outweighs the benefits discounted over time. However, these benefits will extend beyond the lifetime of the appraisal conducted here as the average life of a car in the fleet is nearer 12 years.

Overall, this policy is estimated to have a net present value of around -£20m. It is important to note that the above assessment does not take into account the significant signalling impact of increased ULEV uptake. It is possible that increased adoption at this early stage could lead to associated long-term benefits of increased public understanding, acceptance, and uptake of ULEVs and associated growth of supporting infrastructure all of which would provide longer-term benefits that have not been quantified.

Table 5.8: Summary of impacts of the ULEV assessment[I]			
	Results	**Confidence in assessment**	**Comments**
First year air quality improvement[II]	0.008µg/m^3 in 2017	Indicative	This is the average reduction in the maximum concentration for all UK reporting zones
Total reduction in NO_x emissions[III]	2kt over ten years		
Timing to impact[IV]	<1 years	N/A	Would build upon the existing EV grant scheme, so assumed to be delivered immediately
Health impact	£50m	Indicative	The benefit of the reduction in NO_x emissions resulting from this measure
Government impact	-£290m	Indicative	This is the discounted cost of the funding grant, administration and supporting infrastructure costs have not been modelled
Public impact	£170m	Indicative	The net benefits of the transfer from Government to consumers and the operating cost savings after the third year of ownership
Greenhouse gas emissions impact	£50m	Indicative	The benefit of the reduction in CO_2e emissions
Economic growth impact	Low	N/A	Low but positive impact dependent on growth of the ULEV market.

[I] All monetised values are present values, discounted to 2017 prices, appraised over 2017-26

[II] This is the reduction in average NO_2 concentrations, in the first year where air quality impacts are expected to arise as a result of the implementation of the option. This is relative to the baseline projection for the option in the particular year specified.

[III] This is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period. This is in comparison to the baseline projection for the option over the same ten-year appraisal period.

[IV] Indicative timings are provided for all options as either <1, 1-3 or >3 years.

6. National measures

6.1 Introduction

Sections **4** and **5** presented the analysis of CAZs and options that could support them by addressing some of their impacts on individuals and businesses. However, not all areas of exceedance can be addressed by establishing CAZs and instead require national measures. This section analyses national measures that could be introduced to help reduce NO_2 concentrations at other locations. These are:

- Speed limits on the motorway network;
- Government vehicle purchases;
- Measures to encourage behaviour change.

Each of these has been assessed in turn, using the same criteria applied in the previous sections.

6.2 Speed limits

6.2.1 Introduction

This policy looks at the potential capacity for improving air quality from controlling vehicle speed. Across most of the UK, management of roads is devolved to local authorities and as a result, speed limits are set locally. Optimising speed limits on local roads for air quality purposes could form part of a local package of measures in a Clean Air Zone but would be difficult to implement at a national level because it is a matter for local decision makers. Highways England sets speed limits on the Strategic Road Network (SRN) in England so alterations on these stretches of road are possible.

There is uncertainty in this area and current modelling methods and evidence are subject to testing and further consideration. The impact of speed limits on motorways are also likely to vary significantly on a road by road basis, and although savings are theoretically possible on motorways, on some stretches of motorway there is likely to be little impact (e.g. where average speeds are already lower than 50mph). The evidence would benefit from further monitoring in real world conditions, for example at sites where variable speed limits are used already for traffic management purposes, to understand better the extent of the impact any change to speed limits might have on air quality in differing circumstances.

The COPERT (Calculation of Emissions from Road Transport) speed emission curves suggest that vehicles travelling at higher average speeds should emit more NO_x the faster they go (Fig. **6.1**).

Figure 6.1: Speed vs NO_x emissions curve for a Euro 5 diesel car[60]

However, it should be noted as well as average speed on a motorway, other factors than speed can be a greater influence on a vehicles emissions, including topography, acceleration, and congestion.

Controlling speeds on the SRN can be delivered with fixed or variable speed limit signs and appropriate enforcement. For this analysis, a variable speed limit option has been analysed. This criterion was chosen as it is considered a more flexible and thus proportionate response to allow restoration of the national speed limit rapidly once specific concerns have been addressed.

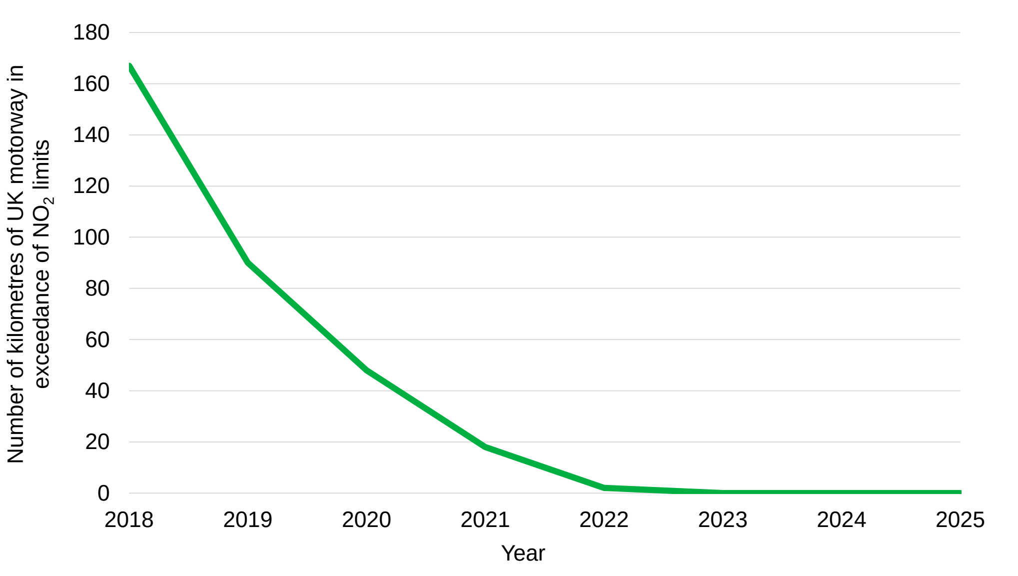
In order to deliver some indicative analysis for this consultation, modelling has been focussed on the motorway network and the introduction of variable 60mph speed limits on sections of motorway projected to be in exceedance of the legal NO_2 limit in each year. This was considered more feasible than the theoretical maximum

[60] This curve is derived from COPERT 5 emission factors. The equivalent data for all other vehicle types and standards is inherent in that dataset and has been used in this analysis. See http://emisia.com/products/copert/copert-5

potential scenario of reductions to 50mph outlined in Section **3.4**, which would have a very high economic cost from slower journeys.

Due to natural fleet turnover, and assuming that the latest Euro standards deliver the expected emission reductions, the baseline projection for the length of UK motorway exceeding the 40µg/m^3 limit reduces over time. About 170km is in exceedance in 2018 but by 2023, it is anticipated that the entire motorway network will achieve compliance (Fig. **6.2**). This analysis assumes that once the air quality issues have been addressed the speed limits will no longer be used for this purpose.

Figure 6.2: Projection profile for the number of kilometres of UK motorway in exceedance of NO_2 limits from 2018 to 2025



Note: This is assuming that the current technological improvements associated with EURO 6 standards, those associated with fleet turnover, and the move to low emission vehicles are all delivered.

6.2.2 Air quality impacts

There is considerable uncertainty about the impacts of speed limit changes on air quality in the real world. This is linked to the important qualification that although higher speeds may typically be associated with higher emissions, other factors than speed including topography, acceleration, and congestion are often more important factors.

Two modelling approaches can be used to illustrate the impact of speed limit changes. It is important to highlight the impact the modelling approach has on the final outputs and the uncertainty around them. The first approach, based on COPERT speed emission curves, is the modelling method used in this report and described in Section **3.2**; the second approach is Highways England's traffic modelling methodology (Box **6.3**).

The COPERT speed emission curves used in the SL-PCM model shows that at high speeds (above 50mph) a reduction in average speed directly feeds through to a reduction in road emissions. Using the COPERT curves is consistent with the approach used when estimating national emissions. However, the COPERT speed emission factors model the impact of changes in average speed, but do not assess the specific policy of imposing a lower than typical speed limit on vehicles on a motorway. They were used to adjust the emission factors of vehicles from the current speed on that road to 60mph[61].

Due to necessary simplifying assumptions in the model, the impact of this option is calculated on the assumption that the speed of traffic on failing motorway links is the same as the national average (for the type of motorway). It is possible that highly polluted motorway links tend to be busier and more heavily congested, and that average speeds on them are lower. In this case, a change in the speed limit may have little impact on air quality - because cars are already travelling at speeds below the limit.

The inputs into the modelling scenario are that:

- Speed limits would be applied only to the motorway road links projected to be in exceedance in 2021 (which is the earliest that variable speed limit equipment could be installed – see Section **6.2.3**). As links come into compliance through fleet turnover or other measures, the speed restriction would be lifted.

- For the purposes of this analysis, it is assumed that the speed limits would remain constant throughout the day. Although the use of variable speed limit equipment would in practice allow the speed limit to be reduced only at certain times this has not been modelled, as the effect of doing so would depend on the circumstances of each link.

- The effect of speed limit change on emission factors (EF) is calculated as the change in EF from 70mph to the proposed speed limit, individually calculated from speed curves for all vehicle types and Euro standards, using COPERT 5 data.

---

[61] Vehicles that are speed limited to less than 60mph, or are already subject to a speed limit of 60mph, are excluded

- Motorway links where traffic is already travelling at or below 60mph on average are assumed not to be impacted. This would be expected to result in an under-estimate of the impacts (as it would not capture the impact of reduced speed limits when traffic on these links is travelling above 60mph). However, this needs to be considered within the context of the other uncertainties referred to above, which may result in impacts being over-estimated.

- HGVs and buses are not affected, as they are speed limited to 60mph.

The main assumptions, which are also listed with a description of their associated uncertainties in Section **8.3**, are that:

- The effect of reducing the motorway speed limit from 70 to 60mph can be simulated by modelling a reduction in the average speed (by 10mph) of affected vehicles on those links where average speeds are over 60mph.

- Effects to flow of traffic can be ignored.

This approach projects an average reduction in NO_2 of 2.5µg/m^3 across the motorway links where the policy is applied. A profile of the changes in NO_2 concentration associated with speed limits on these links over time (Fig. **6.4**) shows no impact from 2023 onward, reflecting the fact that natural fleet turnover lowers the potential impact of the policy to zero by 2023.

Highways England's approach to modelling the effect of speed on air quality (Box **6.3**) would give different results. The uncertainty this creates means the impact of this policy in reducing concentrations is expressed in this report as being *up to* 2.5µg/m^3 of NO_2.

Box 6.3: The interplay of speed and traffic volume and their effects on air quality

To fully assess the impacts of changes in speed on air quality it is necessary to consider both the impact on average speed and traffic volume.

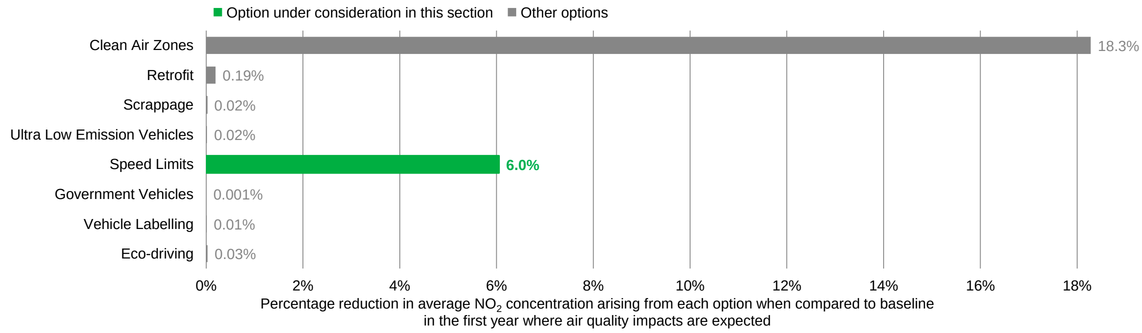
This can be seen in the scheme assessment methodology developed by Highways England to assess the impact of a road improvement on air quality. This approach, as set out in Interim Advice Note (185/15)[62], does not use speed emission curves in the same way as national modelling but rather uses congestion and traffic volume as key determinants of pollution levels. The modelling approach assumes that small changes in speeds have no impact on per vehicle NO_x emissions. Applying this approach (with the assumption of no change in traffic volumes) would result in zero emission reductions from a lower speed limit.

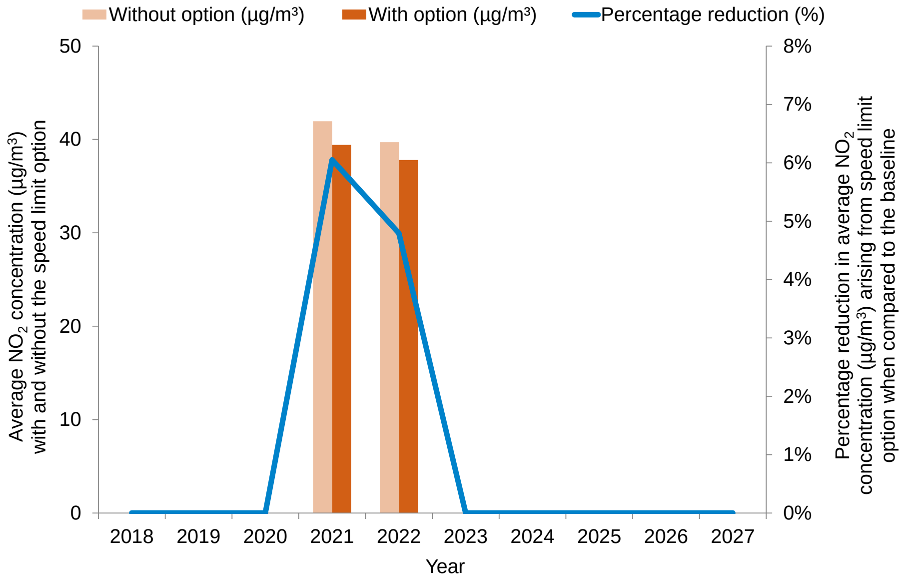
However, if the Highways England approach was followed the reduction in traffic volumes resulting from lower speed limits and the impact of this on NO_x emissions would also be modelled. It has not been possible to reflect changes in traffic volumes within the technical assessment in this report, which creates a notable uncertainty around the results and hence the potential efficacy of the option.

---

[62] Standard for Highways, *'Interim Advice Note 185/15 – Updated traffic, air quality and noise advice on the assessment of link speeds and generation of vehicle data into 'speed-bands' for users of DMRB Volume 11, Section 3, Part 1'*, 2015 <http://www.standardsforhighways.co.uk/ha/standards/ians/pdfs/ian185.pdf>.

Figure 6.4: Reduction in average NO_2 concentrations following the implementation of the speed limit option modelled under the COPERT method





The light and dark shaded orange bars show the projected mean NO_2 concentration with and without the implementation of the speed limit option when modelled under the COPERT method. The blue line shows the percentage reduction in mean NO_2 concentration attributable to the implementation of the speed limit option (i.e. the percentage difference between the 'with' and 'without' option bars). The implementation of the reduction in speed limits policy is assumed to begin in 2018, but due to the long setup time, air quality impact would not be seen until 2021 in the modelled scenario. Speed limits are projected to reduce mean NO_2 concentrations by 5-6% in 2021-2022, but this would be a localised rather than a national impact covering only the sections of motorway projected to be in exceedance in those years (Fig. **6.2**), and by nature of being a mean will include links with higher or lower impacts. Additionally, the reduction in NO_2 concentrations presented is the maximum predicted effect of this option as the effects on traffic volume have not been incorporated (Box **6.3**).

The absolute reduction in NO_2 concentration assumes the baseline scenario is dependent on the effectiveness of the Euro standard. If the Euro standards are less effective than predicted (as with historical real-world operations), the impact of speed limits will differ from the projections presented here.

These projections have been produced from the SL-PCM model. It is not feasible to obtain uncertainty ranges for these estimates. Uncertainty estimates surrounding input data are also limited, but the SL-PCM modelling incorporates the latest assumptions around emissions from each source, to reflect the best range of evidence available. See Section **8.2** for further details.

6.2.3 Timing

The time to implementation of a speed limit policy is dependent on the approach adopted. If the focus is on upgrading affected stretches of motorway with variable signs (as modelled here), it is likely to take until 2021.

The first step to implementing this policy would be installation of gantries with variable sign systems. A small proportion of motorway projected to be in exceedance in 2021 is already on HE's programme for Smart Motorway upgrade. This would provide the required equipment to implement the policy. This is scheduled for completion in late 2020 to early 2021; however, construction has not yet begun.

It is estimated it would be at least two to three years before construction could start on installing gantries along remaining lengths of carriageway unless significant de-prioritisation exercises were conducted in relation to the wider HE investment programme.

As such, the soonest that benefits could start to be seen on motorway lengths not already in the programme for upgrade would be late 2020. This is in line with the currently scheduled work so for all scenarios benefits would begin to be seen in 2021.

These projects are significant construction projects on the SRN, which is critical infrastructure, so there are likely to be risks to meeting the timescales.

6.2.4 Government cost

Implementing lower speed limits on sections of motorway where the requisite equipment is already installed for other purposes would be relatively cheap. However, to implement this policy on other motorways would incur additional costs to putting in gantries and installing and maintaining the necessary equipment.

Costs for installing and maintaining the equipment on the motorway links projected to be in exceedance in 2021 (about 18km, across ten different links) are estimated to have a ten-year PV cost of about £25m. These estimates are based on a high-level unit cost for the equipment and its maintenance representing an average. They should not be used to develop a standard cost for every scheme. It is also likely to be an underestimate, as it does not include the cost of software maintenance and other sundry costs.

6.2.5 Public cost

Significant public cost through longer journey times is likely to be incurred by reducing speed limits. Evidence from a DfT commissioned Transport Research Laboratory (TRL) report into road safety[63] that modelled reducing speed limits to 60mph on motorways has been used to estimate these costs at £8m. The report authors used 'Transport Analysis Guidance: WebTAG'[64] values for work and leisure time and the proportion of journeys in each category in their analysis.

To adjust the published costs they were scaled and profiled to take account of:

- the 18km of motorway (less than 1% of the UK network) where the policy would be implemented initially. Note, this may underestimate costs if links with air quality problems have higher traffic volumes than average;
- the projected reduction in baseline exceedances in following years (Fig. **6.2**); and
- current prices.

There are a number of other costs and benefits to the public that it has not been possible to disaggregate, including:

- fuel savings;
- speed related injuries and fatalities;
- benefits to traffic flow from active management; and
- costs due to delays and diversions during construction.

6.2.6 Health benefit

Estimates of the NO_x emissions savings from the modelling give total health benefits estimated at up to £1m. This is low because the policy is applied to such a small length of the road network.

---

[63] Sexton and Johnson, '*An evaluation of options for road safety beyond 2010'* (2009). Available at <https://trl.co.uk/reports/PPR397>.

[64] Department for Transport, Transport analysis guidance: WebTAG <https://www.gov.uk/guidance/transport-analysis-guidance-webtag>.

6.2.7 Greenhouse gas emissions

As well as NO_x emissions savings, reducing speed limits on motorways would reduce CO_2 emissions. These savings are quantified in the TRL report at 13,000kt over 10 years, which, once scaled and profiled to exceeding motorway and raised to 2017 damage prices, gives a net discounted benefit of £0.5m. This is low because the policy is applied to such a small length of the road network.

6.2.8 Economic growth

Construction of new gantries would provide some short-term positives to employment but counter to this there would be negative impacts from this policy because of the impact on journey times.

6.2.9 Conclusion

Reducing speed limits on motorways to 60mph has a net present value under this analysis of -£25 to -£32m. The results are summarised in Table **6.5**. Unquantified benefits may make upgrades to roadside equipment worthwhile for other reasons – see analysis for more detail.

Table 6.5: Summary of impacts of the speed limits assessment [I]

	Results[II]	Confidence in assessment	Comments
First year air quality improvement[III]	Up to 2.5µg/m^3 in 2021	Indicative	Impacts estimated only for stretches of motorway that are non-compliant in 2021
Total reduction in NO_x emissions[IV]	Up to 0.05kt over ten years		
Timing to impact[V]	>3 years	N/A	For variable speed limit equipment
Health impact	Up to £1m	Indicative	The benefit of the reduction in NO_x emissions resulting from this measure
Government impact	-£25m	Indicative	Equipment installation and maintenance.
Public impact	Up to -£8m	Indicative	Journey times included. Fuel savings, accidents, and benefits to decongestion not included.
Greenhouse gas emissions impact	Up to £0.5m	Indicative	The benefit of the reduction in CO_2e emissions resulting from this measure
Economic growth impact	Negative	N/A	Small short term benefits through increased employment from constructing gantries; large long term cost via longer journeys

[I] All monetised values are present values, discounted to 2017 prices, appraised over 2018-27.

[II] All impacts related to air quality are expressed as 'up to *x*' because there is uncertainty over the modelling approach in relation to vehicle speed.

[III] This is the reduction in average NO_2 concentrations, in the first year where air quality impacts are expected to arise as a result of the implementation of the option. This is relative to the baseline projection for the option in the particular year specified.

[IV] This is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period. This is in comparison to the baseline projection for the option over the same ten-year appraisal period.

[V] Indicative timings are provided for all options as either <1, 1-3 or >3 years.

6.3 Government vehicles

6.3.1 Introduction

This policy measure would involve updating the Government Buying Standards for transport (GBS-T) to include NO_x and PM impacts, in order to guide the procurement process, as committed to in the 2015 Air Quality Plan[65]. Including NO_x and PM considerations would lead to the promotion of low NO_x alternatives (where possible), such as petrol over diesel fuelled vehicles, thus reducing the NO_x impact of the public sector. The updated GBS-T will consist of a Pre-Procurement Tool (PPT) and updated documentation.

Beyond the direct NO_x and PM reductions from this measure, Government action in this area would signal a strong intent to lead by example in tackling air pollution and would be a notable non-quantifiable benefit.

Updating the GBS-T would, over time, replace the Government fleet with vehicles that have lower NO_x and PM emissions. This could potentially have a knock-on positive effect on the second-hand vehicle market with a steady influx of better performing vehicles, in terms of NO_x emissions.

The policy is limited by the fact that low NO_x alternatives do not exist for certain specialist vehicles in the public sector fleet (such as fire engines, mobile plant vehicles, or Non-Road Mobile Machinery (NRMM)). Thus the update to GBS, taking account of NO_x emissions, will have no effect on these vehicle classes.

A further limitation to this policy is that the PPT, which provides vehicle recommendations based on the inputs regarding procurer requirements, places NO_x emissions alongside other factors such as up-front and operational costs and CO_2 impacts. Therefore, the importance of NO_x emissions in the decision process would vary on a vehicle-to-vehicle basis. This means it is uncertain how including air quality factors would alter purchasing decisions.

Whilst all Government Buying Standards are mandatory for central Government, they are only a recommendation for the wider public sector, so this option would not necessarily lead to a change in wider public sector behaviour. Defra is exploring how the GBS-T could be rolled out across the wider public sector. At this stage however, analysis is presented for central Government only.

---

[65] In the 2015 Air Quality Plan, Defra committed to introduce NO_x and PM standards in the GBS by the end of 2017. See Section **6.3.3**.

Section **3.3** discussed the theoretical maximum technical potential of this option. This analysis takes a more feasible approach in line with the limitations outlined above. In addition, there may be some circumstances where only a diesel car is either available or is the most appropriate for a given purpose, such as where a high torque is required. Switch rates may be higher than assumed especially if influenced by other national measures (such as CAZs), however assuming this to happen would pre-empt the outcome of the consultation. It is assumed that 30% of all new central Government vehicles previously bought as diesel are now being bought as petrol.

6.3.2 Air quality impacts

This option would promote consideration of air quality impacts when new vehicle purchasing decisions are made within central Government, changing purchasing decisions to petrol from diesel. New Euro 6 diesel vehicles emit around 10 times more NO_x than new Euro 6 petrol vehicles so switching to petrol should result in positive air quality impacts.

With other vehicle types, there is less certainty that petrol alternatives would be available. Assuming that each year 30% of new cars that central government would have previously bought as diesel are now bought as petrol, the modelling suggests that by 2020 7% of the total central Government vehicle fleet will be a Euro 6 petrol in 2020. This increases to 18% in 2025 and 23% in 2027.

A profile of the changes in NO_2 concentrations associated with the Government Buying Standards option is provided in Figure **6.6**.

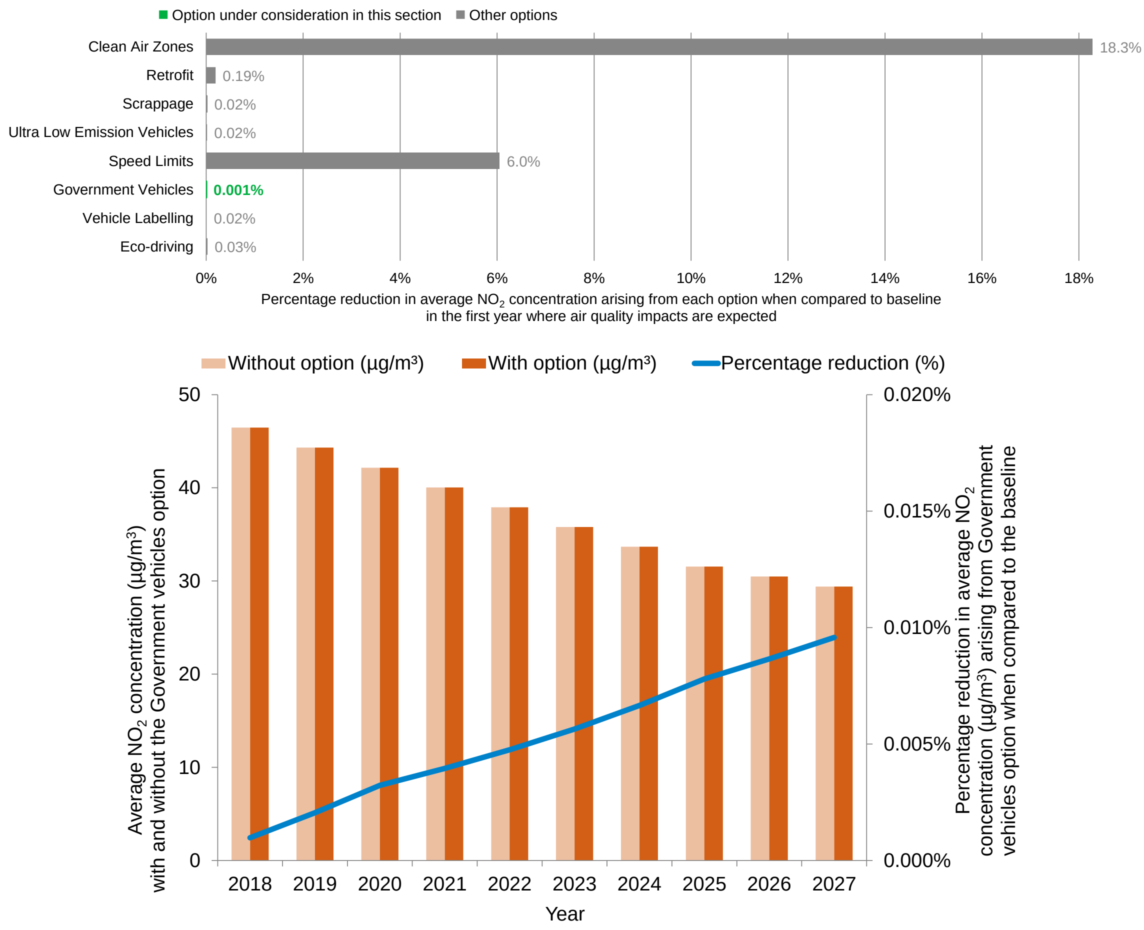
6.3.3 Timing

The GBS-T update is currently under development. Government has committed for this to be in place by the end of 2017. Therefore, the expectation is for the updated GBS-T to be in place for all purchasing decisions at the beginning of 2018. Once in place, this policy is expected to have an immediate impact across central Government.

Figure 6.7: Government vehicles Gantt chart, timeline of measure implementation

Task	2017	2018			
	Q4	Q1	Q2	Q3	Q4
Agree GBS for transport update					
Clearance process					
GBS update comes into force					

Figure 6.6: Reduction in average NO_2 concentrations following the implementation of the Government vehicles option



The light and dark shaded orange bars show the projected mean NO_2 concentration with and without the implementation of the Government vehicles option. The blue line shows the percentage reduction in mean NO_2 concentration attributable to the implementation of the Government vehicles option (i.e. the percentage difference between the 'with' and 'without' option bars). The government buying standards option is assumed to be implemented in 2018 and is projected to have a low but steadily increasing magnitude of impact on NO_2 concentrations, reaching a reduction of around 0.01% per year by the end of the appraisal period.

The absolute reduction in NO_2 concentration assumes the baseline scenario is dependent on the effectiveness of the Euro standard. If the Euro standards are less effective than predicted (as with historical real-world operations), the impact of Government vehicles will differ from the projections presented here.

These projections have been produced from the SL-PCM model. It is not feasible to obtain uncertainty ranges for these estimates. Uncertainty estimates surrounding input data are also limited, but the SL-PCM modelling incorporates the latest assumptions around emissions from each source, to reflect the best range of evidence available. See Section **8.2** for further details.

6.3.4 Government cost

The cost to establish the policy is assumed to be negligible given that it was committed to in the 2015 Air Quality Plan. In terms of the cost to administer this policy, this is also assumed to be negligible.

The government cost calculated is based on two components:

- **Capital switching cost**

  This is the difference between the on the road price[66] of the diesel and petrol variants of a representative car in a given segment[67]. These variants are assumed to be accurate representatives of the petrol and diesel cars the public sector would purchase. The assumptions are detailed in Section **8**. Overall, the switch from diesel to petrol is expected to result in capital cost savings totalling £0.35m in present value terms over the appraisal period

- **Running cost**

  Given these are Government cars their fuel cost is also a cost to Government. The Government cost of this policy is the change in fuel cost due to the switch from diesel to petrol, calculated following WebTAG guidance[68]. Running costs are estimated to increase by a total of £2.0m in present value terms over the appraisal period

The Government cost of this option is estimated to be £1.7m in present value terms.

6.3.5 Public cost

There is no direct public cost as a result of this option as the scope is only the Government fleet.

---

[66] On the road price: recommended retail price plus the delivery charge, plus the cost of half a tank of fuel, the car's number plates, road tax, and the First Registration Fee.

[67] This refers to the vehicle segmentation done by the Crown Commercial Service.

[68] Department for Transport, WebTAG: TAG data book, July 2016 <https://www.gov.uk/government/publications/webtag-tag-data-book-july-2016>.

6.3.6 Health benefit

The health benefits are calculated from the SL-PCM modelling outputs. The SL-PCM model provides an annual emission reduction in NO_x tonnes/year, estimated to be a total of 0.083kt over the appraisal period. The transport average damage cost for the relevant year (uplifted to current prices) is then multiplied by the emission reduction in order to value the health benefit. The result is an estimated present value benefit of £2.04m over the appraisal period.

6.3.7 Greenhouse gas emissions

The switch from diesel to petrol leads to a change in the CO_2 emissions per car. The direction of this change is dependent on the segment being looked at, but overall the modelling indicates an increase in CO_2 emissions of 4.02kt.

The monetary impact of this has been quantified by estimating the distance travelled by these cars and multiplying it by the differences in manufacturer-provided CO_2 emissions in g/km. This results in an estimated present value cost of £0.23m.

6.3.8 Economic growth

Any impact of the government fleet switching from diesel to petrol is expected to be negligible as there would be no overall change in the number of cars being purchased.

6.3.9 Conclusion

Table **6.8** summarises the results for this option.

Table 6.8: Summary of impacts of the Government vehicles assessment[I]

	Results	Confidence in assessment	Comments
First year air quality improvement[II]	0.0005µg/m^3 in 2018	Established (preliminary assumptions)	This is the average reduction in the maximum concentration for all UK reporting zones
Total reduction in NO_x emissions[III]	0.083kt over ten years		
Timing to impact[IV]	<1 year	N/A	Commitment to update by end of 2017 and so impact felt from 2018
Health impact	£2.0m	Established (preliminary assumptions)	The benefit of the reduction in NO_x emissions resulting from this measure
Government impact	-£1.7m	Established (preliminary assumptions)	Whilst the Government benefits from lower capital costs, higher running costs outweigh this benefit leading to a net cost
Public impact	Negligible	Established (preliminary assumptions)	No direct impact on the public
Greenhouse gas emissions impact	-£0.23m	Established (preliminary assumptions)	The cost of the change in CO_2e emissions resulting from this measure
Economic growth impact	Negligible	N/A	No impact expected since number of purchases remain the same only fuel types are substituted

[I] All monetised values are present values, discounted to 2017 prices, appraised over 2018-27.

[II] This is the reduction in average NO_2 concentrations, in the first year where air quality impacts are expected to arise as a result of the implementation of the option. This is relative to the baseline projection for the option in the particular year specified.

[III] This is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period. This is in comparison to the baseline projection for the option over the same ten-year appraisal period.

[IV] Indicative timings are provided for all options as either <1, 1-3 or >3 years.

6.4 Measures to encourage behaviour change

6.4.1 Introduction

The measures identified in the previous sections seek to reduce NO_x emissions through a mix of regulation, fiscal policy, and other methods. Another important policy lever to consider is influencing driver behaviours. This could be achieved through the provision of information, creating credible low-polluting alternatives in the market, or government signalling intent, among many other methods.

This section discusses two such initiatives to tackle NO_x emissions. They attempt to change driver behaviour at two points within a vehicle's lifecycle. Vehicle labelling attempts to change consumer behaviour at the point of vehicle purchase. It does so by changing consumer perceptions of the environmental impact of vehicles through information provision. The 'influencing driving style' option would use education and technology to quantify and reinforce the economic and environmental cost of harsh driving for each driver. By equipping them with the knowledge of how to reduce their impact, this will lead to a cheaper and lower-emission driving style.

The greatest uncertainty in any behavioural measure is the impact a behavioural option will achieve, when people's responses cannot be predicted. However, it is worth noting that behaviour change is easier to bring about if the behaviour is already perceived as normal. Therefore, while the direct impact of these behaviour change measures may be uncertain, they do have the potential to contribute to a wider change in attitudinal and eventually behavioural norms around car choice and driving style. This is a notable non-quantifiable benefit.

The measures presented here are purely illustrative and have been presented without detailing the mechanisms that might be used to achieve behavioural change. Our modelling seeks to present the likely impact of mechanisms such as improved driving style or fuller consumer information being made available at the point of purchase for vehicles. The details of these measures are described in the draft overview document.

6.4.2 Vehicle labelling

Introduction

Vehicle labelling looks to provide consumers with the information they require in order to make an informed purchasing decision. Historically, air pollution has not been reflected because of how Euro standards were introduced. This policy would provide air pollution information in a simple to understand labelling scheme for all new vehicles sold. A further exploration, similar to the current scheme, will be made into whether a new label can be developed for second hand vehicles on a voluntary basis.

A labelling scheme detailing fuel consumption and CO_2 emissions information already exists. Therefore, this could be expanded to include a wider environmental snapshot of vehicle performance. This expanded label system will enable consumers to make informed decisions when purchasing vehicles. This is expected to lead to a reduction in the number of diesel vehicles sold, and an increase in the uptake of petrol cars and ULEVs.

Due to the limited evidence on the behavioural change, a range of feasible impacts following the implementation of this option are presented. These options are notably smaller than the theoretical maximum technical potential presented in Section **3.4** because, as with any impact assessment, it is common practice to take a conservative approach to assessing the impacts a new policy will have.

The following two scenarios have been modelled:

- Scenario A: 0.5% shift in purchasing decisions from new diesel vehicles to new petrol vehicles annually from April 2018.
- Scenario B: 1% shift in purchasing decisions from new diesel vehicles to new petrol vehicles annually from April 2018.

Air quality impacts

The policy will affect air quality by promoting switching new vehicle purchases from diesel to petrol. New Euro 6 diesel vehicles currently emit around 10 times more NO_x than new Euro 6 petrol vehicles.

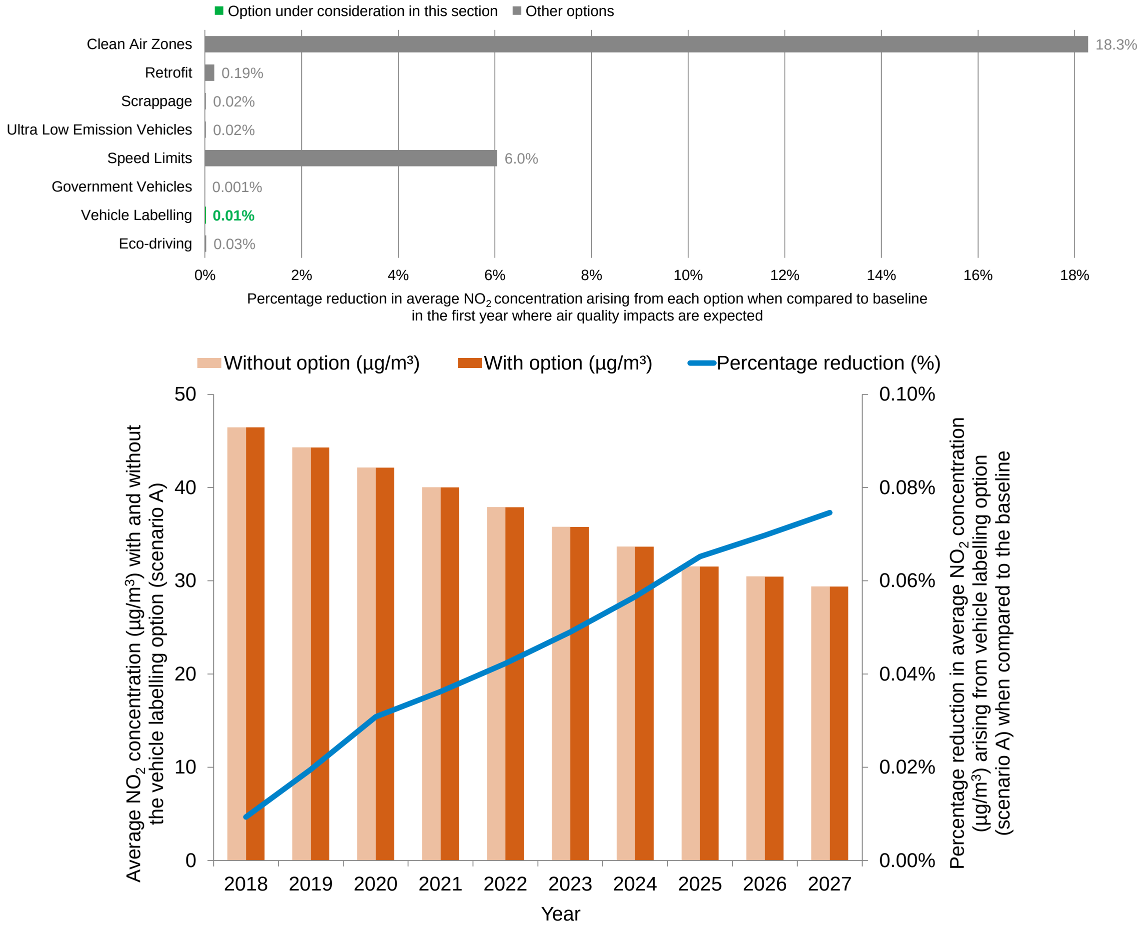
Given the previously mentioned scenarios, the impact is estimated to be

- Scenario A: An additional 0.1% of the national car fleet will be a Euro 6 petrol in 2020, 0.2% in 2025, and 0.2% by 2027.

- Scenario B: An additional 0.1% of the national car fleet will be Euro 6 petrol in 2020, 0.3% in 2025, and 0.4% by 2027.

A profile of the changes in NO_2 concentration associated with the more conservative scenario A is provided in Figure **6.9**.

Figure 6.9: Reduction in average NO_2 concentrations following the implementation of the vehicle labelling scenario



The light and dark shaded orange bars show the projected mean NO_2 concentration with and without the implementation of the scenario A of the vehicle labelling option. The blue line shows the percentage reduction in mean NO_2 concentration attributable to the implementation of the scenario A of the vehicle labelling option (i.e. the percentage difference between the 'with' and 'without' option bars). Scenario A of the vehicle labelling option is assumed to be implemented in 2018. Its impact on NO_2 concentrations is projected to be relatively low, but does increase throughout the appraisal period, from a reduction of around 0.01% in 2018 to almost 0.08% in 2027.

The absolute reduction in NO_2 concentration assumes the baseline scenario is dependent on the effectiveness of the Euro standard. If the Euro standards are less effective than predicted (as with historical real-world operations), the impact of vehicle labelling will differ from the projections presented here.

These projections have been produced from the SL-PCM model. It is not feasible to obtain uncertainty ranges for these estimates. Uncertainty estimates surrounding input data are also limited, but the SL-PCM modelling incorporates the latest assumptions around emissions from each source, to reflect the best range of evidence available. See Section **8.2** for further details.

Timing

The Low Carbon Vehicle Partnership Passenger Car Working Group is currently reviewing the existing car labelling scheme. It is anticipated that changes to reflect environmental pollutants could be included in the label from April 2018.

Figure 6.10: Vehicle labelling Gantt chart, timeline of option implementation

Task	2017	2018				2019			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Working with industry group to review label									
Label launched for new vehicles									

Government cost

The cost to establish the policy is assumed to be negligible given that the review of the labelling system is already funded and the addition of NO_x impacts would simply add onto it. Policy running costs are also assumed to be negligible. Thus, the Governmental cost of the policy is assumed to be negligible.

Public cost

There is no direct cost to the public or business as a result of this measure as the scope of it is towards vehicle retailers and they are already required to print labels. Changing the content of the label would have no impact on their printing costs.

Consumers who choose to buy a petrol vehicle may see an increase in their operating costs; however, this has not been quantified. For this analysis, other indirect impacts have also not been considered.

Health benefit

The health benefits are calculated using the SL-PCM modelling outputs. The SL-PCM model provides an annual emission reduction in NO_x tonnes/year. The transport average damage cost for the relevant year (uplifted to current prices) was then multiplied by this value in order to get a health damage cost. The resulting present value health benefits are £17.5m and £35.0m for Scenarios A and B respectively, with corresponding NO_x emission reductions of 0.73kt and 1.5kt.

Greenhouse gas emissions

The switch from diesel to petrol leads to an increase in the CO_2 emissions per car. The financial impact of this has been quantified by multiplying the average annual distance travelled by a vehicle by the difference in emissions (CO_2 g/km) giving a value for the total additional CO_2 emitted annually per car. This is then multiplied by the number of vehicles switching as a result of the option. The resulting present value GHG costs are £5.30m and £11m for Scenarios A and B respectively, with corresponding CO_2 emission increases of 72kt and 145kt.

Economic growth

A switch from diesel to petrol will not affect economic growth as it is assumed that these vehicles operate within the same sector. Thus, labour and capital inputs into the production process can be easily swapped from diesel car assembly lines to petrol car assembly lines.

6.4.3 Influencing driving style

Introduction

This option would seek to reduce vehicle emissions by improving people's driving styles. Excessive speed, maintaining high engine revolutions, and accelerating hard all are known to increase fuel consumption as well as NO_x emissions. This would promote best practices and driver training to reduce NO_x emissions.

A similar scheme is currently in operation in Scotland. This programme is run via the Energy Savings Trust to train drivers[69].

Section **3.4** outlined the theoretical maximum potential of this option; targeting all car and LGV drivers in the country. This is not deemed feasible given the sheer number of drivers that would be in scope to receive telematics and training. On balance, modelling has been undertaken on training and providing telematics to 100,000 drivers (split proportionally across cars and LGVS) by 2019 as the most feasible option. Assessing this option for 100,000 drivers has been chosen in order to provide an indication of what level would achieve an impact is as short a time as possible. It would be possible to scale the level at which this option is implemented as required.

As with vehicle labelling, this option is purely illustrative.

---

[69] Energy Saving Trust, FuelGood driver training <www.energysavingtrust.org.uk/scotland/businesses-organisations/transport/fuelgood-driver-training>.

Air quality impacts

This option is based on reports[70] that show a 15% reduction in fuel consumption for trained drivers. These reports also indicate that a decline in effectiveness is observed over time, but that the use of telematics can slow down this decline. There is also evidence that NO_x emissions would decline as a result of the techniques taught.

This policy affects air quality by reducing the fuel burnt by a vehicle and thus reducing the emissions.

The models used to assess this option have a necessarily simplified representation of driving behaviour and cannot capture the variability needed to model the precise impact of changes in driving styles. As a result, a percentage reduction in distance travelled by vehicles, where the driver has attended training, has been used to indicate the possible impact of this option. It has been assumed that in 2020 the reduction is 15%, dropping to 7.5% in 2025, and then to 0% in 2030. An extra assumption in the modelling of this policy has been that by training drivers of cars and LGVS we would have a proportionate impact on other vehicle types as well.

Timing

Efficient driving training is already available to fleet drivers, with small subsidies available for such training to reduce the cost of the course for the recipient organisation. Around 11,000 fleet drivers will receive subsidised efficient driver training this year, almost double the take up of the previous year. The scheme, run by the Energy Saving Trust (EST), is delivered in partnership with commercial driving trainer companies whose fleet trainers have been EST certified and endorsed. Nearly 600 fleet trainers, registered with the Driver and Vehicle Standards Agency (DVSA), have been trained to date, with 15 providers participating in the scheme. In addition to fleet trainers, the scheme expanded this year to include training for Approved Driving Instructors (ADI) who can incorporate the training in learner and other post-test learner lessons.

The scheme works to increase the numbers of ADIs trained in efficient driving, with the target of fleet drivers who receive the training being currently planned for the next financial year. Work to increase the numbers of drivers who receive the training and

---

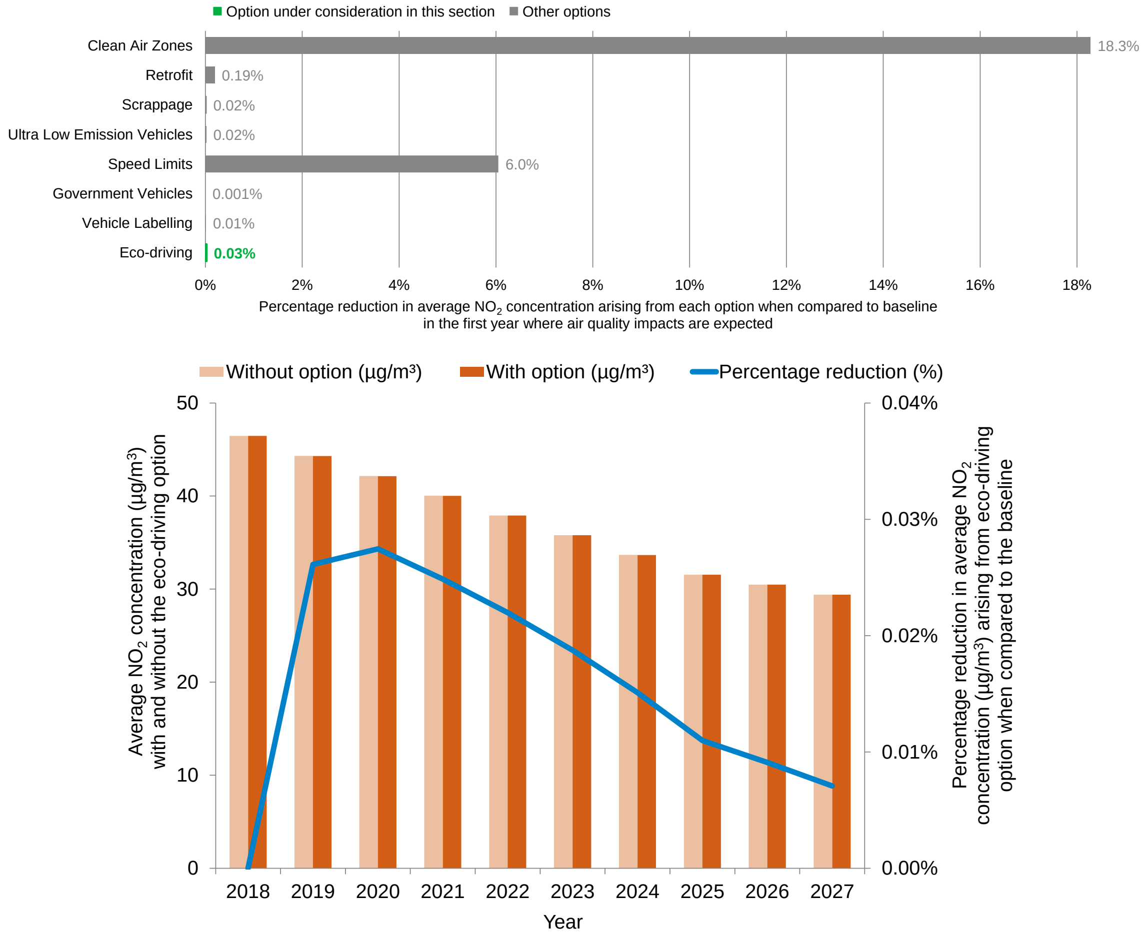
[70] Department for Environment, Food & Rural Affairs, *'Evidence review on effectiveness of transport measures in reducing nitrogen dioxide, Appendix 1 to project summary report for contract AQ0959 – Exploring and appraising proposed measures to tackle air quality'*, 2016, Section 2.4.4 < https://uk-air.defra.gov.uk/assets/documents/reports/cat05/1605120947_AQ0959_appendix_1-evidence_review_on_air_quality_effects_of_transport_measures.pdf>.

extending the training to private motorists could possibly begin during 2017. However, this would be subject to funding being made available and it is not possible to forecast the uptake rate. As such, it is not possible to model with any certainty when any benefit, in terms of lower emissions, would start to be realised. For the purposes of illustrating the possible impact of this option, it has been assumed that there would be sufficient training capacity to enable the training of 100,000 drivers by 2019.

Government cost

The cost to government of this measure would be the cost of a course (£50) and the telematics (£100). Therefore, this would total £150 per person trained. This would have a present value cost of £14.5m over the ten-year appraisal period (2018-2027).

Figure 6.11: Reduction in average NO_2 concentrations following the implementation of the influencing driving style scenario



The light and dark shaded orange bars show the projected mean NO_2 concentration with and without the implementation of the influencing driving style eco-driving scenario. The blue line shows the percentage reduction in mean NO_2 concentration attributable to the implementation of the eco-driving scenario (i.e. the percentage difference between the 'with' and 'without' option bars). The eco-driving option is assumed to be implemented in 2018 and is projected to have its greatest impact on NO_2 concentrations in 2019 and 2020, leading to a relatively small reduction of around 0.025% in both of these years. From 2021 onwards, the reduction steadily decreases, to around 0.005% by the end of the appraisal period.

The absolute reduction in NO_2 concentration assumes the baseline scenario is dependent on the effectiveness of the Euro standard. If the Euro standards are less effective than predicted (as with historical real-world operations), the impact of influencing driving styles will differ from the projections presented here.

These projections have been produced from the SL-PCM model. It is not feasible to obtain uncertainty ranges for these estimates. Uncertainty estimates surrounding input data are also limited, but the SL-PCM modelling incorporates the latest assumptions around emissions from each source, to reflect the best range of evidence available. See Section **8.2** for further details.

Public cost

The Government would fund this scheme and so there would be no direct financial cost to the public, though there would be a small time cost in undertaking the required training. Fuel savings for individuals trained have not been modelled at this stage, and it could be assumed these offset any training time costs.

Health benefit

The health benefits are calculated via the SL-PCM modelling outputs. The SL-PCM model provides an annual emission reduction in NO_x tonnes/year, estimated for this measure at 0.34kt in total. The transport average damage cost for the relevant year (uplifted to current prices) was multiplied by this value. This results in a total estimated health benefit of £8.7m in present value terms.

Greenhouse gas emissions

The reduction in fuel usage would lead to a reduction in CO_2 emissions per car. For the purpose of our analysis, it has been assumed to be the same percentage reduction as our NO_x emission reductions. This has been calculated by multiplying the number of vehicles impacted in each grouping (petrol cars, diesel cars, petrol LGVs, diesel LGVs) by their respective CO_2 emission factors (g/km). We have then multiplied this by the percentage reduction for the year in question to calculate the change in CO_2 emissions for the relevant years. The result of this calculation is a CO_2 reduction of 0.28MtCO_2.

The financial impact of this has then been valued using non-traded carbon price, giving an estimated carbon benefit of £16.8m in present value terms.

Economic growth

The increased demand for eco-driving courses and telematics would potentially translate to increased economic growth in the short term, although effects are expected to be negligible.

6.3.4 Conclusion

Table 6.12: Summary of impacts of the feasible vehicle labelling assessment[I]

	Results	**Confidence in assessment**	**Comments**
First year air quality improvement[II]	0.004µg/m^3 in 2018	Indicative	This is the average reduction in the maximum concentration for all UK reporting zones in 2018. It should be noted that this policy has a greater impact over time
Total reduction in NO_x emissions[III]	0.7kt over ten years		
Timing to impact[IV]	<1 year	N/A	There is already a scheme in progress and this would feed into an upcoming planned update
Health impact	£18m	Indicative	The benefit of the reduction in NO_x emissions resulting from this measure
Government impact	Negligible	Indicative	Costs of implementation are assumed to be negligible over the existing labelling scheme
Public impact	Not Quantified	Indicative	Vehicle dealers will face some cost through reprinting labels however, this is negligible. Cost differences for consumers have not been quantified
Greenhouse gas emissions impact	-£5.30m	Indicative	The cost of the increase in CO_2e emissions resulting from this measure
Economic growth impact	Negligible	N/A	No effect expected since total vehicle purchases are assumed to remain the same

[I] All monetised values are present values, discounted to 2017 prices, appraised over 2018-27.

[II] This is the reduction in average NO_2 concentrations, in the first year where air quality impacts are expected to arise as a result of the implementation of the option. This is relative to the baseline projection for the option in the particular year specified.

[III] This is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period. This is in comparison to the baseline projection for the option over the same ten-year appraisal period.

[IV] Indicative timings are provided for all options as either <1, 1-3 or >3 years.

Table 6.13: Summary of impacts of the influencing driving style assessment[I]			
	Results	**Confidence in assessment**	**Comments**
First year air quality improvement[II]	0.012µg/m^3 in 2019	Indicative	This is the average reduction in the maximum concentration for all UK reporting zones
Total reduction in NO_x emissions[III]	0.00028kt over ten years		
Timing to impact[IV]	1-3 years	N/A	Small scale schemes already in place however there may be potential issues regarding scalability
Health impact	£8.8m	Indicative	The benefit of the reduction in NO_x emissions resulting from this measure
Government impact	-£14m	Indicative	This is the cost to government of funding the course and telematics
Public impact	Negligible	Indicative	Not quantified – potential fuel savings considered negligible
Greenhouse gas emissions impact	£17m	Indicative	The benefit of the reduction in CO_2e emissions resulting from this measure
Economic growth impact	Negligible	N/A	Increased uptake of better driving courses and telematics may boost growth in the short-term

[I] All monetised values are present values, discounted to 2017 prices, appraised over 2018-27.

[II] This is the reduction in average NO_2 concentrations, in the first year where air quality impacts are expected to arise as a result of the implementation of the option. This is relative to the baseline projection for the option in the particular year specified.

[III] This is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period. This is in comparison to the baseline projection for the option over the same ten-year appraisal period.

[IV] Indicative timings are provided for all options as either <1, 1-3 or >3 years.

7 Distribution of effects across population groups

7.1 Introduction

The health of different groups within the population may be affected to differing degrees by poor air quality. The costs of policies put forward to address air quality issues may also affect specific populations, particularly those on low incomes.

This section brings together the key material on both of these areas and then looks in more detail at the impact of the central measure, CAZs. It finishes with a brief summary of the distribution of effects of other policies.

7.2 Health effect

There is increasing evidence that air quality has an important effect on public health. Overall effects are discussed in Section **1.1**.

Deprived communities are more likely to experience adverse health effects from poor air quality because they live in environments more exposed to air pollution, for example, close to major roads. They are less likely to live close to well-maintained green spaces associated with lower levels of air pollution, increased physical activity, and improved mental wellbeing[71]. However, on average, air quality is low even in areas of London that are generally considered affluent, such as Westminster. This accords with the overall national distribution of air pollution with highest average levels in the South East and lowest in the North of England, Scotland, Wales, and Northern Ireland[72].

A national level analysis of environmental quality and social deprivation carried out for the Environment Agency was published in 2003. This examined the social

---

[71] Public Health England, 'Local action on health inequalities: Improving access to green spaces' *Health equity briefing 8* (September 2014) <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355792/Briefing8_Green_spaces_health_inequalities.pdf>.

[72] Brunt et al. 'Air pollution, deprivation and health: understanding relationships to add value to local air quality management policy and practice in Wales, UK' *Journal of Public Health* (2016) <https://www.ncbi.nlm.nih.gov/pubmed/27613763>.

distribution of pollutant concentrations. It concluded that the highest pollutant concentrations occur disproportionately amongst the most deprived electoral wards for all pollutants studied, with, for most pollutants, over half of the most exposed 5% of the population (2.5 million people) resident in the 20% most deprived electoral wards[73].

Similarly, Defra's 'Air Quality and Social Deprivation in the UK: an environmental inequalities analysis' (2006) report[74] provided a comprehensive assessment of the inequalities in the exposure to air pollution. It found that:

- Generally, inequalities were greater in areas with highest level of NO_2 and PM. This however was not true in Wales where the pattern was reversed.

- While policies can reduce the scale of exposure, this inequality was expected to persist. A relatively small variation in the level of improvement was expected by decile[75] between 2003 and 2010 (Fig. **7.1**).

- Over half (57%) of the people living in the most polluted areas for NO_2 were in the bottom three income deciles[76]. In the same areas, only around one in ten people were from the top three deciles (10%). The distribution of particulate matter was similar, which means there was a strong trend towards lower income people being disproportionately exposed to these forms of air pollution. The pattern was however different for other pollutants: it was much less pronounced for SO_2 and was reversed for ozone.

---

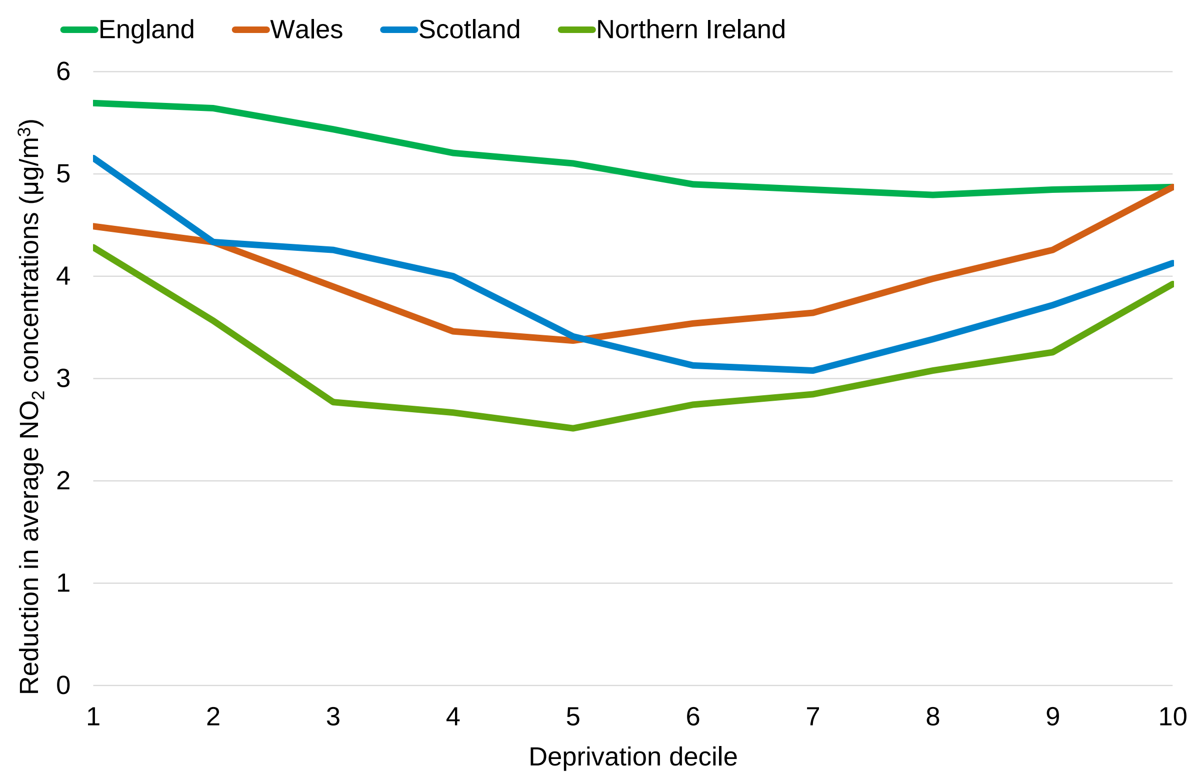
[73] G Walker et al. 'Environmental Quality and Social Deprivation' (2003) <www.gov.uk/government/uploads/system/uploads/attachment_data/file/291071/se2-067-1-tr-e-e.pdf>.

[74] AEA Technology plc, 'Air Quality and Social Deprivation in the UK: an environmental inequalities analysis' (2006) <http://uk-air.defra.gov.uk/reports/cat09/0701110944_AQinequalitiesFNL_AEAT_0506.pdf>.

[75] Here, a decile refers to 10% of the population characterised by a specific level of deprivation: decile 1 being the most deprived and decile 10 the least deprived.

[76] Income deciles are arrived at by taking all incomes and dividing these into ten equal groups so that the 10% earning the least are in decile one, the next 10% are in decile two and so forth.

Figure 7.1: Projected reduction in average NO_2 concentration by deprivation decile and each nation, 2003-2010[77]



Note: The figure shows projected change in distribution of NO_2 concentrations in each country by deprivation decile, based on the implementation of planned policies (as included in the UK air emission projections published in 2005). The largest reductions were found where concentration levels were highest in 2003. For Scotland, Wales and Northern Ireland these were in the most and least deprived deciles (as opposed to the mid-deciles). In England, absolute reductions were similar across all deciles, though slightly higher in the most deprived deciles.

In their research on 'Associations between air pollution and socio-economic characteristics, ethnicity and age profile of neighbourhoods in England and the Netherlands'[78], Fecht et al. estimated the distribution of effects across a range of characteristics and found that:

---

[77] AEA Technology (2006). Figure 6.5: Reduction in average pollutant concentration by decile between 2003 and 2010, NO_2. In *Air Quality and Social Deprivation in the UK: an environmental inequalities analysis, 2006, p. 35*

[78] D. Fecht et al. 'Associations between air pollution and socioeconomic characteristics, ethnicity and age profile of neighbourhoods in England and the Netherlands', *Environmental Pollution*, Vol. 198, (2015), pp. 201-210 <http://dx.doi.org/10.1016/j.envpol.2014.12.014>.

- Air quality inequalities were largely an urban problem

- There were higher concentrations in the most deprived areas by 4.4μg/m^3 NO_2

- Ethnically diverse areas had increased exposure of 10.1μg/m^3 NO_2

Across the literature reviewed, there is a notable negative correlation between income and exposure to NO_2. On this basis, any action that focuses on reducing the highest concentrations of NO_2 will disproportionately benefit lower income and more ethnically diverse groups.

There is also strong evidence to show that more socio-economically deprived populations, as well as being more exposed, have a higher proportion of people with risk factors that make it more likely that they will be detrimentally affected by poor air quality. This includes children and people with pre-existing illnesses.

One of the key conclusions from the WHO's 'Review of evidence on health aspects of air pollution – REVIHAAP' (2013)[79] was that:

> *There is significant inequality in exposure to air pollution and related health risks: air pollution combines with other aspects of the social and physical environment to create a disproportionate disease burden in less affluent parts of society.*

While care needs to be taken in picking out particular studies, it is useful to note some examples of more specific evidence to support these overall conclusions. For example, during Defra's recent work to engage with Local Authorities on air quality plans, Southampton City Council reported that those areas of the city with high air pollution levels were also areas with high levels of respiratory conditions and hospital admission rates. These are also areas of high deprivation within the city.

Poor air quality has also been linked to dementia. In January 2017, the media reported the findings of a Canadian study that made the connection. There is emerging evidence linking cognitive decline and dementia with poor air quality and/or noise, but further research is needed. Because poor air quality is thought to be linked to vascular disease via systemic inflammation, effects on cognitive decline and dementia are plausible. The Canadian study found a statistical association between

[79] World Health Organization '*Review of evidence on health aspects of air pollution – REVIHAAP project: final technical report*' (2013) <www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2013/review-of-evidence-on-health-aspects-of-air-pollution-revihaap-project-final-technical-report>.

dementia and living close to major roads. The authors suggested that both traffic-related emissions and noise were factors in increasing the risk of dementia[80].

7.3 Financial effect

7.3.1 Introduction

The cost of taking action to improve air quality will depend both on the policies selected and how they are implemented. Sections **7.3.3** to **7.3.4** provide more detailed distributional analysis of the financial effect of the individual policies. However, on the assumption that actions taken will focus on road transport (as the key driver of the NO_2 challenge) the following section provides some background on the ownership and use of vehicles relevant across the measures discussed.

7.3.2 Vehicle ownership

Private cars

The most considerable effect on individuals' disposable income would be through any actions that affected private car usage.

For actions affecting *new* car registrations, the effect is expected to be largely on industrial users and higher income groups since more than half of new car registrations[81] (55 per cent) are by companies, and those on lower incomes are less likely to be able to afford to purchase new vehicles. The short-term effects of measures affecting new cars may also be mitigated by the increasing use amongst small businesses and individuals of finance arrangements such as personal contract purchase (PCP) for new car purchases[82], affecting both up-front payments and longer-term liabilities.

For controls affecting the entire fleet, the distributional effects are expected to be very different. If a measure were to target the most polluting cars, such as older

---

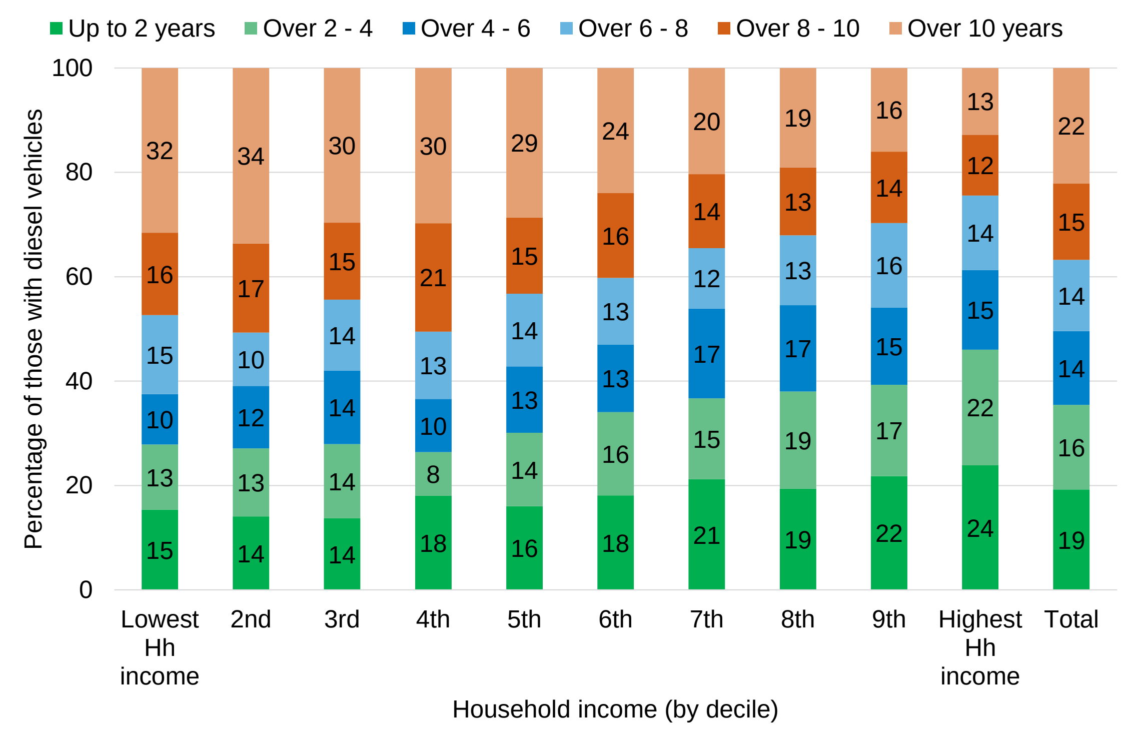
[80] H. Chen et al. 'Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: a population-based cohort study', *Lancet*, Vol. 389, No.10070, (2017), pp.718-726 <www.thelancet.com/journals/lancet/article/PIIS0140-6736(16)32399-6/abstract>.

[81] Department for Transport, Vehicle Licensing Statistics (2015), data table VEH0252 <https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars>.

[82] See for example I. Pollock, 'The way we buy cars today – the rise of personal contracts', *BBC news online*, 28 September 2015 <www.bbc.co.uk/news/business-34383082>.

diesel vehicles for example, the effect would be greater upon lower income groups since the proportion of people owning older diesels is highest amongst those with the lowest incomes[83] (Fig. **7.2**).

Figure 7.2: Age (in years) of diesel vehicle ownership by household (Hh) income decile in England, 2015[84]



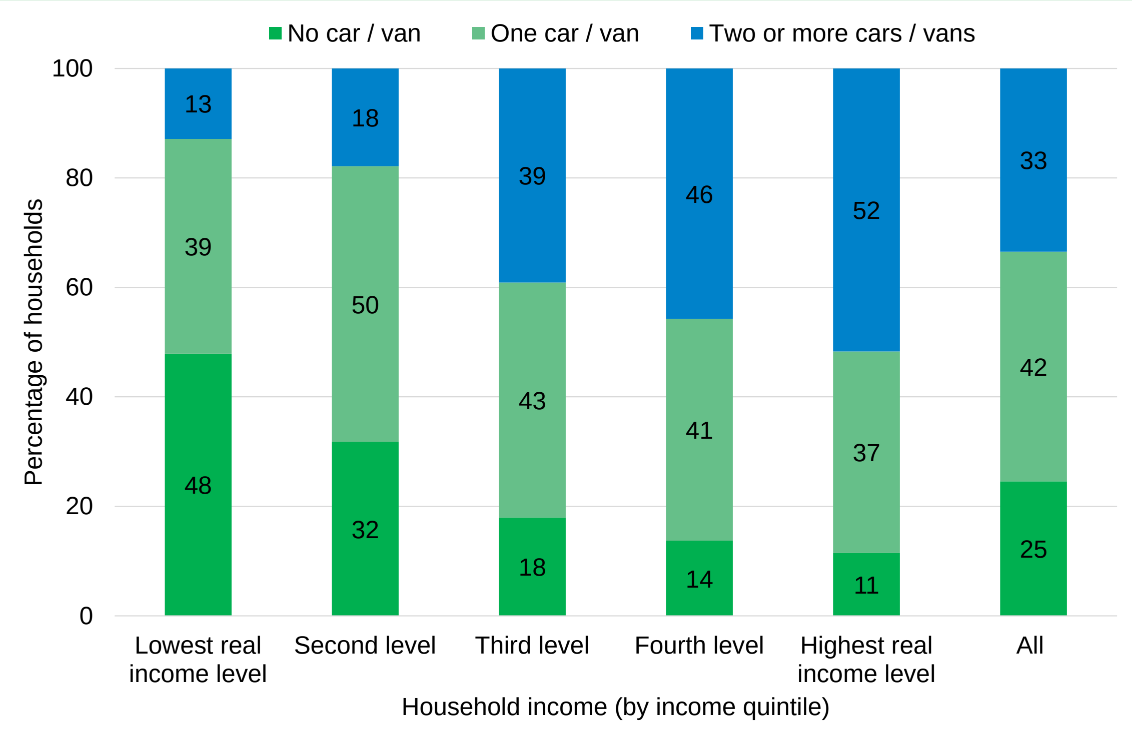
While those in lower income groups who do have vehicles tend to have older (hence more polluting) cars, it is also important to recognise vehicle ownership is lower amongst these groups. Households with lower incomes are less likely to have access to a car at all, and also less likely to have access to more than one car, offsetting some of the distributional effects set out above when lower income groups are taken as a whole (Fig. **7.3**).

---

[83] Much of the available data on transport use is based on the National Travel Survey (2015). This survey only covers England. It is therefore assumed that the patterns described are similar in other parts of the UK.

[84] Department for Transport National Travel Survey, 2015 <https://www.gov.uk/government/statistics/national-travel-survey-2015>.

Figure 7.3: Household car availability by household income quintile, (% households in England, 2015[85]



However, for those in lower income groups who do have a car, the ability to respond to any actions affecting private vehicles is clearly lower, especially if they lack access to finance arrangements to help mitigate up-front costs. Those in the lowest income quintiles have little (or nothing) to spare even with lower levels of spending on transport (Tab. **7.4**).

[85] Department for Transport National Travel Survey (2015), data table NTS0703 <https://www.gov.uk/government/statistics/national-travel-survey-2015>.

Table 7.4: Annual average income and expenditure of UK households by income quintile (£), 2014[86]					
	1 (Lowest)	2	3	4	5 (Highest)
Disposable income[87]	9,300	19,000	28,000	40,000	74,000
Final consumption expenditure	10,000	16,000	22,000	29,000	43,000
Of which transport	1,000	2,200	3,400	4,900	7,900

Buses

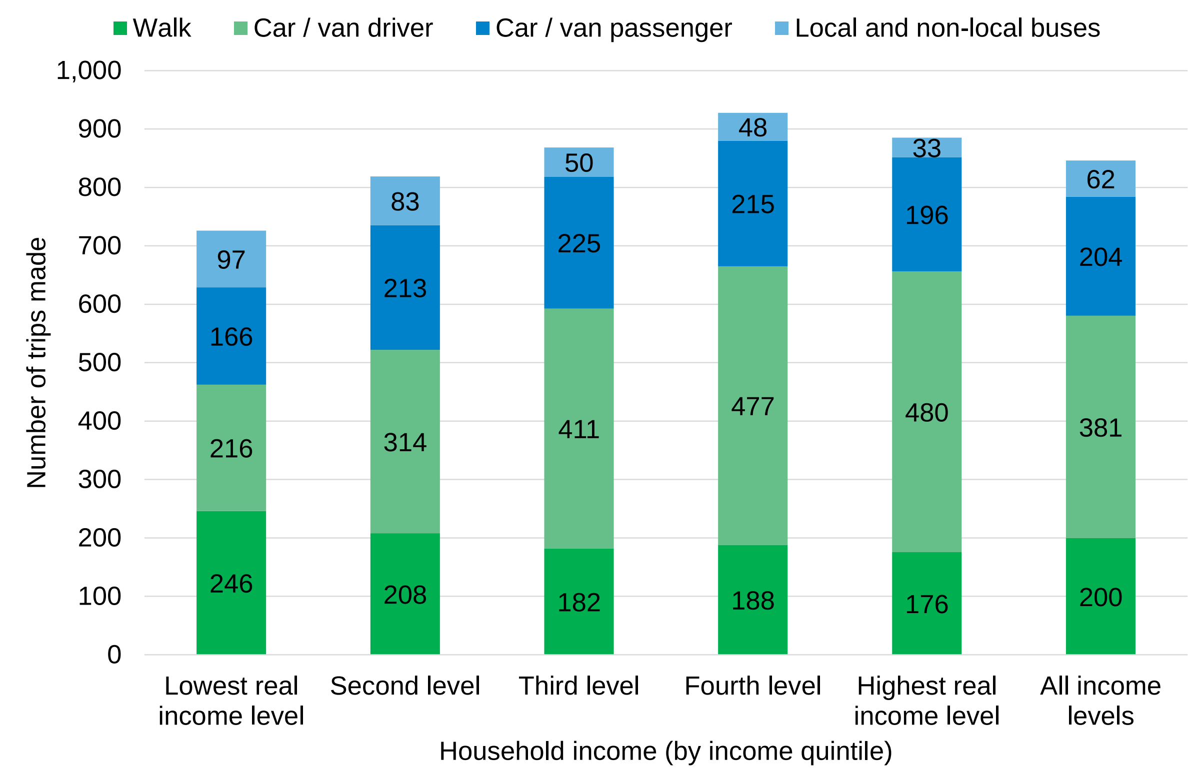
Those in the lowest income group make far fewer trips by car (both as drivers and as passengers) and are more reliant on other means of transport such as walking and using buses or coaches (Fig. **7.5**).

The increased reliance on buses and coaches amongst those with the lowest income levels means that they may be particularly affected by controls on these vehicles. This is especially true for those who pay for their fares (as distinct from those benefitting from concessionary passes) as discussed further in Section **7.3.3**.

[86] User requested data: Annual expenditure of household by income quintile, Reference number: 005250, 2016 <https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/expenditure/adhocs/005250annualexpenditureofhouseholdbyincomequintile>.

[87] This is all post tax, National Insurance, benefits income (available to be spent on housing, utilities, clothing, etc.).

Figure 7.5: Annual number of trips per person made using the four most common modes of transport, by household income quintile in England, 2015[88]



Heavy goods vehicles (HGVs)

Haulage is used for transporting commodities with food products an important element (Fig. **7.6**). In the US, transport as a whole is estimated to account for around 3.4% of grocery prices[89].

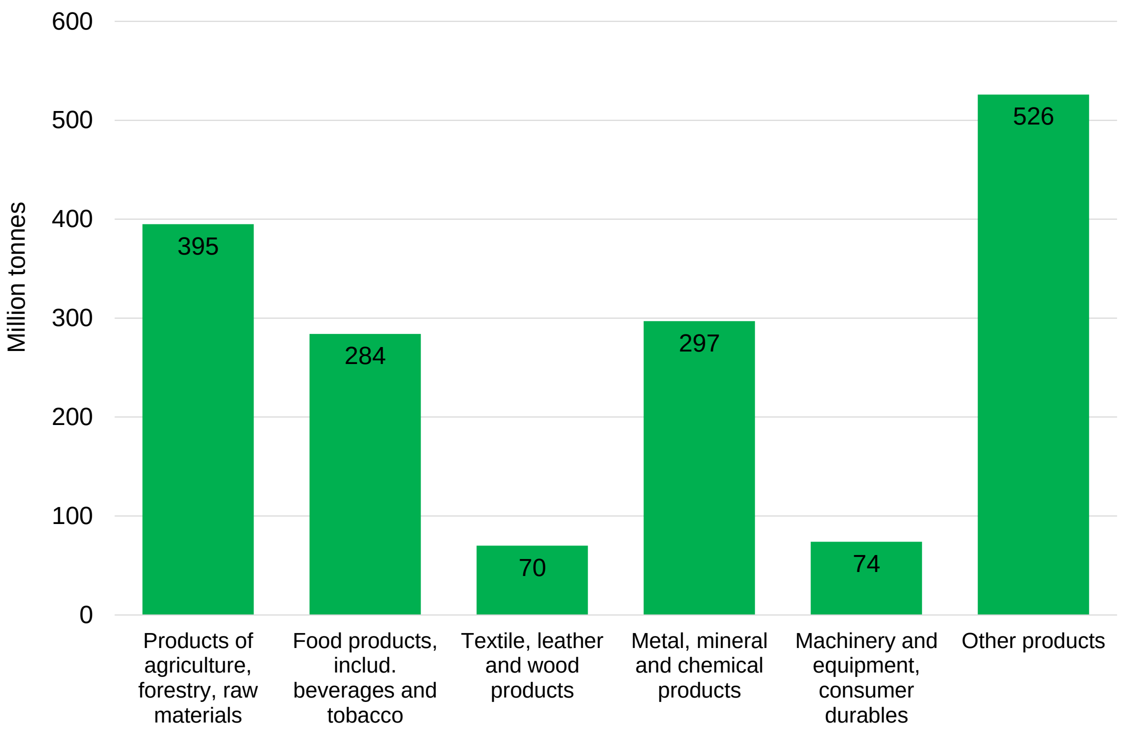
It is estimated that if HGVs that are non-compliant with emissions regulations have an operating life of around 5 years, the policies could lead to an increase in retail prices of between 0.01 and 0.2%.

---

[88] Department for Transport, National Travel Survey 2015, data table NTS0705 <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/336452/nts0705.xls>.

[89] M. Wilde ‘Food inflation: Rising transportation costs increase grocery bills’, *Cedar Valley Business Monthly*, 15 April 2012 <http://wcfcourier.com/business/local/food-inflation-rising-transportation-costs-increase-grocery-bills/article_f8f05f14-84d1-11e1-a885-0019bb2963f4.html>.

Figure 7.6: Annual haulage (goods moved[90]) by commodity grouping (billion tonne kilometres), 2015[91]



7.3.3 Distributional effects of Clean Air Zones

Initial focus of the distributional effects of measures has been on CAZs. This is because they are central to the draft Plan and, by being geographically targeted, risk having the most uneven distribution of impacts.

It has been assumed that the main areas in which the cost of the proposed improvements delivered by CAZs may have a differentiated effect across socio-economic groups are:

- Replacement of cars which are not compliant with emission standards (for CAZ class D) – i.e. cars with diesel engines over five years old and petrol

[90] Goods moved is a measure of freight moved which takes account of the weight of the load and the distance through which it is hauled. It is measured in tonne kilometres. For example, a load of 26 tonnes carried a distance of 100 kilometres represents 2,600 tonne kilometres.

[91] Department for Transport Road freight domestic activity tables, data table RFS0104 (UK activity of GB registered heavy goods vehicles) < https://www.gov.uk/government/statistical-data-sets/rfs01-goods-lifted-and-distance-hauled#table-rfs0104>.

engines over 15 years old in 2020 (Euro 5 and Euro 3 standard and below, respectively).

- Replacement of buses and coaches that are non-compliant with emissions standards (for all proposed CAZs).
- Replacement of older LGVs (for CAZ class C and D).

Cars

Only a minority of vehicles would be affected if a charging CAZ were implemented (and Government will only mandate the measures that are identified by Local Authorities as leading to compliance at the earliest point). Ultra Low Emission Vehicles, petrol cars that are Euro 4 or later and Euro 6 diesel cars would not be subject to charging, even in class D CAZs. Based on the current national fleet, this means around 60% of the cars would not be subject to charging even if owners wanted to enter a CAZ. Due to fleet turnover, by 2020 this is due to rise to around 73%.

Were the modelled charging CAZ measures to be implemented, the overall cost of scrappage and upgrades to the car fleet is estimated to be c. £369m or around £313 per affected vehicle, (though upfront costs are greater). This covers the initial cost of selling an existing non-compliant vehicle and buying a compliant one, set against higher resale values and changes in fuel efficiency (see Section **4.2.5**)[92]. In the main, these will be diesel vehicles, which make up around 39% of household vehicles overall and 34% of vehicles owned by people on middle to lower incomes[93] [94].

[92] As recommended by an independent expert, this is implemented in the fleet adjustment model by comparing the overall costs of vehicles in the baseline with those of vehicles subjected to the policy by comparing their overall depreciation and dividing the difference by two as a proxy for incorporating the value of better fuel efficiency, reduced maintenance and improved drivability associated with a newer vehicle.

[93] Where income data is available by decile, it was been assumed that 'people on middle to lower incomes' corresponds to the second, third, fourth and fifth lowest deciles. Where income data is only available by quintile, it has been assumed that 'people on middle to lower incomes' corresponds to the second lowest and middle quintile.

[94] Based on data from the Department for Transport National Travel Survey 2015, unpublished. It has been assumed that patterns of car ownership and vehicle use by income level in the Class D CAZs are similar to the national picture recorded through the National Travel Survey (that is - levels of ownership, age of vehicles and number of journeys).

Amongst diesel owners on middle to lower incomes, around 85% have vehicles that are currently over two years old[95]. Assuming owners are not subject to exemptions[96], these are vehicles that do not meet Euro 6 standard and would need replacing if they were to be used in Class D zones after 2020 (Fig. **7.2**).

Table **7.7** shows average sale and purchase prices per vehicle, based on Defra modelling (reflecting capital costs only, not total welfare costs as above). This is based on people upgrading to the cheapest compliant vehicle within fuel type, which would be a Euro 6 diesel in the case of diesel drivers or Euro 4 petrol in the case of petrol drivers.

Table 7.7: Mean sale and purchase prices by vehicle type (£)

	Cars	LGVs	Buses	Minibuses/ coaches
Average sell value	2,500	4,400	11,000	6,700
Average buy value	3,400	6,200	45,000	28,000

However, in reality drivers choosing to upgrade their vehicles would have a range of options available to them depending on their appetite for capital outlay[97]. For instance, a Euro 5 diesel car driver could:

- Upgrade to a new diesel car (£18,000) and sell their current vehicle (£3,100) at an overall cost of £14,900 (plus a small transaction cost); or
- Purchase a Euro 5 petrol of equivalent value to their existing vehicle (£3,100) and sell their current vehicle (£3,100), incurring a small transaction cost only.

Meanwhile, a Euro 3 petrol car driver could:

- Upgrade to a new diesel car (cost £18,000) and sell their current vehicle (£500) at an overall cost of £17,500 (plus a small transaction cost); or

[95] Based on data from the Department for Transport National Travel Survey 2015, unpublished.

[96] Exemptions will be set out in the national level framework with appropriate local flexibility where necessary. For instance, the framework envisages (i) that vehicles within the disabled passenger vehicle tax class will be exempt, and (ii) that Blue Badge holders will not be generally exempt, but that a local authority may choose to make exemptions based on local circumstance.

[97] Drivers of Euro 3 cars and below choosing to upgrade would, as a minimum, have to upgrade to the lowest compliant Euro 4 petrol car.

- Purchase the oldest compliant Euro 4 petrol car on the market (cost £1,150) and sell their current vehicle (£500) incurring an overall cost of £650 (plus a small transaction cost).

It is also worth noting that there may be differences in running costs between petrol and diesel cars.

The cost estimates for upgrading the fleet assume that the resale market is unaffected by the changes to policy, allowing owners of older cars to sell them on and buy compliant replacements at current market rate.

If owners are unable to sell their non-compliant vehicles at the assumed rate because the market has been affected, they may be exposed to lower ‘sell’ values as well as increases in ‘buy’ costs for an equivalent compliant vehicle. Table **7.7** gives an idea as to the scale of risk for owners should the market be affected. However, the initial analysis is that availability of compliant, second hand cars should remain stable.

The numbers of cars in the 2020 fleet affected by the proposed measures are estimated to be around 7.5 million diesel vehicles and around one million petrol vehicles (see Annex **D** for more detail). Assuming c. 14% of these were replaced (Table **4.4**), around one million diesel vehicles and 140,000 petrol vehicles would be needed (1.2 million cars in total). 20 million compliant cars are potentially available (six million diesel and 14m petrol)[98]. SMMT figures show that around eight million second-hand cars changed hands in 2016[99] representing around 27% of a total 2016 fleet size of 29.5 million. It would therefore be expected that a large proportion of the potentially available compliant cars would be available for purchase in the run up to 2020 – approximately five million (25% of 20 million) per year[100]. This should comfortably cover the 1.2 million needed, even taking regional differences into account.

The overall discussion on private vehicles in Section **7.3.2** helps improve understanding of the possible effect of CAZs on owners of private cars. However, for a more detailed assessment of the effects of the proposed measures across the population, a better understanding of current driving practices, vehicle use and the

---

98 Calculated as total number of compliant vehicles minus those affected by CAZs.

99 SMMT, Used Car Sales: Q4 2016, 15 February 2017 <https://www.smmt.co.uk/2017/02/used-car-sales-q4-2016/>.

100 Please note, this is based on 2020 fleet sizes so the actual number available in 2017-2019 will be slightly lower.

alternatives is required (for instance the ability of public transport networks to provide a viable alternative to those currently driving the most polluting vehicles). This is briefly discussed in Section **9**.

Buses

The economic analysis of buses and coaches has assumed that the cost of upgrading the fleet would be passed onto passengers directly over the course of a year, on a per journey basis and excluding passengers under five and over retirement age[101].

Based on modelling undertaken with the Fleet Adjustment Model (see Section **3.3.3**), the overall cost to the fleet is estimated to be c. £270m or around £5,700 per affected vehicle. This assumes the resale market is unaffected by the changes to policy, allowing owners of older buses to sell these on at current market prices and trade up to compliant ones. Averaged across the UK population aged between five and 62/65[102], this is an average per person cost of c. £5.50 and an average per journey cost of around 9p. As those in the lowest income levels make greater use of buses and coaches (Fig. **7.5**), this translates to an average overall cost of c. £8.60 for those in the lowest income quintile and £5.90 for people on middle to lower incomes compared with £2.90 for those in the highest income quintile.

We have not accounted for the fact that the cost of upgrades might only be passed onto passengers using buses and coaches in particular geographic areas (areas with CAZs or older bus fleets for example). Nor has the fact that bus usage (and payment) is not spread evenly across the population within income quintiles. Costs are therefore likely to be higher for fare payers who make regular use of buses in and around CAZ areas. This said, some costs might be borne by Local Authorities through their funding of free travel for eligible groups. Bus operators may also be able to reassign buses and coaches in their fleet based on which buses are and are not likely to enter CAZs to minimise costs.

---

[101] Entitlement to free travel varies across the UK. However, children under five and those who have reached retirement age usually travel without charge under the 'English National Concessionary Bus Travel Scheme' or the 'Freedom pass' scheme in London.

[102] These are the respective state pension ages for women and men reaching retirement age in 2015.

LGVs

The overall cost of scrappage and upgrades to the LGV fleet is estimated to be around £577m and around £1,430 per affected vehicle.

Information of how ownership of LGVs is spread across socio-economic groups is not currently held by Defra; however it is likely that those in lower income brackets will have a greater proportion of older vehicles and, therefore, greater exposure to the costs of replacing non-compliant vehicles.

7.3.4 Financial effects of other measures

Other measures with differentiated financial effects across socio-economic groups have been briefly considered as follows:

Local measures

As local measures will be designed to be responsive to local needs, there is a great deal of flexibility in how they might be used. Because of this, there cannot be any certainty around their distributional effects across the population. However, any moves to encourage a modal shift away from private cars are likely to have a positive effect on lower income groups both because they may be able to benefit from alternatives directly and because they are adversely affected by current traffic levels. As well as suffering directly from poor air quality, as described in Section **7.2**, there is evidence those in lower income groups are more likely to be killed or seriously injured in road traffic accidents. DfT research shows that in 2013 around one third of people suffering such casualties lived in the 20% most deprived areas while only 13% lived in the 20% least deprived areas[103].

Retrofit

As this measure targets businesses and local authority bus fleets, there will not be any direct effects on lower socio-economic groups. However, there may be indirect benefits for lower socio-economic groups if retrofit funding is used to minimise the upgrade costs passed onto passengers.

---

[103] Department for Transport, ‘Facts on Pedestrian Casualties’ (June 2015) <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/448036/pedestrian-casualties-2013-data.pdf>.

Scrappage

As the option proposed targets the oldest vehicles, a scrappage scheme (affecting c.15,000 vehicles, the majority of which are likely to be cars) could be very relevant to lower income groups. However, the extent of this effect depends on exactly how the scheme is implemented.

The option modelled in Section **5** requires scrapped vehicles to be replaced with Battery Electric Vehicles (BEVs). As these vehicles are relatively more expensive it might be less likely that those on lower incomes would take up this scheme. However other designs of scrappage schemes could avoid such impacts, for instance not including a requirement to replace with a BEV or targeting at those who are most in need of support.

Ultra Low Emission Vehicles (ULEVs)

Extending the Plug-in Car Grant is unlikely to have a direct effect on lower income groups, as they are less likely to purchase a new (electric) car, even with a grant (Table **7.4**).

The authors of a recent rapid evidence assessment for DfT felt that, based on insights from more developed ultra low emission vehicle (ULEV) markets, the basic socio-demographic profile of ULEV owners in the UK was not likely to change substantially over the coming years. They identified this demographic as middle-aged, male, well educated, affluent, and living in urban areas with households containing two or more cars and with the ability to charge at home[104].

The Plug-In grant is therefore likely to support more affluent households; however it is also likely to support lower income groups by increasing availability (and reducing costs) of second hand cars.

Speed limits

Reducing speed limits is likely to have a smaller effect on those with lower incomes than on the population as a whole as, on average, they make fewer trips by car than those in higher income groups (Fig. **7.5**).

---

[104] Brook Lyndhurst, 'Uptake of Ultra Low Emission Vehicles in the UK. A Rapid Evidence Assessment for the Department for Transport' (2015) <http://www.brooklyndhurst.co.uk/uptake-of-ultra-low-emission-vehicles-in-the-uk-_270?path=19,270>.

Government vehicles

There is no direct financial effect on the public or lower socio-economic groups given that the scope of this measure is the Government fleet. How the policy would be financed (and other indirect effects) has not been considered for this analysis.

Vehicle labelling

Including NO_x information on labels is expected to have some effect in directing individuals towards petrol vehicles and/or to downsize. In the short term, this would mainly affect industrial users and higher income groups making new purchases (see Section **7.3.2**). However, in the longer term, lower income groups will be affected by the availability of these cars on the second hand market. Individuals that travel long distances would be disadvantaged by the higher running cost of petrol vehicles but those who choose to downsize should see a reduction in running costs.

Influencing driving style

Efforts to influence driving style are likely to have a positive financial impact on drivers in lower income groups, thanks to the resulting fuel savings.

It is possible that drivers in lower income groups may draw a disproportionate benefit since indicative evidence of existing variation in driving practices across demographics suggests well educated, affluent women (aged 25 to 65, with low annual mileage and using a small vehicle) are currently the most likely to practise efficient driving[105].

There is a broad consensus that training for existing private drivers can lead to a reduction in fuel use although estimates of likely reductions vary, partly due to the range of interventions possible to influence driving style. One synthesis study quoted savings of up to 25% immediately following training; and up to 10% in the long-term[106,107]. Meanwhile, evidence from the Energy Saving Trust (2013)[108] found that most drivers could improve their fuel consumption by up to 15% in the *short-term*

---

[105] Brook Lyndhurst, ‘Efficient Driving. A Rapid Evidence Assessment for the Department for Transport’ (2016) <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/509972/efficient-driving-rapid-evidence-assessment.pdf>.

[106] Ibid.

[107] Findings on the impact of training employee drivers are similar – suggesting an immediate reduction of up to 25%; and of up to 6.5% in the long-term.

when taught ‘eco-driving’ techniques. Additionally, a TNO study[109] showed that in combination with gear shift indicators (which show a driver when it is most economical to change up a gear), eco-driver training can result in over 4% fuel savings in the *long-term*.

7.4 Conclusion

Through greater exposure to NO_2 and greater prevalence of underlying risk factors, it is likely that those on lower incomes will benefit disproportionately from attempts to reduce high concentrations of NO_2. However, specific groups within these populations, such as those who are heavily reliant on the oldest cars or who make frequent use of buses for which they are paying directly, may also be disproportionately affected by the cost of the proposed measures.

[108] Quoted in Ricardo, ‘Evidence review on effectiveness of transport measures in reducing nitrogen dioxide’ (2016).

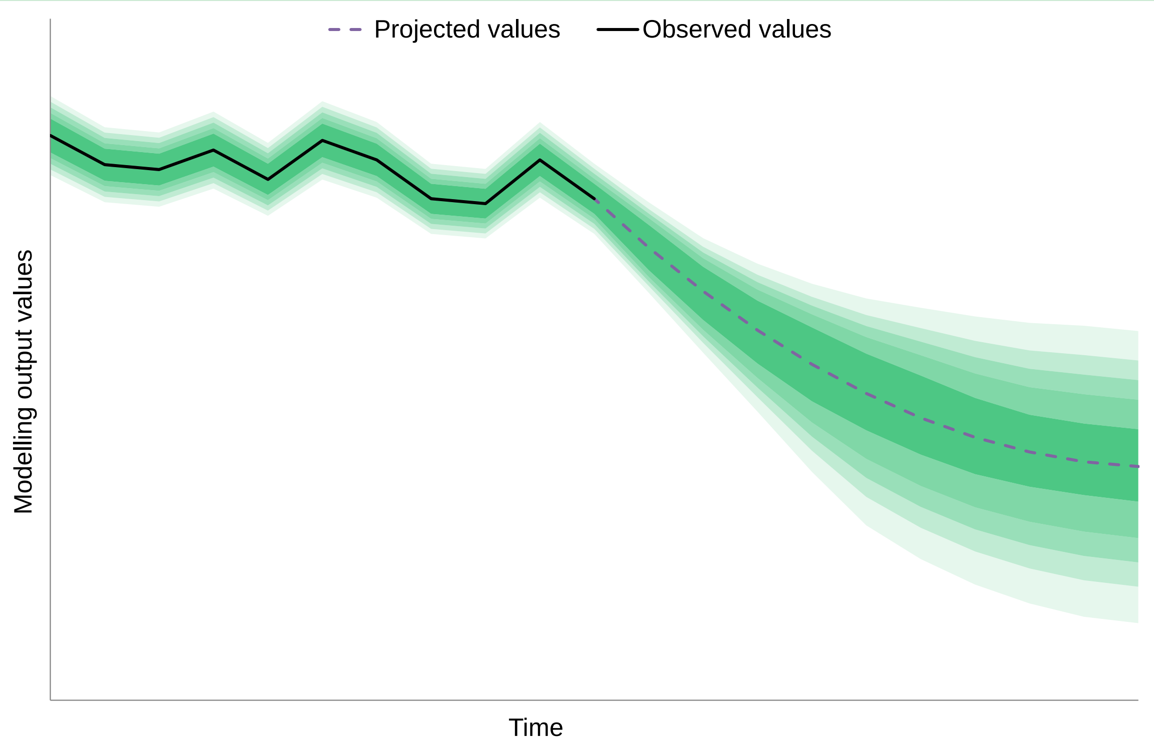
[109] TNO (2006) quoted in Ricardo, ‘Evidence review on effectiveness of transport measures in reducing nitrogen dioxide’ (2016).

8. Sensitivities and uncertainties

8.1 Introduction

Inherent with any piece of analysis is an element of uncertainty, particularly when attempting to predict the future under a certain set of conditions (Fig. **8.1**). Understanding these potential uncertainties forms an integral part of the analysis presented in this technical report, and in doing so supports the draft Plan by making clear the probable variabilities which exist in the evidence regarding the measurement and modelling of air quality, and its connected economic and health consequences.

Figure 8.1: Uncertainty is present in analysis of both the past and the present, and increases for projections made further into the future



Note: This graph displays an illustrative scenario. It displays the outputs of an artificial model based on a given set of input data (solid line) with the models corresponding predictions for the future based on a certain set of criteria (dotted line). The shaded green ranges surrounding the lines represent the uncertainty ranges associated with the estimates produced by the model. The uncertainty ranges surrounding the solid line are broadly similar in width, representing the quantified uncertainties associated with the measurements of the input data that produces variabilities in the estimate. For projected values, the uncertainty ranges gradually increase over time, with the lighter shades of green highlighting this. Increased uncertainty for projections represent the different levels of confidence placed on particular scenarios holding true in the future.

The modelling carried out to predict future air quality is extremely complex, particularly when the impacts of the proposed policy options are incorporated into the assessment. This section describes the key inputs and assumptions underpinning the analysis and the effect that these may have on contributing to the uncertainty of the results is considered.

The inputs and assumptions used in the analysis for this technical report have been informed by the best available evidence. This evidence draws upon existing data, results from existing studies, and expert judgement. However, the inherent uncertainty associated with the analysis presented can be categorised broadly as:

- Uncertainties in the modelling of air quality and the resulting future predictions.
- Uncertainties in the modelling of the options to improve air quality, including their impact on public behaviours and the effectiveness of new technologies.
- Uncertainties surrounding the quantification and valuation of air quality impacts, particularly on human health.

As recognised in Section **1.4**, the treatment of uncertainties in the report will be aligned to IPCC guidance; details of this process are set out in Section **9.1.3**. Each of these categories is considered in the following sections. Where uncertainties have been quantified, these have been considered for the Clean Air Zone option, unless otherwise stated.

8.2 Uncertainties in the modelling of air quality

8.2.1 Modelling prediction uncertainty

The Pollution Climate Mapping (PCM) model provides a best estimate of concentrations of NO_2 consistent with the requirements for the annual compliance assessment but it does not provide uncertainty ranges. This is because the model was designed to allow an assessment of regulatory compliance and cannot, in practice, be used to provide quantified uncertainties associated with the individual inputs and assumptions, because each run of the model takes up to three months to complete. The primary reason for this is the large number of complex data inputs, all of which would individually require information on uncertainty in order to propagate overall uncertainty. Uncertainty estimates surrounding input data are also very limited (Table **8.2**).

Table 8.2: Description of the uncertainties surrounding key inputs of the PCM and Streamlined PCM model	
Input	**Associated uncertainties**
Calibration of the PCM model using air concentration measurements for pollutants from national monitoring stations[110]. These include separate calibrations for roadside and background concentrations.	There are uncertainties surrounding the accuracy and precision of concentration measurement data of pollutants from monitoring sites. This could in turn lead to uncertainties in the calibration of the modelled concentrations. There are additional uncertainties introduced when the model is calibrated to perform at national scales, rather than conducting calibration at local levels.
Modelled traffic flow, which includes the Annual Average Daily Flow (AADF) from DfT's national traffic census. This provides traffic counts (e.g. number of HGVs, buses, LGVs and passenger cars), specific to each individual road modelled.	There are uncertainties in the measurements of traffic count (e.g. the frequency of sampling).
Road traffic fleet composition (which refers to the detailed composition of the fleet, that is, the Euro standard and fuel type of the vehicle). Based on a range of information including historic vehicle licensing data, Automatic Number Plate Recognition data from around 275 ANPR cameras, fleet turnover, mileage and age assumptions (i.e. vehicle usage with age on the road).	Assuming the national average fleet composition (by road type) outside London, rather than using local fleet composition data specific to each individual road introduces some uncertainty. Further, the actual number of vehicles of each fuel type, technology type and age mix on the road add additional uncertainty.
The modelled traffic speed.	The average speed applied in the modelling has been based on the type of road (30 road types) rather than locally monitored speed measurements or data.
Speed dependent NO_x emission factors from road transport vehicles.	Uncertainties in this input arise due to the limited availability of test data and varying amount of data for different vehicle types. Emission factors also contribute to the

[110] Department for Environment, Food & Rural Affairs, *Automatic Urban and Rural Network (AURN)*, 2015 <https://uk-air.defra.gov.uk/networks/network-info?view=aurn>.

	uncertainty, particularly for future vehicle types (e.g. Euro 6 after further Real Driving Emissions testing) based on expert judgement (Emisia).
Proportion of low carbon passenger cars and LGVs with electric and hybrid electric propulsion systems.	There are uncertainties in the figures for the uptake of vehicles using alternative fuel or propulsion technologies which are based on estimates provided by DfT
Projected future activity and emissions data from the National Atmospheric Emissions Inventory (NAEI), including road traffic forecasts provided by DfT and TfL, and energy projections from BEIS.	There are inherent uncertainties associated with predicting future activity based on modelled data.
NO_x/NO_2 relationship based on the Jenkin equation[111].	General roadside and background relationships are estimated in the modelling, rather than reflecting location specific complex atmospheric chemistry.
Annual average weather data.	Data taken from a single monitoring station (Met Office station at Waddington[112]), assumes uniform annual average weather across UK.
Additional uncertainties in SL-PCM modelling versus PCM modelling.	The impact of measures on cold start emissions, minor roads, fleet-weighted f-NO_2, and the specific impact on background concentrations cannot be modelled using the SL-PCM model.

For many of these inputs, a large amount of targeted research would be required in order to quantify and reduce the associated uncertainties. However, due to the continually evolving nature of air quality evidence and data, further research only forms part of a bigger picture in combating uncertainty. A deeper understanding of the wider environment of factors that interact with the air quality modelling also needs ongoing investigation.

[111] M.E. Jenkin, *'Investigation of the NOx-dependence of oxidant partitioning at UK sites using annual mean data 1991-201'*, 2012, Atmospheric Chemistry Services, Okehampton, Devon, UK. Available upon request.

[112] Met Office, UK climate - Historic station data <http://www.metoffice.gov.uk/public/weather/climate-historic/#?tab=climateHistoric>.

For instance, data on the emissions of air pollutants which are reviewed and updated annually through the National Atmospheric Emissions Inventory form a key input to the PCM model. These updates reflect changes in activity data across all pollutant sources, changes to assumptions around the distribution of emissions across the UK and updates to emissions factors. As a result, the PCM modelling incorporates the latest assumptions around emissions from each source, to reflect the best range of evidence available.

Section **2.1** describes the Streamlined PCM (SL-PCM) model that was used to analyse the air quality impact of possible measures, and how it differs from the full PCM model. Using the SL-PCM model, rather than the full PCM model, introduces some additional uncertainty to the results of the assessment.

Testing undertaken in 2015 by Ricardo Energy & Environment allows a quantification of this uncertainty. These tests showed that the margin of error between the PCM and SL-PCM model assessments for a given scenario is relatively small. This conclusion, reached by examining the impact of four Clean Air Zone (CAZ) types, modelled both the PCM and SL-PCM models (Table **8.3**). Across the four CAZ types, the SL-PCM model primarily produced larger changes in NO_2 concentrations than the full PCM model. Differences for the mean level of NO_2 concentration ranged in the magnitude of 0.15-0.25µg/m^3 across the four CAZ scenarios, highlighting the typically small variabilities in outcomes produced by the two models.

Table 8.3: Mean and percentile differences between PCM and SL-PCM model outputs by CAZ type for the concentration of NO_2 (µg/m^3)

CAZ type	Class A	Class B	Class C	Class D
Mean	-0.15	-0.20	-0.25	-0.16
5th percentile	-0.67	-0.71	-0.73	-0.64
25th percentile	-0.18	-0.24	-0.29	-0.18
50th percentile	-0.06	-0.11	-0.16	-0.09
75th percentile	0.00	-0.04	-0.08	-0.03
95th percentile	0.12	0.07	-0.02	0.14

Note: The figures presented in this table take the mean and percentiles of the concentration of NO_2 arising from the full PCM model and subtracting the outputs generated by the SL-PCM model for each CAZ type.

A further example where air quality evidence is changing are the COPERT NO_x emission factors (Section **8.1.2**). Under the normal modelling process, updated inputs are first incorporated within the PCM model, after which a version of the SL-PCM model is developed that is fully consistent with that PCM model. Due to the length of time required for a full PCM model assessment, the existing SL-PCM model has been adjusted accordingly to take account of the updated emission factors, without the waiting for a full PCM model run. This will reduce the differences between current modelling and the outputs of the future PCM modelling run with organically integrated COPERT 5 factors. However, there are still likely to be some difference between the results provided by these two models due to the reasons highlighted in Section **2.1** and Table **8.2**.

A sensitivity analysis, showing the effect of a ±3µg/m^3 estimation error in projections from the adjusted SL-PCM model, allow an assessment of these potential differences (Table **8.4**). The table shows how the number of areas in compliance could change through variation in the projections. It is important to note that this sensitivity test is showing the effect of the estimation error occurring equally in each assessment group (i.e. every one of the 43 zones modelled having a ±3µg/m^3 estimation error).

Table 8.4: Number of directive compliant assessment groupings based on whether there was an under or over-estimation of the true NO_2 concentration in 2020

Assessment grouping	Total	True value (µg/m^3 above central projection)			Central projection	True value (µg/m^3 below central projection)		
		3µg/m^3	2µg/m^3	1µg/m^3		1µg/m^3	2µg/m^3	3µg/m^3
Zones	43	8	9	9	12	17	21	22
Local authorities	406	297	306	317	325	334	343	353
Postal towns	748	638	645	659	670	682	692	702
Road links	9,251	8,148	8,289	8,403	8,518	8,608	8,686	8747

Note: The SL-PCM reports results by zones, local authorities, and road links. Converting the road link outputs through reverse geocoding produces the ‘postal town’ assessment grouping.

The results show a non-linearity in the significance of over or underestimating by zone. For example, if subsequent estimates produced by the PCM model were to be consistently 3µg/m^3 lower than the central scenario, ten further zones would become compliant. In contrast, only four further zones would become non-compliant for estimates 3µg/m^3 above the central projection. Therefore, an upward revision of modelled concentrations would have a notably smaller impact than a revision in the opposite direction.

Using this analysis, an estimation of how the number of Clean Air Zones could vary due a ±3µg/m^3 estimation error in the projections (Table **8.5**) was conducted. While

Table **8.4** considers numbers in compliance, the number of CAZs required relates to the number of exceedances, so more CAZs are needed under the scenario where concentrations are higher than the central projections. The change in the overall number of CAZs required is similar for both over and underestimates – in both cases a 3µg/m^3 difference results in a change of 8-15 CAZs. The number of Class D CAZs required increases significantly, from 15 to 31, when estimates are 3µg/m^3 above the central projection.

Table 8.5: Number of Clean Air Zones (CAZs) required based on an under or over-estimation of the true NO_2 concentration in 2020

Grouping	True value (3µg/m^3 above central projection)	Central projection	True value (3µg/m^3 below central projection)
Class A	6	4	3
Class B	0	3	1
Class C	5	5	8
Class D	31	15	7
Total	42	27	19

8.2.2 Sensitivity to real world performance of new vehicles

Emissions of particulate matter (PM) and nitrogen oxides (NO_x) from road transport are regulated under the European vehicle emissions regulations (called the Euro standards). These emission regulations are adopted as part of the EU framework for the type approval of cars, vans trucks, buses, and coaches. Current standards are Euro 6 for light duty vehicles such as cars and vans, and Euro VI for heavy-duty vehicles.

The introduction of increasingly strict Euro standards over the last decade (from Euro 1 to Euro 6 and Euro I to Euro VI) has contributed to the reduction in pollutant emissions. However, these regulations have not delivered the expected NO_x emission reductions from diesel vehicles in real-world circumstances.

Historically, vehicle emissions in real-world operations have exceeded their approval limit for NO_x emissions (measured in laboratory test cycles) by considerable amounts (Fig. **8.6**). This has resulted in NO_2 concentrations around transport infrastructure being substantially higher than had previously been predicted. A report published by the International Council on Clean Transportation (ICCT)[113] found that the implementation of NO_x control technologies by a few manufacturers resulted in some vehicles meeting the Euro 6 limit of 0.08g/km when subjected to both the New European Driving Cycle (NEDC), and the Worldwide Harmonized Light Vehicles Test Cycle (WLTC)[114]. These results demonstrate that compliance with the Euro 6 standard is technically feasible.

On 30th September 2016 updated COPERT vehicle emission factors from Emisia became available. The UK and a majority of other Member States use COPERT emission factors to estimate emissions of air pollutants from road transport. This revision, referred to as COPERT 5, provides three Euro 6 emission factors for diesel cars and LGVs, reflecting the reduction in emission factors over time for Euro 6 diesel vehicles in response to Real Driving Emission (RDE) testing. This RDE testing consists of two phases:

- a temporary phase, Euro 6d-TEMP, with a ‘conformity factor’ of 2.1, meaning that vehicles approved under Euro 6d-TEMP can emit 2.1 times the Euro 6 limit; and

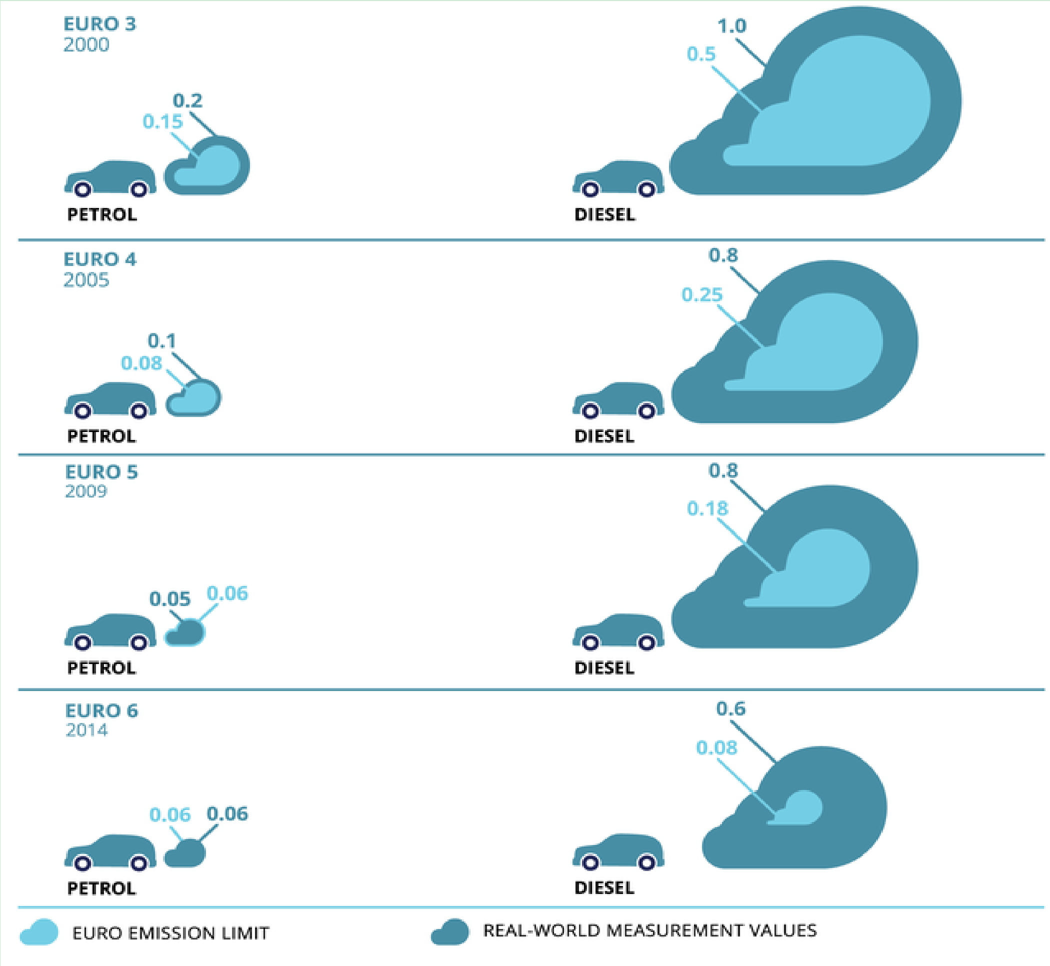
- a final phase, Euro 6d, for which the conformity factor is the margin of uncertainty of the Portable Emissions Measurement System (PEMS) measurement (currently 1.5).

---

[113] The International Council on Clean Transportation (ICCT), *‘NOx control technologies for Euro 6 diesel passenger cars’*, 2015 <www.theicct.org/nox-control-technologies-euro-6-diesel-passenger-cars>.

[114] The New European Driving Cycle (NEDC) serves to represent typical car usage in Europe; the Worldwide Harmonized Light Vehicles Test Cycle (WLTC) better represents the range of real world driving conditions.

Figure 8.6: Comparison of NO_x (g/km) emission standards for different car Euro classes, by emission limit and real-world performance (NO_x emissions measured in g/km)



Source: Adapted from a report by the European Environment Agency[115].

The COPERT 5 emission factors for Euro 6 used for the central analysis broadly reflect three phases, indicating a gradual improvement in emissions due to the effectiveness of RDE testing. They do however reflect the fact that despite improvements in the testing procedure, there is likely to continue to be some difference between vehicle emissions during approval testing compared to everyday real world emissions (although this is reduced over time). While petrol cars have performed consistently better than the Euro standard from Euro 5 onwards, diesel cars have performed consistently worse.

---

[115] European Environment Agency (EEA), *'Explaining road transport emissions – A non-technical guide'*, 2016 <http://www.eea.europa.eu/publications/explaining-road-transport-emissions>.

Historically, more extensive emissions testing had been undertaken for older vehicles. This is because they represent a larger fraction of the fleet and have been in circulation longer than newer vehicles, leading to greater opportunities for testing. Consequently, emissions from newer vehicles had larger associated uncertainties compared to older vehicles. Since the Volkswagen emissions issue in September 2015, there has been widespread testing of Euro 6 diesel cars throughout Europe, which has provided increased confidence in emissions from Euro 6 cars. The greatest uncertainty is associated with future Euro 6 emissions (Euro 6d-TEMP and Euro 6d) from diesel cars and LGVs, since evidence regarding the effectiveness of different abatement technologies continues to evolve, and the impact of RDE legislation is not yet known.

Given the inherent uncertainty around predicting emission factors for future vehicles, two alternative scenarios (agreed through discussion with experts, including representatives from Ricardo and Emisia) were modelled in addition to the central scenario. One scenario is based on lower emissions compared to the central scenario, whilst the other assumes higher emissions relative to the central scenario, in order to present the possible range of likely outcomes.

The lower emissions scenario assumes that under real-world driving conditions, new Euro 6 light duty vehicles are fully compliant with the relevant RDE legislation in place at the time of manufacture (for both Euro 6d-TEMP and Euro 6d). The higher emissions scenario assumes the same emission factors as COPERT 5 (which are already considered to be cautious), but incorporates the latest possible uptake for RDE step 1 and 2 for new vehicles permitted by the legislation. However, it should be noted that there are already some vehicles that meet the Euro 6 standards in the real world[116].

The assumed conformity factors (scaling factors that show the number of times that the modelled emission factors exceed the Euro 6 limit value of 0.08g/km) for light duty vehicles, such as cars and vans, show a gradual decline in the number of times the modelling emissions factors exceed the Euro 6 limit leading up to 2020 (Table **8.7**).

---

[116] The International Council on Clean Transportation (ICCT), *'NOx control technologies for Euro 6 diesel passenger cars'*, 2015 <www.theicct.org/nox-control-technologies-euro-6-diesel-passenger-cars>.

Table 8.7: Scaled assumed factors showing the number of times that the modelled emission factors exceed the Euro 6 limit for cars and vans																				
	2016				**2017**				**2018**				**2019**				**2020**			
Cars	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Central	6.7	6.7	6.7	6.7	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Low	6.7	6.7	6.7	6.7	6.7	6.7	6.7	2.1	2.1	2.1	2.1	2.1	2.1	2.1	1.5	1.5	1.5	1.5	1.5	1.5
High	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	5.1	5.1	5.1	5.1	5.1	5.1	2.5	2.5	2.5	2.5
LGVs	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Central	7.6	7.6	7.6	7.6	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0	2.0	2.0	2.0
Low	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	2.1	2.1	2.1	2.1	2.1	2.1	2.1	1.5	1.5
High	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	4.0	4.0	4.0	4.0

The impact of the high and low emissions scenarios on NO_x emissions was modelled using these conformity factors. This then allowed for a valuation of the health benefits (Table **8.8**).

Table 8.8: Sensitivity analysis on diesel Euro 6 LDV emissions and associated impacts on benefits for Clean Air Zones				
Scenario	**Inside zone emissions change, tonnes**	**Outside zone emissions change, tonnes**	**Total NO_x benefits (£m)**	**Overall NPV (£m)**
Central	-40,841	17,264	£3,612	£1,099
Low conformity factors	-33,118	13,065	£3,280	£768
High conformity factors	-43,589	18,759	£3,729	£1,216

8.3 Measure modelling uncertainties

A range of additional uncertainties exists in relation to the design of each possible measure, which has not been possible to quantify. Many of these stem from an absence of information on the behavioural responses that people may choose to adopt in response to the implementation of a particular measure.

There is a large amount of uncertainty surrounding the responses of vehicle owners to the implementation of a Clean Air Zone due to the number of potential choices that affected vehicle operators may choose. These include avoiding the zone, cancelling the journey, upgrading vehicle, redeploying vehicles elsewhere or continuing into the zone. The proportions of vehicle owners responding in each way will affect the vehicle kilometres driven by compliant and non-compliant vehicles within the zone, and therefore the level of emissions in the zones and outside the zone, as well as the costs imposed to society.

Additional uncertainties exist over the actions of individuals choosing to upgrade their vehicles. Individuals are assumed to buy the cheapest compliant vehicle available. For example, in the case of an affected LGV driver, a second hand, four-year-old Euro 6 van (£6,400) is modelled, whereas in reality a brand new Euro 6 van (£25,000) could be purchased. Alternatively, some vehicle operators will have a larger fleet and therefore be able to redeploy compliant vehicles in Clean Air Zones and non-compliant vehicles elsewhere. However, the feasibility of this will depend on the extent of coverage of the Clean Air Zones that are proposed. These vehicle operators would incur a negligible cost of compliance, however this scenario has not been considered in analysis. Given the number of Clean Air Zones proposed for implementation, further investigation is also required to assess the availability of second hand vehicles across the country. Preliminary analysis suggests there would be sufficient numbers of cars and LGVs available, although HGV supply may be constrained, meaning a larger proportion would need to either buy a new vehicle or retrofit their existing vehicle. The consequential costs of this scenario are factored into the modelling, but the approach to assessing this will be revisited and refined for the final Plan.

All relevant assumptions and associated uncertainties for all proposed measures that have been assessed (Table **8.9**).

Table 8.9: Key assumptions relating to the assessment of measures in the draft Plan

Overarching assumptions	
The number of trips and distance travelled by those who purchase new vehicles will not change from how frequently and far they travelled with their older vehicle.	Owners of newer vehicles in general drive them more often or further than older vehicles. If purchasing new vehicles results in more driving, then the predicted reduction in NO_2 concentrations would be overstated.
While the modelling takes into account DfT fleet change projections, local growth conditions have not been considered in the modelling.	Areas may experience local economic growth, which could increase traffic and congestion. This is not taken into account in the analysis.
The total UK fleet is assumed not to change due to the policies; where new vehicles are bought a corresponding number of the oldest most polluting vehicles are removed from the market.	It is difficult to know how many vehicles will be newly purchased due to the policies, but it is reasonable to assume, given supply constraints, that a certain proportion would be.

Unless stated otherwise, people will act to minimise financial costs. Thus, they will decide upon the action that fulfils their objectives at minimum cost, buying the cheapest CAZ compliant vehicle as an example.	In reality, people do not always make the financially optimal decision, meaning they might not have bought the cheapest vehicle for their aims. Thus, some will choose to spend more. It is also possible that some people will not be able to act in a financially optimal way either because they do not have sufficient money to cover upfront costs or because they are unable to borrow money to cover these costs. However, it has not been possible to quantify this.
Unless stated otherwise, the administration and start-up costs of a policy are zero.	In reality, there are often sizeable costs in both setting-up and administering a policy. However, because many of the proposed measures are simply expansions or variations on existing ones, much of these costs have already been taken into account.
Clean Air Zones	
Assumption	Associated uncertainty
The assumption for the behavioural responses of vehicle owners is based on an assessment of the number of vehicles available and one previous study on individual and business responses in London.	London is not representative of the rest of the UK, and therefore depending on how people and businesses behave in response to measures, there could be a larger or smaller change in NO_x emissions compared to the modelling predictions.
The Clean Air Zone delivers an 80-95% reduction in the distance travelled within the zone by non-compliant coaches, HGVs, LGVs and cars; and a 100 percent reduction in those of buses. However, it is assumed that all lost business activity is replaced by compliant business activity.	In reality, there may be a higher or lower proportion of non-compliant vehicles that continue to enter the Clean Air Zone. This would alter the estimated reduction in emissions although it is not possible to assess the direction or scale. There will be a larger proportional impact on vehicle kilometres than unique vehicles that change behaviour, given those that upgrade are more likely to be frequent entrants of the zones.
The analysis presented here considers the access restriction element of Clean Air Zones only. Other elements such as accelerating uptake of ULEVs, raising awareness, encouraging active travel, and improving public transport services are not quantified.	There are a large number of additional measures in the national overview and zone plan documents that are already planned by local authorities that could not be modelled but could be expected to lead to greater NO_x reductions than shown in the analysis, as well as possible additional costs.

The modelling assumes the profile of ownership length data, from DfT, will be equally represented by the vehicles affected by the Clean Air Zones.	The profile of ownership length may be longer or shorter.
DfT GPS journey information has been used to identify the number of unique vehicles that are likely to enter different networks of Clean Air Zones. This tracks a sample of around 160,000 vehicles travelling around the UK, and identifies where they enter multiple cities. This dataset has been combined with data from the London LEZ, which identifies the total number of unique vehicles entering London in a year.	The sample of vehicles in the GPS sample is not derived statistically, and may be biased towards newer vehicles. Therefore, the sample may overestimate the number of unique vehicles entering Clean Air Zones. Reduced vehicle numbers entering Clean Air Zones would reduce costs of measures compared with the calculations.
Robust fuel consumption data is only available for cars and diesel LGVs. This has been adjusted for a factor reflecting the difference in real world and test cycle emissions. There is no data available for other vehicle types so it is assumed that there are no improvements in fuel efficiency for these vehicles.	We expect that newer vehicles other than cars and LGVs experience greater improvements in fuel efficiency and savings in CO_2. Therefore, there may be additional unquantified CO_2 benefits.
Zone perimeter lengths were estimated for Nottingham, Southampton, Derby, Leeds, and Birmingham for the 2015 Plan. The average of these five cities has been calculated and this is assumed to be the perimeter length of an average Clean Air Zone.	Until a full run of the PCM has been completed, the exact areas of non-compliance cannot be determined. These will be obtained and indicative perimeters will feed into the analysis for the final Plan. Actual perimeters for CAZs will be determined through feasibility studies conducted by Local Authorities longer term.
The second hand value of vehicles is based upon depreciation rates of the most popular cars and vans.	The actual depreciation rates of vehicles is uncertain, making the cost of second hand vehicles uncertain. More or fewer second hand vehicles may be bought than expected.
The implementation of Clean Air Zones is assumed not to lead to vehicles owned by businesses cancelling journeys.	Controls on the cost of the transportation of goods could have unforeseen effects on supply. At the same time, the wider benefits for business from being located in a healthier, more attractive city (for example in terms of attraction and retention of staff, reductions in sickness levels, etc.) have also not been quantified.

In the modelling, setup costs are to be spent in the earliest year the zones are expected to be operational (2020) and discounted to 2017 prices - £270m in present value.	In reality, much of the capital expenditure will happen prior to zones being operational; however, this simplification has been made for modelling the appraisal period 2020-2029.
25% of vehicles that are upgraded will be bought new.	A 25% figure was selected via engagement with experts involved in the implementation of other schemes, and agreement that it was a reasonable assumption to make. However, it is worth noting that no empirical evidence exists as to how large this proportion will be.
It is assumed that all CAZs will be implemented in 2020.	In reality implementation make take longer or shorter than anticipated and it is likely that CAZs will not all be implemented at the same time. Implementation dates will be determined at a local level by local feasibility studies. If implementation dates are different to those modelled, the costs and benefits are likely to change together meaning that the net impact will be broadly the same.
Retrofit	
Assumption	Associated uncertainty
Market capacity is sufficient to deliver the level of retrofit modelled.	Retrofit for buses are well established. However, retrofit for HGVs remains unproven. Retrofit for taxis has been undertaken to date, but there is uncertainty about what scale can be delivered.
Scrappage	
Assumption	Associated uncertainty
The grant levels are sufficiently high to: Incentivise vehicle owners to scrap their vehicles earlier than they otherwise would have done; and Incentivise these vehicle owners to participate in the scheme to buy new vehicles instead of used vehicles; and/or Incentivise around 15,000 Euro 1-5 diesel/Euro 1-3 petrol car owners to buy a battery electric vehicle if in addition to the £2,000 grant they are also offered an additional incentive of £6,000.	It has not been possible to quantify the premium that vehicle owners are likely to need (over and above the residual asset value of their vehicle) to incentivise them to change their behaviour (scrap their car, buy a new car and/or buy a BEV). This could mean uptake of the scheme would be higher or lower than assumed and consequently the cost to government could be higher or lower than currently estimated. The key associated uncertainties are the estimated residual values, the premium

	needed for the behaviour change, and take-up rates for the scheme.
The analysis presented in this report has focused on the first order effects of the policies (i.e. no behaviour change has been assumed)	The assessment has not taken into account possible rebound effects such as the potential increase in vehicle mileage (as a result of increased fuel efficiency) which could offset the emissions savings that have been estimated
Ultra Low Emission Vehicles (ULEVs)	
Assumption	Associated uncertainty
The criteria and grant levels of the current scheme continue to apply. So the average grant size is £3,500 and the additional cost of purchasing an ULEV is £9,400	In reality, the grant size and additional cost of an ULEV will vary and is dependent on individual vehicle specifications.
The whole of the funding pot is used to finance ultra-low emission cars	An assumption made to simplify the modelling. In reality, a small part of the grant will fund a switch to ultra-low emission vans/motorcycles, which have a different emissions profile.
Around 50% of purchases, in the central scenario, would have occurred in the baseline and as such would have no additional benefits.	The baseline profile of ULEV take up may differ from this assumption.
New ULEV purchases would come equally from consumers switching from a new conventional Euro 6 car, split equally between petrol and diesel	Due to the cost differential, it is logical to assume consumers would not be incentivised to replace their current vehicle earlier than they otherwise would have. The behavioural differences this policy would trigger among current diesel and petrol owners have not been fully assessed.
The average price difference between an ULEV and conventional car is larger than the size of the grant and will remain the same over the 10 year modelling period	The current cost of an electric or hybrid vehicle is higher than a comparable conventional car but overtime this cost differential may fall.
Because the existing scheme is in place, this scheme could be extended without lags	In reality, there may be a small administration lag, which has not been modelled.
The scheme will be complete by 2020 and take-up will increase linearly	The purchase of additional ULEVs through this scheme is assumed to increase at a linear rate, with a smaller uptake in the first year compared to the last. By 2020, this additional uptake is assumed to be complete.

Consumers are rational, so will only purchase an EV if the additional cost of the vehicle is less than the additional benefit of the car	The consumer's choice of purchasing an ULEV is assumed to be rational. As such, they would only purchase an ULEV if the benefit they obtain from this consumption is equal or higher than the cost they must incur.
Costs of charging and benefits lower noise pollution have not been quantified and are set to zero	These two factors will largely work to cancel each other out, thus the effect on the estimates would be negligible
The purchaser of an ULEV will drive it similar to the average driver, i.e. urban/rural drivers are equally likely to purchase an ULEV	Modelling is based on the national average. In reality, there may be a regional or area type difference in the purchase of ULEVs.
The effect of signalling is ignored	This assessment does not take into account the signalling impact of increased ULEV uptake
Speed limits	
Assumption	Associated uncertainty
The effect of reducing the speed limit from 70mph to 60mph can be simulated by modelling a reduction in the average speed (by 10 mph) on those stretches of motorway that are failing (and have average speeds at or close to 70mph).	The analysis is based on average modelled speeds on the types of motorways affected. It takes account of where average speeds are already below 70mph. However, it is possible that failing motorway links tend to be busier and more congested, and therefore speeds on them lower than average (so the impact of lowering speed limits on these links will be lower). The analysis does take account of vehicles like HGVs that are already limited to 60mph or below and road links of a type with average speeds well below 70mph.
Effects to flow of traffic have not been considered for the analysis of speed limit reduction.	As flow could be projected to increase or decrease during a reduction of speed, no adjustment in flow was accounted for. A reduction in speed can aid transport to flow at a steady speed, but can also decrease flow due to travelling at a lower speed or increasing congestion. There is uncertainty in this area, as speed limits have not previously been used for air quality management purposes on the SRN. Highways England has a range of preliminary evidence, which shows that, in fact, NO_x emissions may not reduce in the way that the SL-PCM modelling suggests

	if reduced speed limits were to be employed. This evidence is subject to quality assurance and further consideration. The evidence would benefit from further monitoring in real world conditions, for example at sites where variable speed limits are used already for traffic smoothing purposes, to understand better the extent of the impact any change to speed limits might have on air quality.
Government Buying Standards	
Assumption	Associated uncertainty
Real on the road (ORR) price[117] difference between cars bought in baseline and as a result of the measure does not change over the appraisal period.	Lower demand for diesel from updating GBS might lead the price to fall and ORR price difference to change, thus the capital switching cost will be too low.
CO_2 emissions differential between cars bought in baseline and as a result of the measure do not change over the appraisal period.	Technology change may lead to an increased proportional reduction in CO_2 emissions of one fuel over the other. This will then factor into the cost or benefit of these emissions.
Average annual distance driven (by cars within public sector fleet, and when the vehicles are sold on the second hand market) does not change over the appraisal period	Unknown factors might influence the amount of miles driven, which will affect running costs and both CO_2 and NO_x emissions. Further, a change in miles driven may have a greater effect dependent on the sector, since government may drive more (less) than the average member of public.
Size of central government fleet does not change over the appraisal period	Variation will affect the number of new vehicles purchased annually and so the magnitude of impacts.
Company car fleet assumptions are based on information received from CCS.	Variation in the size of the fleet will have impacts on our calculations for both the number of vehicles purchased annually and average distance driven. This would impact on estimates of the policy's costs and resulting changes in CO_2 and NO_x
The impact of the GBS for central	In reality, the timing has not been finalised and could change, thus the policy might have a

[117] On the road (ORR) price is the recommended retail price plus the delivery charge, plus the cost of half a tank of fuel, the car's number plates, road tax, and the first registration fee.

government begins at the start of 2018.	slightly different effect. However, as the effects are not that large and the variation in start time is unlikely to be over 6 months in either direction, the uncertainty is small.
The GBS contains 3 car segments, with the following vehicles chosen as 'representative' of the average car in each segment. Segment A: Fiat 500 Petrol: 500 Pop Star 0.9 Twinair 85HP Turbo Dualogic Diesel: 500 Pop Star 1.3 Multijet 95hp Segment B: Ford Fiesta Petrol: 1.0T Eco Boost 100 PS Diesel: 1.5 TCDi 75PS Segment C: Ford Focus Petrol: 1.0T Eco Boost 100PS 26 Diesel: 1.5 TCDi 95 PS S6	In reality, there are a multitude of vehicles each with varying engine specifications and consequently CO_2 emissions. The vehicles modelled are merely representative examples and so both vehicle cost and CO_2 saving will depend on exactly which vehicle is chosen.
Vehicle labelling	
Assumption	Associated uncertainty
Any switching that occurs as a result of this measure will be from diesel to petrol	ULEVs have the best performance in terms of NO_x emissions, so labelling may encourage some to buy EVs. However, given that EVs already perform well on CO_2 labelling, the switch will be marginal.
Influencing driving style	
Assumption	Associated uncertainty
Cars are driven by one person. Thus, the number of cars impacted is the same as the number of individuals receiving training.	Not everyone drives one car. Some people share their car with other drivers whilst others drive multiple vehicles. Thus, the modelling may over- or under-estimate reality.
Drivers of 'other vehicles' (not cars or LGVS) also drive either a car or LGV. Thus, improvements caused by training car or LGV drivers carry across to other vehicles proportionally (55 cars/LGVs to each "other vehicle").	In reality, this proportion is unknown and there is no certainty that the improvements in driving style for one vehicle class translate to those in another. Thus, the modelling might under or over predict the spill over benefits of the course.
The average cost of an eco-driving course and a telematics device totals £150 and	The government increasing demand for eco-driving courses would raise the price of the

that this price remains constant over the appraisal period.	course. If government agrees a contract each year then this will increase the cost.
A percentage reduction in fuel usage equates to an equal percentage reduction in NO_x emissions.	The vehicles being targeted will range across different categories, Euro standards, and engine sizes. Thus, it is quite likely that the relationship between fuel consumption and NO_x emissions will vary. Thus, a % reduction fuel consumption may not lead to an equal % reduction in NO_x emissions.

8.4 Uncertainties in quantifying and valuing air quality impacts

8.4.1 Introduction

An element of uncertainty with the modelling stems from identifying and assessing the air quality impacts of any proposed measure to control air quality. Much of this uncertainty relates to the potential health impacts to the public that originate from NO_2 exposure, which can be made difficult to quantify as the isolation of the effects of NO_2 from other air pollutants is not always clear. A range of additional impacts also results from air pollution, such as worker productivity and harm to natural ecosystems, which also require attention in order to fully grasp the full extent of air quality impacts.

8.4.2 Sensitivity on health impacts of NO_2 exposure

The quantification of health impacts (Section **3.3.2**) is based on epidemiological studies that investigate statistical associations between NO_2 concentrations and mortality risk. Such studies usually use outdoor air pollution concentrations at the residential addresses as a proxy for personal exposure to NO_2.

The Committee on the Medical Effects of Air Pollutants (COMEAP) has noted that there is no clear evidence for a threshold effect[118] from exposure to NO_2. Therefore, during the modelling it has been assumed that mortality changes in a linear manner with changes in NO_2 concentrations. The impact on the analysis in this report, were a threshold to be present, is expected be minimal as the reduction in concentrations through the measures is focused on populations with higher levels of exposure.

[118] A threshold effect is a dose or exposure concentration below which a defined effect will not occur.

To reflect the range of current evidence of the mortality effect associated with NO_2 concentrations, the central risk coefficient (2.5%) has been compared against the range of risk coefficients as recommended by COMEAP (1% and 4%). Using COMEAP's lowest risk coefficient of 1%, the benefits of reducing NO_2 are 40% lower than the central estimate. In contrast, the maximum risk coefficient leads to estimated benefits that are 60% higher than the central estimate (Table **8.10**).

Table 8.10: Monetised health benefits of NO_2 reduction from Clean Air Zones

Scenario	NO_2 health benefit (£m)	NPV (£m)
Central risk coefficient (2.5%)	3,611.5	1,098.8
High-risk coefficient (4%)	5,778.4	3,265.7
Low risk coefficient (1%)	1,444.6	-1,068.1

Importantly there is also uncertainty in assessing the mortality impacts of policies that primarily reduce NO_2 concentrations, compared with actions that reduce the whole mix of air pollutants. This is because of the uncertainty, noted by COMEAP[119], about the extent to which NO_2 itself is responsible for the associations with mortality reported in epidemiological studies. These issues have been discussed by COMEAP a number of times since the interim advice was provided. A decision on how the question of causality could be addressed quantitatively is still in development. However, from the current discussions, it appears likely that this may considerably reduce the coefficient recommended for assessing the benefits of measures that would primarily reduce NO_x emissions alone.

There is likely to be substantial overlap if effects are estimated on the basis of both NO_2 and $PM_{2.5}$ concentrations when coefficients from single-pollutant models are used in the same analysis. To avoid this risk only the impact of NO_2 concentrations has been valued.

COMEAP has noted that uncertainty still remains around the potential overlap between the health effects found in epidemiological studies to be associated with PM and NO_2. They previously suggested reducing the NO_2 coefficient by 33% to take account of double counting of effects associated with PM, but have noted that

[119] Committee On The Medical Effects of Air Pollutants (COMEAP), *'Interim statement on quantifying the association of long-term average concentrations of nitrogen dioxide and mortality'*, 2015 <www.gov.uk/government/uploads/system/uploads/attachment_data/file/485373/COMEAP_NO2_Mortality_Interim_Statement.pdf>.

uncertainty around the magnitude of this adjustment still exists[120]. Nevertheless, it should be recognised that COMEAP advice is evolving in response to current scientific evidence and changes will have implications for the cost benefit analysis.

8.4.3 Sensitivity on NO_x damage cost

Damage costs provide a coherent way to value changes in air pollution. They seek to estimate the cost to society of a change in the emission of a given pollutant. They can be provided by pollutant, source, as well as location. However, damage costs are only as good as the information used to derive them. Defra is currently updating its damage costs to account for new information, which includes updating the NO_x damage costs and the dispersion modelling underlying this. In the current published damage costs, the emission to concentration relationships for NO_x emissions to NO_2 concentrations was assumed to be equivalent to the relationship between $PM_{2.5}$ emissions and $PM_{2.5}$ concentrations. However, in light of new information, revisions to the latest dispersion modelling will ultimately lead to a better representation of the costs of air pollution to society.

Sensitivity on morbidity impacts

The change in mortality associated with exposure to NO_2 concentrations has been valued in the economic assessment. However, other costs such as short-term health impacts on hospital admissions and other health care costs have not been assessed. This is likely to lead to an underestimate of the benefits of reducing NO_2 concentrations.

A quantified sensitivity analysis has been conducted on bronchitic symptoms in asthmatic children and respiratory hospital admissions using World Health Organization guidance[121]. The expected reduction in costs associated with these types of admissions because of a reduction in NO_2 concentration is expected to be in the region of £38m. However, this estimate does not capture the impacts on a wide range of additional morbidity impacts, which have not been possible to quantify, but are likely to be influential.

---

[120] Ibid.

[121] World Health Organization, '*Health risks of air pollution in Europe – HRAPIE project. Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide*.' (2013) <http://www.euro.who.int/__data/assets/pdf_file/0006/238956/Health-risks-of-air-pollution-in-Europe-HRAPIE-project,-Recommendations-for-concentrationresponse-functions-for-costbenefit-analysis-of-particulate-matter,-ozone-and-nitrogen-dioxide.pdf?ua=1>.

A report, published by the Royal College of Physicians in 2016[122], outlined the impacts of air pollution on health. It found that air pollution, including NO_2, is linked with a number of morbidity impacts, which have not been valued in the analysis presented in this report. In addition to respiratory problems and reduced lung function, these also include damage to neurodevelopment, cognitive function, and cardiovascular disease.

8.4.4 Other air quality impacts

Productivity

Air pollution has an impact on morbidity; both the amount of time people physically are at work and through their efficiency while working. There may also be additional impacts on mortality and morbidity in non-market productive activities such as volunteering and non-paid caring. It has not been possible to quantify the reduction of these impacts, but it is likely the benefits will be significant. Defra has commissioned work considering the links between air quality and productivity[123] and identified a number of relevant impact pathways. However due to the uncertainties surrounding the pathways quantification of these has not been incorporated into the central guidance on quantification.

Ecosystem services

Air pollution has considerable impact on the natural environment via processes such as eutrophication of terrestrial and aquatic ecosystems, acidification of soils and freshwaters, and direct toxicity effects of ground level ozone. These ecological impacts affect supporting ecosystem services, with a large number of consequential effects. Defra has commissioned work considering the impacts on ecosystems of pollution[124]. However, as with productivity impacts, given the uncertainty over the

---

[122] Royal College of Physicians, *'Every breath we take: the lifelong impact of air pollution'*, 2016 <https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution>.

[123] Ricardo-AEA, *'Valuing the Impacts of Air Quality on Productivity'*, Final Report for the Department for Environment, Food & Rural Affairs, 2014 <https://uk-air.defra.gov.uk/assets/documents/reports/cat19/1511251135_140610_Valuing_the_impacts_of_air_quality_on_productivity>.

[124] Centre for Ecology and Hydrology (CEH), *'Using the Ecosystems Services Approach to Value Air Quality'*, Report for the Department for Environment, Food & Rural Affairs, 2012 <https://uk-air.defra.gov.uk/assets/documents/reports/cat10/1511251138_NE0117_Using_the_ecosystems_services_approach_to_value_air_quality.pdf>.

magnitude of these impacts they have not been incorporated into the central guidance on quantification.

8.5 Discussion

Acknowledging the inevitable uncertainties with the modelling and its associated risks forms an important in step in understanding the relative strengths and weaknesses of the approach taken to measure the impacts of any proposed measure and in doing so supports the decision-making process. Throughout the analysis, the best possible data sources, evidence and expert judgement surrounding both the modelling of air quality and its connected health and economic consequences have been utilised, thus providing a solid foundation for the results produced.

In many cases, a number of assumptions have been employed and an assessment into the robustness of these assumptions allows an identification of the true limitations of the current data (Table **8.9**). Within this assessment, it is evident that there is a certain degree of 'noise' present with the data used to inform the analysis of intervention measures. These are small amounts of error that can occur naturally on all data points in every dimension (e.g. variations in the precision of measurements, rounding or having other background data that is indistinguishable from the actual data being measured), but generally have little effect when evidence is analysed. Thus, the existence of noise and adjustments to individual parameters do not drive fundamental changes in outcomes and consequently allows confidence to be placed in the processes and analysis presented in this report.

The inherent uncertainties surrounding the analysis does not present reason for inaction, but rather motivation to continually develop knowledge, evidence and monitoring of air quality so that an increasing high-quality evidence base can be achieved. In doing so, uncertainties can be reduced in a multi-faceted way, thus incrementally building confidence in the way intervention measures can be effectively implemented. The steps that are required to attain this goal are addressed in Section **9**.

9. Future steps

This section describes the longer-term plan to improve air quality, covering:

- Developing the final Plan following this consultation
- Evidence requirements for implementation and evaluation of the final Plan
- Plans to further improve the evidence in the longer term
- Developing an air quality strategy

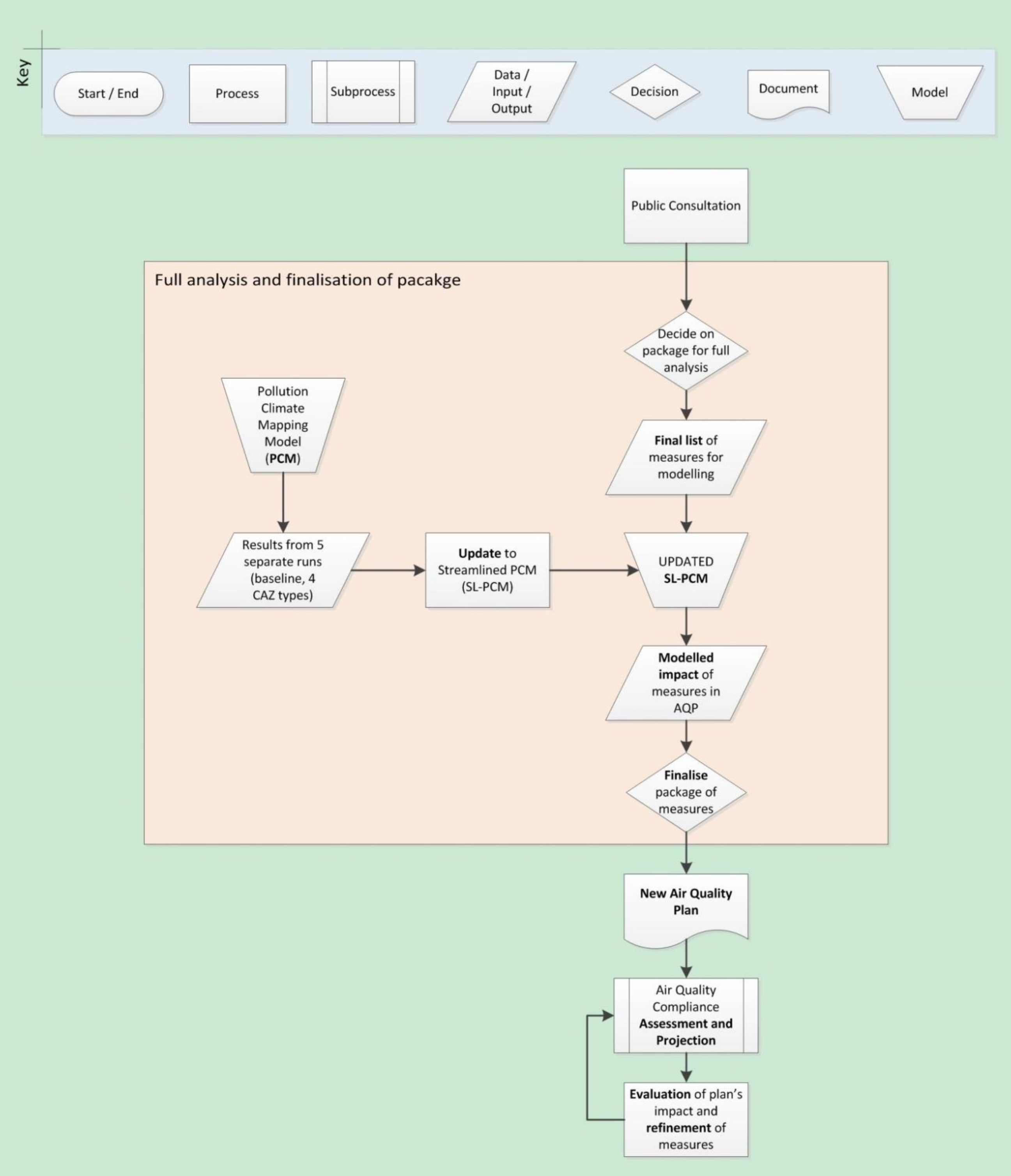
9.1 Developing the final Plan

The work required to move from the analysis presented in this report to that in the final Plan will include:

- Incorporating consultation responses
- Conducting a full analysis of the final Plan
- Improving the quantification of expression of uncertainties

An overview of the plan for this process is illustrated by Figure **9.1**.

Figure 9.1: A flow chart to illustrate the process of transitioning from consultation to the final analysis



9.1.1 Incorporating consultation responses

Responses to this consultation may lead to changes in the assessment methods or the measures that are assessed. These changes will be described in detail in the final technical report and reasons for change will be incorporated.

9.1.2 Full analysis of the final Plan

The next stage of the process will be to identify and assess the package of measures that will form the final Plan. Given the time required to complete this analysis it will be necessary to use a modular approach. This approach is formed of four parts:

- PCM modelling
- Updating the SL-PCM model
- Package analysis – air quality impacts
- Package analysis – option assessment

PCM modelling

The Pollution Climate Mapping (PCM) model is described in detail in Section **2.1**. The model requires the collation of a wide range of inputs across different source sectors to make air quality projections. The complexity of the PCM model means that significant set-up, processing, computation and quality assurance is required, with the model taking around three months to run scenarios once the policies to be assessed have been agreed. Steps to improve this situation are considered in Section **9.3**.

To provide the most up to date assessment of the expected future compliance challenge, updated baseline projections from a base year of 2015 are currently being calculated using the PCM model for every year from 2017-2030 inclusive.

These projections will be the basis for the final Plan and will reflect the latest evidence around road transport emission factors (COPERT 5) and road traffic projections, and will be based on the latest available base year (2015).

Updating the modelling in this way means there will be some differences in the evidence base used for the consultation and final Plan. However, these differences should primarily arise in the detail, rather than significantly changing the scale of the challenge.

Updating the SL-PCM model

To enable more flexible assessments, a simplified version of the full PCM model, known as the Streamlined PCM (SL-PCM) model, has been developed. This was also used to model a small number of measures in the 'Air quality plan for nitrogen dioxide (NO_2) in UK (2015)'.

The SL-PCM model is based on the PCM model but incorporates some simplifications which together substantially reduce the modelling time thereby allowing assessments of policies under multiple scenarios (see Section **2.1** for more details).

The routine process for updating the SL-PCM model involves first calculating the PCM modelled projections, and then building a SL-PCM model that is fully consistent with that PCM assessment. For this draft Plan there was not sufficient time to update the PCM projections first and then develop a new SL-PCM model for assessment of measures. As such, the baseline projections and analysis of measures presented in the draft Plan for consultation were derived using a previous version of the SL-PCM model. The version of SL-PCM model used for this report projects concentrations from the 2013 base year (2013-SL-PCM), but has been updated as far as possible (e.g. including September 2016 COPERT 5 NO_x emission factors, and using the latest model calibration against the measurement data).

The analysis for the final Plan will be undertaken using an updated version of the SL-PCM model that is fully consistent with the updated PCM modelling using the latest evidence and 2015 base year (2015-SL-PCM). The differences arising between the projections provided by the 2013-SL-PCM model and the 2015-SL-PCM model should not hinder consultees' ability to respond now. It is not expected that the overall scale of the challenge will change significantly although there will be differences in the detail (e.g. specific concentrations on individual roads or detailed source apportionment).

Package analysis – air quality impacts

The new 2015-SL-PCM will be used to assess the impact of the final package of measures for the final Plan. As part of this assessment, the following scenarios will be modelled:

- National type A CAZ (in 2018-2025 & 2030)
- National type B CAZ (in 2018-2025 & 2030)
- National type C CAZ (in 2018-2025 & 2030)
- National type D CAZ (in 2018-2025 & 2030)

Bringing together the modelling from these different scenarios will provide an assessment of the impact of CAZs of different stringency in different areas.

As well as the additional scaling of CAZs a number of other measures are likely to need to be assessed. This package of measures will not be defined until the consultation has been concluded and the responses assessed.

This model will take the agreed CAZ implementation as the baseline and then make changes to the fleet as appropriate to reflect the wider measures. This will be done in line with the methodology set out in Section **2.1**.

Package analysis – option assessment

Finally, the package of measures will be assessed with the methods described in Section **3.3** to understand its full impact on society including health, the economy, and the distribution of impacts on different groups. This analysis will take account of emerging advice on health impacts (Section **8.4.2**) and any early findings from ongoing work to improve the accuracy of distributional analysis (Section **9.3.2**).

9.1.3 Improving the expression of uncertainty

A particular area of development recommended by the Air Quality Review Group (Annex **F**) before production of the final Plan is the consideration and presentation of the broad range of uncertainties that affect it. As stated earlier in Sections **1.4** and **8.1**, work is ongoing to assess the uncertainties using IPCC guidance on calibrated uncertainty language[125] [126].

Defra will look to convene a panel of relevant experts with the aim of providing an independent expert assessment of the degree of uncertainty in our analysis. This will be presented in the final Plan following the IPCC recommended approach.

The assessment can be conducted using two methods:

- A qualitative assessment of the confidence of the validity of a given finding

---

[125] Mastrandrea, M.D. et al., '*Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*' (2010) Intergovernmental Panel on Climate Change <https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf>.

[126] Mastrandrea, M.D. et al., 'The IPCC AR5 guidance note on consistent treatment of uncertainties: a common approach across the working groups', *Climatic Change* 108: 675 (2011) <http://link.springer.com/article/10.1007/s10584-011-0178-6>.

- A quantified, probabilistically-expressed measure of the uncertainty, based on analysis

The decision on which method to use will be made based on the nature of the evidence that is being evaluated (see Annex **E** for more detail).

Qualitative assessment

IPCC guidance recommends that for qualitative assessments, expert judgements are used to evaluate key findings and that transparent accounts are maintained of the process followed in coming to the judgements.

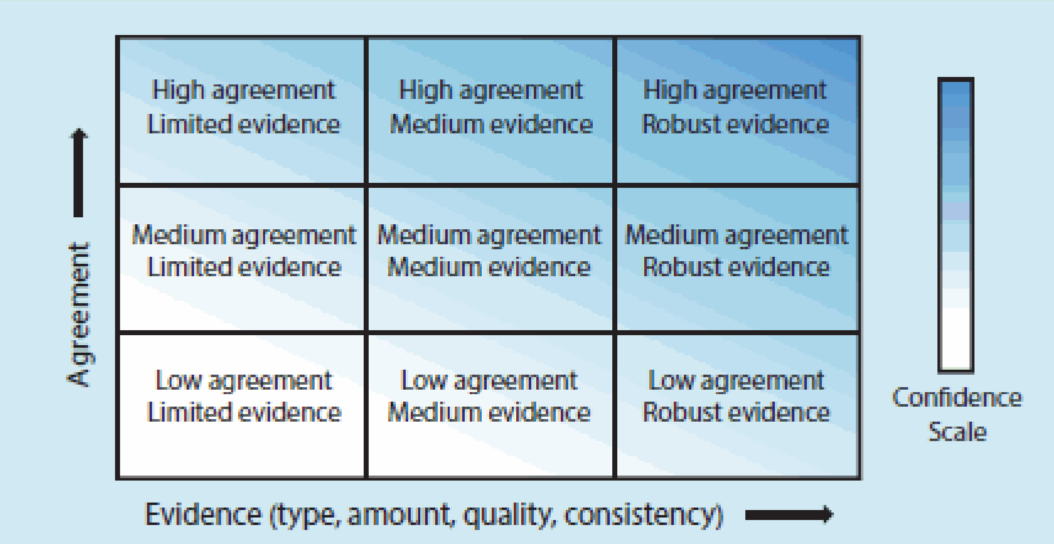
Judgements of confidence follow two ways of assessing validity:

- ‘Evidence’ statements based on type, amount, quality, and consistency (using the summary terms “limited,” “medium,” or “robust”)

- The degree of ‘agreement’ (using the summary terms: “low,” “medium,” or “high”).

A level of confidence is then expressed using the qualifiers ‘very high’, ‘high’, ‘medium’, ‘low’ and ‘very low’, which synthesises these evidence and agreement statements (Fig. **9.2**).

Figure 9.2: Evidence and agreement statements and their relationship to confidence[127]



Note: Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.

Quantitative assessment

For quantitative assessments, the IPCC guidance recommends that a probabilistic estimate of the occurrence of a single event or outcome is produced, using the measures of likelihood defined in Table **9.3**.

[127] Mastrandrea, M.D. et al., '*Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*.' (2010) Intergovernmental Panel on Climate Change <https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf>.

Table 9.3: Likelihood terms associated with outcomes used by the IPCC[128]	
Term	**Likelihood of the outcome**
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability
Note: Additional terms (extremely likely: 95–100% probability, more likely than not: >50–100% probability, and extremely unlikely: 0–5% probability) may also be used when appropriate.	

9.2 Evaluation of the final Plan

Given the uncertainties in the evidence on the impacts of the proposed measures (Section **8**), it will be important to use an adaptive approach to implementation whereby the impact of the measures is monitored and they are adjusted as necessary based on emerging evidence.

By adopting this flexible approach to implementation, and integrating robust measurement and evaluation of the performance of these interventions to control air quality, measures can be adjusted in a way that builds on an improving evidence base. In this way, the final Plan will be able to respond to any uncertainty in a constructive manner and so incrementally build confidence in which methods are most effective and drive continuous improvement.

Ongoing implementation of the measures in the UK Air Quality Plan for tackling nitrogen dioxide published in 2015 is a useful learning opportunity providing lessons that can feed into the delivery of the final Plan. For example, the guidance given to local authorities implementing CAZs will be refined based on feedback and their

[128] Ibid.

experiences of conducting feasibility studies can provide useful lessons and information for any further feasibility studies required in the final Plan[129].

To ensure the right evidence is available to use an adaptive management approach to the implementation of these policies, consideration is being given to:

- The design of proportionate evaluation processes that will measure the impacts of the measures in the final Plan and compare them to ‘control areas’ where there have been no interventions.
- Setting up appropriate monitoring and data collection processes
- Conducting feasibility studies in cities that are implementing CAZs to improve evidence on a local level and increase confidence that the design of the zone is correct to deliver the desired impact.
- Ensuring robust appraisals of any local measure or retrofit funding to allow for evaluation of associated air quality, health and economic consequences
- Addtional evaluation of data collected, widening the evidence base for measures that work effectively with regards to improving air quality.
- Adaptation of national and local measures to optimise the range of policy interventions in use.

The detail of this process will depend on the makeup of the final Plan but it is anticipated that a high level of evidence and resource will be required because air quality is high profile and the policies are expected to have wide-ranging environmental, economic, and social impacts.

Data collection by local authorities with CAZs, along with appropriate data about other national policies, will be integral to assessing the success of different interventions to control air quality. Consideration will be given as to whether sufficient value will be obtained from commissioning an evaluation contractor to collect primary data and conduct a more in-depth review.

Therefore, for each package of measures it will be necessary to consider the evaluation methods, data collection requirements, and stakeholder feedback mechanisms that will be necessary to conduct the review. Some initial principles for monitoring and evaluation of the measures are:

---

[129] Plans for reviewing the implementation of the UK Air Quality Plan for tackling nitrogen dioxide published in 2015 will be in the Committed Clean Air Zone Impact Assessment when published.

- Establishing a baseline for the analysis (ideally establishing one full year of data collection before the measures are introduced)
- Taking a centralised approach to ensure results are consistent and comparable
- Seeking efficiencies where possible – such as using LA monitoring sites where possible
- Monitoring in such a way as to develop a greater indication of source categories and apportionment
- Focus on areas affected by the measures implemented.

9.3 Improving air quality evidence in the longer term

9.3.1 Air quality monitoring and modelling improvements

Continued commitment to investing in national monitoring and modelling capability will ensure air quality assessments remain fit for purpose and are able to reflect and incorporate new evidence as it becomes available.

The UK utilises an integrated monitoring and modelling framework for air quality assessment, which is described in Section **2.1**. The PCM model is increasingly being used for policy development purposes, however the considerable analysis time is a key limitation to this application. Most of the time taken to run the model is related to defining and updating the large range of inputs needed, developing modelling assumptions for policies, and quality assuring inputs and outputs. Therefore, there are limits to how much the assessment speed can be accelerated without a systematic review of the entire process.

A faster running assessment process would facilitate the ability to better represent uncertainty through more sensitivity analysis and scenario testing. In the short-term, Defra will be exploring options for reducing the average run time for the PCM model.

Although monitoring networks are well established, external factors can impact specific sites (such as developments close to the monitoring site, for example) and therefore they are kept under review to ensure they continue to meet needs. A full monitoring regime assessment review is undertaken every five years and this considers the overall structure of the networks to deliver both statutory needs as well as wider needs such as providing inputs for calibration and validation of the national modelling.

Wider evidence needs are also considered under the reviews ensuring networks deliver best value for money and remain fit for purpose. The most recent monitoring review[130] resulted in the significant expansion of the near real time monitoring network – the Automatic Urban and Rural Networks or AURN – with the implementation of additional NO_2 and PM monitoring sites at key locations in the UK.

Instrumentation used on the networks is limited to that which has undergone and met the requirements of equivalence testing in comparison to reference methods. Although currently limited, opportunities for incorporation of innovative monitoring technologies into our monitoring networks are being explored. A review[131] was undertaken in 2015 to help identify opportunities for streamlining such opportunities whilst continued investment in our current networks continues to future proof them, ensuring they remain robust and fit for purpose.

Innovation is also sought with regards model development to ensure approaches do not remain static but evolve to meet new needs, with opportunities to deliver more streamlined assessments with likely developments in speed, resolution, and accuracy.

Further development of more deterministic chemical transport models[132], either as part of PCM or as alternative models, may enable more opportunities to quantify and present uncertainty in modelling results that are currently limited in PCM.

A key area under consideration for improvement is the PCM model's ability to fully take account of local level information. Some of the assumptions in the PCM model are national assumptions (typically with more detailed area-specific assumptions used for London). This limits the extent to which the model can take account of local variation in vehicle fleet composition, or assess the impacts of local measures. It therefore results in differences between outputs from national level modelling and detailed dispersion modelling undertaken at local level, for example by Local

---

[130] Department for Environment, Food and Rural Affairs, 'Air Quality Assessment Regime Review for the Ambient Air Quality Directive 2008/50/EC' (2013) <https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1312171445_UK_Air_Quality_Assessment_Regime_Review_for_AQD.pdf>.

[131] Lingard et al., 'Investigating the Feasibility of Innovative Technologies to Improve Air Quality Monitoring over the Medium to Long Term' (2015) <https://uk-air.defra.gov.uk/assets/documents/reports/cat20/1607061156_DEFRA_innovative_tech_Final.pdf>.

[132] In this context a deterministic chemical transport model refers to a physically based model; it tries to represent physical properties and processes observed in the real world based on monitored data.

Authorities. Opportunities are also being explored to develop more streamlined approaches for models to work across the national to local scale.

Continued commitment to testing and benchmarking model performance will ensure models learn from, and are evaluated against, alternative models that include more research-focussed innovations.

The National Atmospheric Emissions Inventory (NAEI) underpins modelling by providing key emissions inputs. The annual NAEI improvement program will continue to prioritise how evidence gaps can be addressed to ensure better information from key sources of air pollution in the UK. Ensuring the needs of models inform this development program will ensure targeted improvements and an integrated prioritisation program such that models are developed to utilise more granular inputs as they become available.

One of the inputs to the NAEI is traffic forecasts from DfT's National Transport Model. Work to update the model, which will improve traffic forecasts, is underway.

Further improvements as regards modelling parameterisation are ongoing that will continue to improve model performance whilst informing prioritisation of future model development.

9.3.2 Provision of more accurate distributional analysis

Evidence on the way different groups across the population are likely to be impacted by measures put forward to improve air quality is still developing.

Health impacts

Work across Government and more widely will continue to develop a fuller picture of emerging research, which may help refine the evidence base. In particular, it will look to improve evidence of the health impacts on deprived communities; specifically, how underlying health conditions in particular socio-economic groups may increase vulnerability.

Work will also look to improve understanding of the health impact of high pollution episodes in terms of hospital admissions and GP visits, to enable a real time understanding of the effects on people and impacts on the NHS.

Economic impacts

Work will continue across Government to refine understanding of economic impacts. In particular (and subject to data availability) it will seek to extend analysis undertaken to cover light goods vehicles and use of cars for commercial purposes and to better understand the impact of bus and coach charges. Other areas of interest include gaining better understanding of the ownership patterns of older petrol cars, how older diesel and petrol cars are used, and how regional variations may affect the impact of the proposed measures

As part of Local Authorities' feasibility studies, work may also be undertaken to provide a more accurate assessment of the proportion and characteristics of the population affected by specific CAZs and the alternatives available to them. This would refine understanding of the impacts of the proposed measures across the population and enhance modelling assumptions.

9.4 Broader air quality strategy

Plans for developing the UK's long-term air quality strategy are described in the draft National Overview Document. They reflect the fact that whilst long term emissions are falling for most substances there is more to do and the UK has signed up to challenging new international limits for 2020 and 2030.

The UK has signed up to tough legally binding ceilings in 2020 and 2030 for emissions of five major pollutants (NO_x, $PM_{2.5}$, SO_2, NH_3, and NM-VOCs). These ceilings will require significant reductions in emissions (Table **9.4**).

Table 9.4: UK emission reduction commitments, the percentage reduction in emissions from 2005 levels required over time

	NO_x	$PM_{2.5}$	SO_2	NH_3	NM-VOCs
2020	-55%	-30%	-59%	-8%	-32%
2030	-73%	-46%	-88%	-16%	-39%

The focus of this Technical Report is NO_2 concentrations, which is where our immediate challenges lie and where immediate action is needed. Over the medium and longer term, emissions of other pollutants will also require action to meet the emission reductions set out above. This will require measures that cut across all sectors of the economy, unlike the current measures, which have a road transport focus.

There are potential trade-offs between taking action now to address our immediate challenges and the long-term path to meeting our 2030 obligations. Some measures that are very costly (such as ULEVs) may be important to encourage the transition to a cleaner economy that will be necessary looking to 2030 and beyond. Alternatively taking action to reduce NO_x emissions now could lock us in to a path that could increase the costs of meeting our 2030 obligations. For instance, if more new diesel cars are bought now instead of in the early 2020s, the cars being purchased will be dirtier than they might otherwise have been. This could however be mitigated through a shift to ULEVs.

The draft Plan explains the broader air pollution problem including developing the strategy for dealing with it. Evidence will play an important role, as it can inform where emission reductions come from and at what cost, helping to ensure reductions are achieved cost-effectively and without disproportionate impacts on individual sectors. This evidence base is being developed and can be informed by evidence gathered for this NO_2 plan. A key tool is the Multi-Pollutant Measures Database (MPMD), developed for Defra by Amec Foster Wheeler[133]. This database details measures that have been identified that could reduce emissions of one or more of the pollutants in Table **9.4**. Where relevant, information from the MPMD has been used when developing the evidence in this Technical Report, building in consistency of approach with the longer-term strategy.

[133] See, for instance: Green et al., 'Draft Final Report - Multi Pollutant Measures Database (MPMD): Extension to 2030' (2012) <https://uk-air.defra.gov.uk/library/reports?report_id=725>.

10. Conclusion

10.1 Summary of results

The quality of our air is fundamental to public wellbeing and, while there have been major improvements in recent years, controlling concentrations of NO_2 continues to be challenging. The UK currently exceeds the recommended limits for NO_2 in 37 of the 43 reporting zones. Road vehicles are responsible for around 80% of NO_2 pollution at the roadside so actions to tackle them are central to dealing with the problem.

Throughout the analysis in this report, the best available data sources, evidence, and expert judgement have been used to model air quality and its associated health and economic consequences. This has provided a solid foundation for the results produced. However, there are inevitable uncertainties with the modelling that create associated risks. These uncertainties come from the use of a number of assumptions and the existence of a certain degree of 'noise' within the data used to inform the analysis of intervention options. The inherent uncertainties surrounding the analysis do not present justification for inaction, but rather they are a key reason to continue to develop knowledge, evidence, and monitoring of air quality to improve the quality of the evidence base. In so doing, uncertainties can be reduced and confidence can be built incrementally in the way intervention options can be effectively implemented to improve air quality.

This document sets out the process by which 60 possible policies to reduce NO_2 concentrations were narrowed down to eight shortlisted options categorised into three broad groups:

- **Clean Air Zones (CAZs)** – which reflects the adaption of the existing Air Quality Plan to address the latest evidence.

- **National actions to support Clean Air Zones** – comprising national action undertaken to aid the transition to effective CAZs in the form of retrofit, scrappage and support for Ultra Low Emission Vehicles.

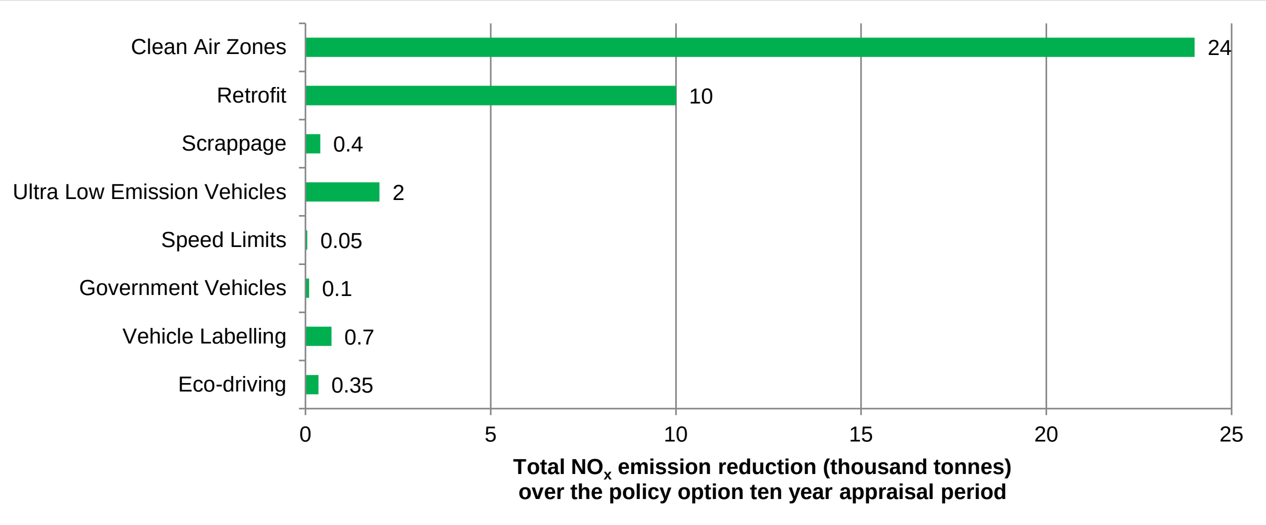
- **Supplementary national options** – covering options that would be complimentary to the improvements delivered through CAZs including speed limits, Government Buying Standards for transport, vehicle labelling and influencing driving styles.

These options were considered to achieve the critical factors of delivering air quality improvements in the shortest time possible, whilst providing a feasible route of delivery. The options were then assessed over a ten-year appraisal period, consistent with Government appraisal guidance, on the basis of their impact on: health; the public (including wider societal impacts such as traffic flow improvements); central Government cost (in setting up and running options); greenhouse gas emissions; and the potential impact on economic growth.

A summary of this assessment is presented in Table **10.2**. To identify options that would work in the quickest time possible, air quality impacts are provided for the first year where reductions in NO_2 concentrations are expected. However, because implementation timings differ between policies the total reduction in NO_x emissions over the option's ten-year appraisal period is also provided (Figure **10.1** and Table **10.2**). Although NO_2 concentrations are the primary concern, comparing these NO_x emission figures gives a fuller picture of the cumulative impacts expected under the implementation of each option.

The air quality impacts of all except two of the options assume implementation on a UK-wide basis. For CAZs, impacts are presented for the specific areas where CAZs are modelled to be introduced. For speed limits, impacts are presented for the 18km of motorway projected to be in exceedance of NO_2 limits in 2021. This difference in approach means the scale of impact on concentrations and emissions varies across options, but highlights the value of targeting measures by location.

Figure 10.1: Total NO_x emission reduction (thousand tonnes) over each policy options ten year appraisal period



Note: The total ten-year NO_x reduction is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period relative to the baseline projection for the option over the same ten-year appraisal period. How emissions relate to concentrations is explained in Box **3.3**.

The distributional effects of options across the population have also been analysed. This analysis has shown that a disproportional benefit is likely for those on lower incomes as a result of attempting to reduce high concentrations of NO_2. This is due to the fact that lower income groups face higher exposure to NO_2 as well as underlying risk factors. However, it is equally likely that specific groups within these populations, such as those who are heavily reliant on the oldest cars or who make frequent use of buses for which they are paying directly, may also be disproportionately affected by the cost of the proposed option. Therefore, it will be imperative that any package of policy options that aims to deliver a reduction in NO2 concentrations is implemented in a way that supports public health and the local economy to ensure that the associated benefits are sustainable for the long term.

Table 10.1: Summary of impacts from the analysis of the feasible scenario of each policy

		Air quality impact[I]		Timing to impact[II]	Category of impact (£m)[III]				Type of modelling	Impact on growth
		First year of impact	Total 10 year NO_x reduction		Health	Government	Public	Greenhouse gases		
CAZ	**Clean Air Zone[IV]** Expansion from 5 plus London to a further 21	8.6µg/m³ in 2020	24kt	1-3yrs	£3,600m	-£600m	-£1,900m	£19m	Established	Positive through higher vehicle purchases. Negative through higher business costs
Supporting Measures	**Retrofit** Retrofitting of buses, HGVs and black taxis between now and 2020	0.09µg/m³ in 2019	10kt	1-3yrs	£440m	-£170m	Negligible	Negligible	Established	Benefits through expansion of retrofit industry
	Scrappage National scheme promoting a transfer from older conventional cars and vans to electric	0.008µg/m³ in 2020	0.4kt	1-3yrs	£10m	-£110m	£70m	£10m	Indicative	Short term positive through higher BEV demand, long term more uncertain
	Ultra Low Emission Vehicles Providing additional support to purchasers of electric vehicles	0.008µg/m³ in 2017	2kt	<1yr	£50m	-£290m	£170m	£50m	Indicative	Small positive through higher demand for ULEVs

		Air quality impact[I]		Timing to impact[II]	Category of impact (£m)[III]				Type of modelling	Impact on growth
		First year of impact	Total 10 year NO_x reduction		Health	Government	Public	Greenhouse gases		
National Measures	**Speed Limits[V]** Reduce motorway speed limits to 60mph where there is poor air quality	Up to 2.5µg/m^3 in 2021 [IV]	Up to 0.05kt	>3yrs	Up to £1m	-£25m	Up to -£8m	Up to £0.5m	Indicative	Positive through increased infrastructure investment. Negative via longer journeys
National Measures	**Government Buying Standards** 30% of all new central government diesel cars are petrol from 2018	0.0005µg/m^3 in 2018	0.083kt	<1yr	£2.0m	-£1.7m	Negligible	-£0.23m	Established	Negligible as total purchases remain the same, only proportion of fuel types changed
National Measures	**Vehicle Labelling** AQ emissions information on new car labels	0.004 µg/m^3 in 2018	0.73kt	<1yr	£18m	Negligible	Not quantified	-£5.3m	Indicative	Negligible as total purchases remain the same, only proportion of fuel types changed
National Measures	**Influencing Driving Style** Training and telematics for 100,000 car and van drivers by 2020	0.012 µg/m^3 in 2019	0.34kt	1-3yrs	£8.80m	-£14m	Not quantified	£17m	Indicative	Small positive through increased demand for better driving courses and telematics

I Air quality impacts are expressed in two ways. The first year of impact is the reduction in average NO_2 concentrations, in the first year where air quality impacts are expected to arise as a result of the implementation of the option, relative to the baseline projection for the option in the particular year specified. The total 10 year NO_x reduction is the total reduction in NO_x emissions resulting from this policy option over its ten-year appraisal period relative to the baseline projection for the option over the same ten-year appraisal period.

II Indicative timings are provided for all options as either <1, 1-3 or >3 years.

III All monetised values are ten year Net Present Values

IV Clean Air Zones are expected to be implemented in non-compliant areas in 2020. This represents the average reduction in the maximum concentration for these areas in 2020.

V Speed limit impacts are shown just for the <1% of motorway projected to be in exceedance in 2021. These impacts cannot be extrapolated to other roads. All impacts related to air quality are expressed as 'up to *x*' because there is uncertainty over the modelling approach in relation to vehicle speed. Highways England's approach (Box 6.3) would not give a reduction in NO_2 concentrations or congestion following speed limit reduction. The air quality impact of this measure is calculated on the assumption that traffic on failing motorway links is travelling at the same speed as the national average (for the type of motorway). It is possible that failing motorway links tend to be busier and more heavily congested, and that average speeds on them are lower. In this case, a change in the speed limit may have little impact on air quality - because cars are already travelling at speeds below the limit. Work is ongoing to improve our understanding of speeds on these links.

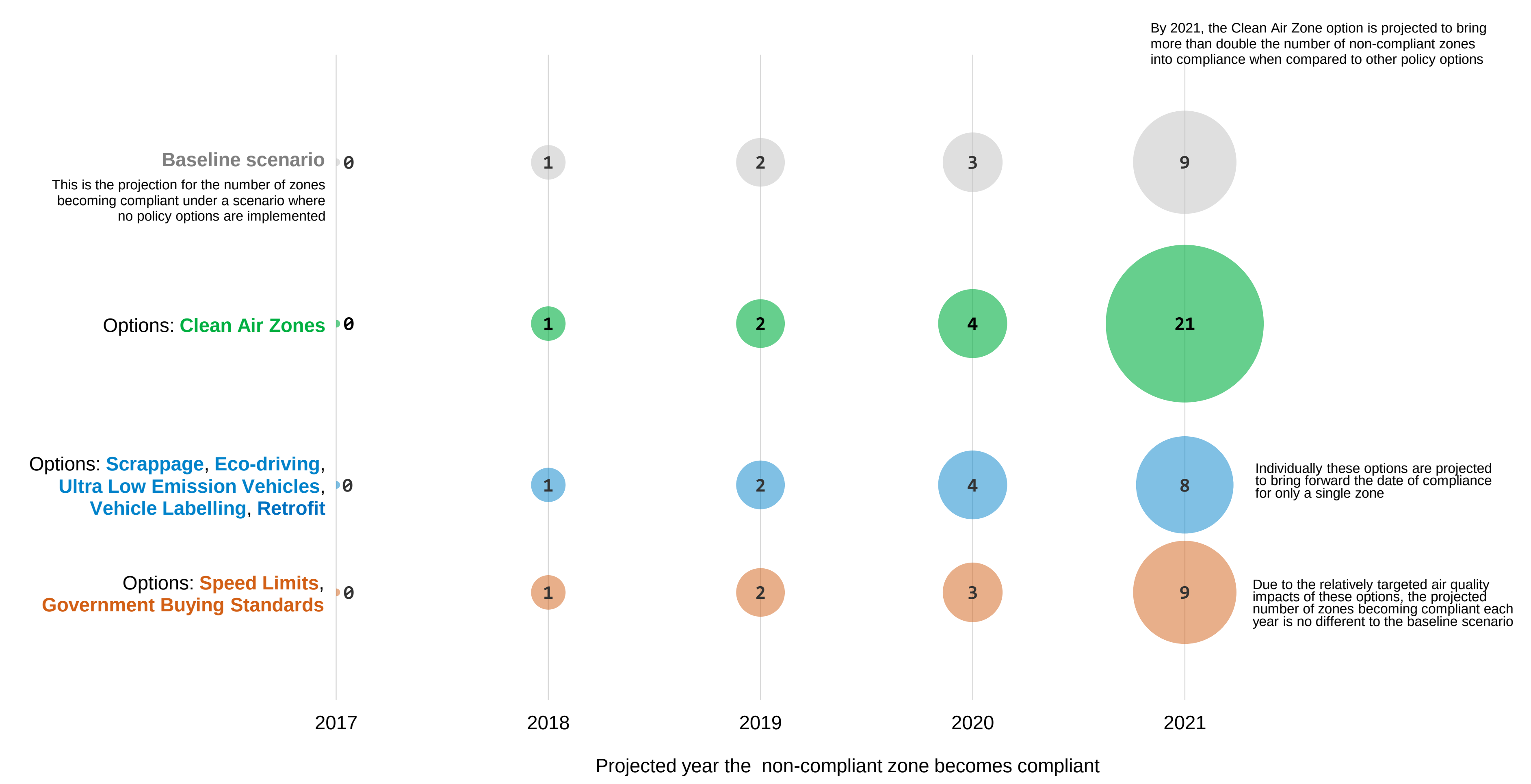
10.2 Discussion

Whilst this assessment, which presents an overall national picture, allows a transparent and consistent approach to the valuation of different options, it does not provide a disaggregation to local areas. In order to fully gauge the extent of the challenge and understand which policy options are required where, the local context also requires consideration.

As outlined in Section **2.2**, UK compliance assessment of annual NO_2 concentrations is reported by 43 reporting zones. This framework has been used to establish, at a more local level, the scale of action that would be required to bring forward compliance date by zone.

Figure **10.3** illustrates the impact of each shortlisted option on achieving compliance with NO_2 concentration limits over time. All options, except charging CAZs, are shown to be similar to the baseline projection, bringing forward compliance in only a small number of zones where the exceedance is small. It is clear that charging CAZs have the greatest impact by bringing the majority of zones into compliance by 2021.

Figure 10.4: The number of UK reporting zones projected to become compliant with NO_2 concentration limit levels over time for the baseline scenario and under the implementation of the analysed policy options



Note: This bubble plot represents the number of UK non-compliant reporting zones (37 of 43 **in 2015**) projected to become compliant with the NO_2 concentration limit value of $40 \mu g/m^3$ over the period to 2021. The size of each bubble is proportional to the number of zones projected to become compliant in the year in question, thus the larger the bubble, the greater the number of zones becoming compliant. When assessing achievement of compliance for each option, the bubbles over the entire projection horizon should be compared to the baseline scenario, with larger bubbles appearing earlier in the projection horizon indicating that the option is bringing forward compliance of zones at a faster rate.

Table **10.4** presents a more detailed summary of the projected NO_2 concentration reductions that are required in the UK to achieve compliance for all reporting zones (see Annex **G** for more granular detail). To represent the scale of the challenge, the analysis considers the two zones with the highest and lowest average annual concentrations above the limit of 40µg/m^3, in 2017 to 2021.

Table 10.4: Highest and lowest reductions of NO_2 concentrations (µg/m^3) needed to bring UK zones from projected non-compliance to compliance with annual NO_2 limits in each year, 2017-2021

	2017	**2018**	**2019**	**2020**	**2021**
Projected number of non-compliant UK reporting zones (out of 43)	37	36	34	31	22
Concentration reduction needed to bring the zone with the highest average annual concentration into compliance	62	56	50	44	37
Concentration reduction needed to bring the zone with the lowest average annual concentration above the concentration limit into compliance	1.7	2.3	1.3	0.01	0.7

Comparing the results in Table **10.4** with the analysis of projected air quality impacts in Table **10.2** it is evident that, of the options modelled only charging CAZs are expected to deliver concentration reductions of sufficient size to bring forward the compliance of zones. It is also possible that targeted local actions within a non-charging CAZ would be sufficient to bring some of the other zones into compliance. Local feasibility studies will determine whether charging CAZs are necessary or whether non-charging CAZs can deliver the necessary improvements. CAZs of either form will have to form a key element of any package of policies designed to bring zones into compliance in the shortest possible time. Further, the flexibility in the nature of CAZs will mean that Local Authorities will have the ability to develop and introduce a CAZ, coupled with any number of supporting options that can be tailored to solving the specific challenges in their local area.

There is one exception to this: a single zone with the lowest non-compliant NO_2 concentration in 2020, which is projected to be only 0.01µg/m^3 above the limit value. This zone contains one non-compliant motorway road link where it might be possible to achieve compliance through implementing a range of other options to tackle the problem such as support for Ultra Low Emission Vehicles, retrofit, vehicle labelling, or influencing driving styles. Given a scenario where the NO_2 problem on this road link was solved, the next lowest non-compliant zone in 2020 would require a concentration reduction of 0.5µg/m^3. The only modelled option that could bring this zone into compliance would be the introduction of a charging CAZ. The results of the analysis in this Technical Report are being used to inform policy development for the Plan.

Annexes

Annex A – Air quality model quality assurance

A.1 Pollution Climate Mapping model

To provide assurance on the outputs from the Pollution Climate Mapping (PCM) model, a number of quality assurance (QA) and quality control steps have been taken. Approaches include comparisons of model estimates to monitoring data, testing the performance of the PCM model against other models, checks to ensure that both model inputs and calculations are correct, and internal as well as independent expert peer review of the PCM model.

The PCM model is operated under the Modelling Ambient Air Quality project, which was subject to BS EN ISO 9001:2008. It has been audited by Lloyds and the Ricardo Energy & Environment internal QA process. The emphasis of these audits is on document control, data tracking, and spreadsheet checking. Model QA implements the recommendations made in the "Review of the air quality assurance framework of the National Atmospheric Emissions Inventory, Pollution Climate Mapping, and Impact Pathway Models" report prepared by Hartley McMaster Ltd[134]. The general QA process also takes into account the recommendations from HM Treasury's 'The Aqua Book: guidance on producing quality analysis for government'[135].

Hartley McMaster Ltd. found that the QA policies and practices adopted by the model builders were evolving during the review. They also found that by the end of the review these practices compared relatively well against three independent sets of best practice guidelines: the Intergovernmental Panel on Climate Change 2006 QA guidelines[136], the Department of Energy and Climate Change QA guidelines[137], and

---

[134] Department for Environment, Food and Rural Affairs, '*Review of the air quality assurance framework of the National Atmospheric Emissions Inventory, Pollution Climate Mapping and Impact Pathway Models*', (2015) <http://uk-air.defra.gov.uk/assets/documents/reports/cat09/1511251152_AQ0962_Review_of_Quality_Assurance_framework_for_models-Final_report.pdf>.

[135] HM Treasury, 'The Aqua Book: guidance on producing quality analysis for government', (2015) <www.gov.uk/government/publications/the-aqua-book-guidance-on-producing-quality-analysis-for-government>.

[136] Intergovernmental Panel on Climate Change, '*2006 IPCC Guidelines for National Greenhouse Gas Inventories*', Volume 1, Chapter 6 (2006) <www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_6_Ch6_QA_QC.pdf>.

the guidance within the final report of the Macpherson Review of the quality assurance of Government analytical models[138]. Defra's air quality modelling review[139] and in-depth inter-comparison exercises[140] were conducted between 2011 and 2013. The performance of the PCM model was found to be comparable to that of other Defra models and therefore suitable for continued use and development.

Legislation sets data quality objectives (DQOs) where air quality modelling is used for supplementary assessment alongside monitoring. These DQOs set a maximum deviation for modelled concentration levels as compared to measured concentrations. The maximum deviation varies according to pollutant but for NO_2 it is +/-30%. Data from the national air quality monitoring network are used to calibrate the PCM model. Data from independent monitoring sites are also used for verification. Figure **2.3** summarises verification of the modelled versus measured NO_2 background relationship (2013) and calibrated modelled versus independent measured NO_2 concentrations (at verification sites).

A.2 The Streamlined Pollution Climate Mapping model

The Streamlined PCM model (SL-PCM) has been fully quality assured through:

- In-house quality assurance by Defra following the principles of the Aqua book
- Testing by Ricardo Energy and Environment
- External peer review by an expert in air quality modelling
- Defra in-house review

The SL-PCM tool uses information from the PCM model, which has been independently quality assured (Section **A.1**)

---

137 Department of Energy and Climate Change, '*Quality Assurance: Guidance for Models*' (2015) <www.gov.uk/government/uploads/system/uploads/attachment_data/file/465785/DECC_QA_Guidance_for_Models_v2_2.pdf>.

138 HM Treasury, '*Review of quality assurance of Government analytical models: final report*' (2013) <www.gov.uk/government/uploads/system/uploads/attachment_data/file/206946/review_of_qa_of_govt_analytical_models_final_report_040313.pdf>.

139 Department for Environment, Food and Rural Affairs, '*Review of Air Quality Modelling in Defra*' (2011) <http://uk-air.defra.gov.uk/reports/cat20/1106290858_DefraModellingReviewFinalReport.pdf>.

140 Department for Environment, Food and Rural Affairs, '*Defra's Model Intercomparison Exercise*' (2013) <https://uk-air.defra.gov.uk/research/air-quality-modelling?view=intercomparison>.

In order to assess the robustness of the tool, results from the SL-PCM mode have been compared with equivalent results from full PCM concentration calculations for four possible scenarios resulting from the implementation of one option (charging Clean Air Zones) in 2020. For a detailed description of the option, refer to Section **4**. The SL-PCM model results compare well with the full PCM model results for each scenario. In terms of the distribution of these differences, there is some variation across roads but the spread is small and provides confidence in the SL-PCM tool (Table **A.2**)

Table A.2: Difference between PCM and SL-PCM across percentiles (μg/m^3)

CAZ Type	A	B	C	D
Mean	-0.15	-0.20	-0.25	-0.16
P_5	-0.67	-0.71	-0.73	-0.64
P_{25}	-0.18	-0.24	-0.29	-0.18
P_{50}	-0.06	-0.11	-0.16	-0.09
P_{75}	0.00	-0.04	-0.08	-0.03
P_{95}	0.12	0.07	-0.02	0.14

The SL-PCM model slightly overestimates the impact of the charging Clean Air Zone measure compared to the full PCM model. However, a small overestimate is expected as the measures will tend to have slightly less impact on gridded major road, minor road, and cold-start emissions than on the local major road emissions, particularly for measures involving buses and HGVs, which typically contribute less to minor road than major road emissions and have no cold-start emissions.

Defra commissioned an expert in air quality modelling to conduct an external peer review of the SL-PCM model, to assess the methodology, robustness, and suitability of the model for the purposes of evaluating different policy options. The peer review found the overall concept of the SL-PCM model to be sound, and the methodology and quality assurance proportionate.

Annex B – Fleet Adjustment Model

B.1 Summary

The Fleet Adjustment Model quantifies the societal costs and benefits associated with changes in UK vehicle fleet. Fleet changes may be triggered by a number of different policies. In this case, the model has been used to assess the impact of an expanded network of charging Clean Air Zones to inform preparation of the draft Plan. The principles, data, and approaches of the model were used to assess the impacts of other policies where appropriate.

The Fleet Adjustment modelling approach follows a number of sequential stages as outlined in Figure **B.1** below. The other sections of this annex elaborate on the assumptions and approach of the modelling.

The baseline scenario establishes the vehicle fleet in different years prior to the implementation of any adjustments. The baseline is established via two key inputs:

- The fleet composition (number of vehicles by age and vehicle type (buses, coaches, taxis, HGVs, LGVs and cars)) in each year modelled;
- The number of vehicle kilometres driven by each type of vehicle and their location in each year.

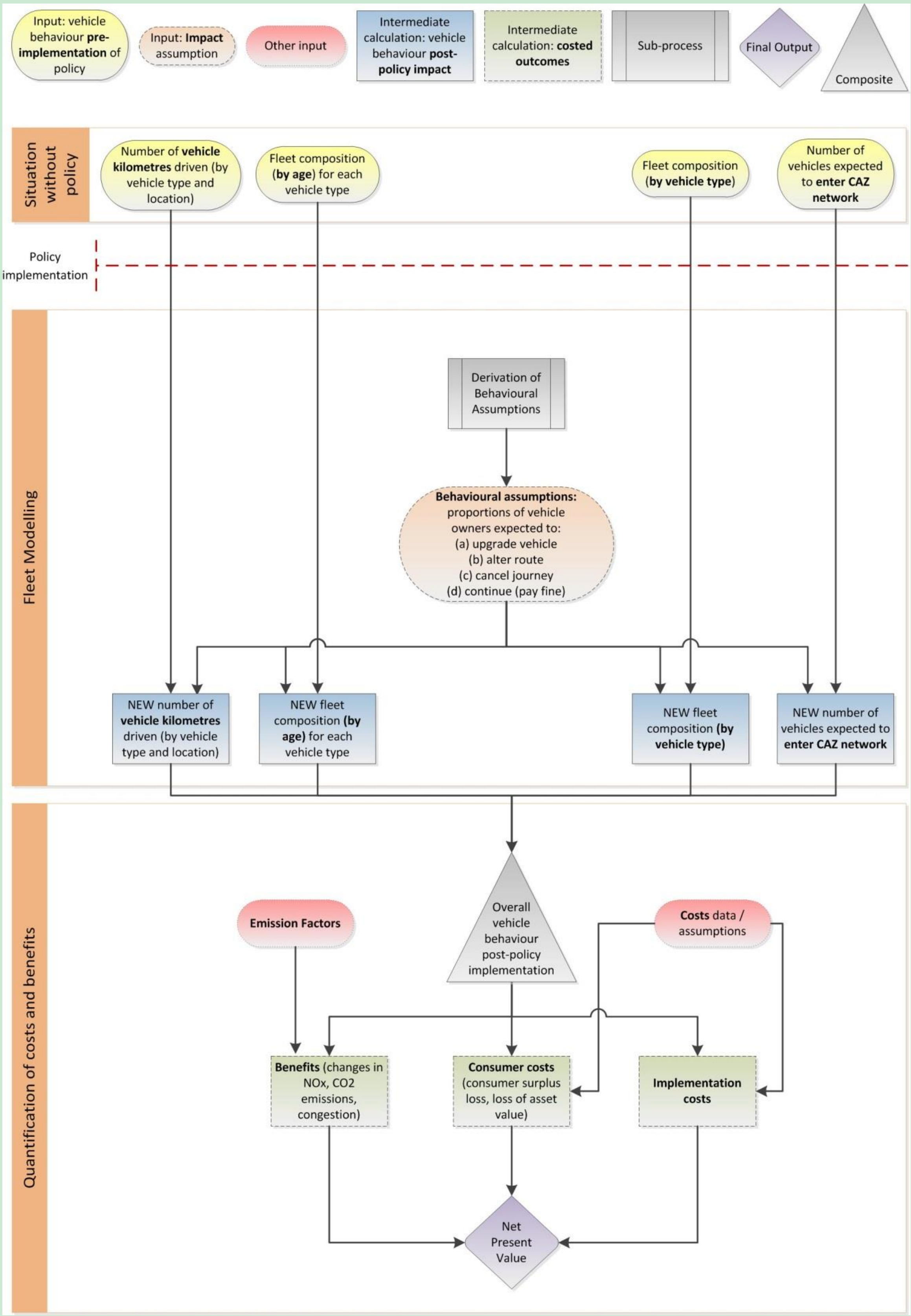
More information on the definition of the baseline is set out in Section **B.2**.

The second stage of the model introduces measures that have an impact on the vehicle fleet. It models individual owners' specific responses to the measures introduced. The responses will depend on the costs of the different options available and the nature of the measure. In this example, some vehicle owners may choose to upgrade vehicles or avoid the restricted zone, triggering changes in the fleet composition and to the proportion of time non-compliant vehicles spend driving in different locations. The detailed assumptions are set out in Section **B.3**.

The third stage then quantifies and values the main societal impacts of the changes in fleet composition relative to the baseline. Some examples of these impacts are the loss of asset value from vehicles scrapped, the cost to society of upgrading to a vehicle exempt from the charge, and the health benefits attributable to the resulting reductions in NO_X, PM and CO_2 pollution. The methodology and assumptions are set out in Section **B.4**.

Finally, all the impacts are discounted and the total costs are subtracted from the total benefits to provide a net present value (NPV), in 2015 prices. Full details of this step are contained in Section **B.5**.

Figure B.1 Flow diagram of the assessment of costs and benefits in the FAM



B.2 Model design

The primary application of the Fleet Adjustment Model is to assess the societal impact of changes in the UK's fleet of road-vehicles. This model has predominantly been used to assess four types of charging Clean Air Zone as set out below. These zones levy a charge on the most polluting vehicles entering the areas to encourage behavioural changes that will improve air quality. The four types of zone are:

- Type A – Buses, coaches and taxis only
- Type B – Buses, coaches, taxis, and heavy goods vehicles (HGVs)
- Type C – Buses, coaches, taxis, HGVs and light goods vehicles (LGVs)
- Type D – Buses, coaches, taxis, HGVs, LGVs, cars, motorcycles and mopeds

The Fleet Adjustment Model calculates the monetised social impact of measures over a ten-year period. For the purpose of the proposed Clean Air Zone measure, this period is 2020-2029 as 2020 represents the earliest date by which zones may be implemented. In reality zones may be implemented earlier which may mean the analysis slightly underestimates both the benefits and costs of the policy. The monetised social impact is intended to inform policy design to ensure value for money.

Model design principles

The assessment has been made in line with best practice as set out in the HM Treasury Green Book[141]. This is supported by the following Green Book supplementary guidance:

- Valuing impacts on air quality: Defra Supplementary Green Book Guidance (2013)142 and interim guidance on valuing oxides of nitrogen[143]

---

[141] HM Treasury, The Green Book: appraisal and evaluation in central government, <https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent>.

[142] HM Treasury, Valuing impacts on air quality: Supplementary Green Book guidance, <www.gov.uk/government/uploads/system/uploads/attachment_data/file/197893/pu1500-air-quality-greenbook-supp2013.pdf>.

[143] Department for Environment, Food and Rural Affairs, Valuing impacts on air quality: Updates in valuing changes in emissions of Oxides of Nitrogen (NO_X) and concentrations of Nitrogen Dioxide

- Web-based Transport Analysis Guidance: WebTAG (2014)[144]

- DECC Valuation of energy use and greenhouse gas emissions for appraisal (2014)[145]

The Fleet Adjustment Model works alongside the Pollution Climate Mapping (PCM) model. The models use consistent input sources where applicable, for example the National Atmospheric Emissions Inventory (NAEI) projections data on fleet compositions by Euro Standard and kilometres travelled by each vehicle type.

B.3 Establishing the baseline

Fleet size projections, fleet composition data, and vehicle usage data provide the baseline scenario against which any modelled changes are compared.

Fleet size projections were calculated using historic data to 2015 produced by DfT[146], projected forwards based on a five-year rolling average of year-on-year change. Fleet composition projections by vehicle type and emission standard for years 2020-2029 are sourced from the national transport model produced by DfT. This tracks both current levels and forecast vehicle composition by stock and distance travelled measured in vehicle kilometres (vkm). The following vehicle types are included in the model (impacts on taxis are modelled as impacts on diesel cars):

- Bus

- Coach

- Articulated HGV

(NO_2), <www.gov.uk/government/uploads/system/uploads/attachment_data/file/460401/air-quality-econanalysis-nitrogen-interim-guidance.pdf>.

[144] Department for Transport, Transport analysis guidance: WebTAG, <www.gov.uk/transport-analysis-guidance-webtag>.

[145] Department for Business, Energy and Industrial Strategy, Valuation of energy use and greenhouse gas, <www.gov.uk/government/uploads/system/uploads/attachment_data/file/360316/20141001_2014_DECC_HMT_Supplementary_Appraisal_Guidance.pdf>.

[146] Department for Transport (2016), *Licensed vehicles by body type: Great Britain and United Kingdom*, Table VEH0102 [Data file]. Available at <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/515959/veh0103.xlsx>.

- Rigid HGV
- Diesel LGV
- Petrol LGV
- Diesel car
- Petrol car

Inputs

The inputs described within Boxes **B.2** and **B.4** as well as Table **B.3** are used when quantifying the impacts of policy implementation. Box **B.2** describes the inputs defined as vehicle characteristics within the model.

Box B.2 Vehicle characteristics used within the Fleet Adjustment Model
Average vehicle age Euro standards relate to vehicle age, for example a diesel van registered from 2006-2009 is a Euro 4 standard. The years in which each standard was sold are averaged to give the vehicle age.
Vehicle depreciation rates Depreciation rates are attributed to each vehicle type over a ten-year period. Depreciation rates for cars were estimated based upon the depreciation rates of the most popular 10 cars sold in the UK in 2014. Van depreciation rates were estimated from published data on resale values. After ten years the rate of depreciation is assumed to remain constant for all vehicle types. Table **B.3** shows the assumed depreciation rates, given as the proportion of value lost per year.
Vehicle annual distance travelled Vehicle annual distance data are sourced from the National Atmospheric Emissions Inventory (NAEI)[147]. The NAEI provides average annual distance travelled by vehicle type. This distance changes year on year throughout the period of the policy.
Average length of vehicle ownership Length of vehicle ownership data, broken down by vehicle type, sourced from the RAC[148].

147 National Atmospheric Emissions Inventory <http://naei.defra.gov.uk/>.

148 Royal Automobile Club Foundation for Motoring, '*Car ownership in Great Britain*' (2008) <www.racfoundation.org/assets/rac_foundation/content/downloadables/car%20ownership%20in%20great%20britain%20-%20leibling%20-%20171008%20-%20report.pdf>.

Table B.3 Vehicle depreciation rates		
Year	**Cars**	**Other vehicle types**
1	0.37	0.35
2	0.18	0.18
3+	0.16	0.18

Box **B.4** describes the inputs that are defined as local authority characteristics within the model.

Box B.4 Local authority characteristics used within the Fleet Adjustment Model

Zone perimeters and population (local authority characteristics)

For modelling purposes, the perimeters of each Clean Air Zone were defined to include all roads that were projected to exceed the limit values (40µg/m^3) in 2020. Each zone was defined based on natural boundaries such as existing roads or rivers, or based on existing local authority research where possible. The population within these areas has been provided from Ricardo Energy & Environment using ONS data. This data is used to calculate the set-up and running costs of Clean Air Zones.

Zone area, surrounding built up area and trip length distribution

The comparative area covered by the Clean Air Zones and the built-up area that surrounds them is combined with trip-length distribution (from the DfT National Traffic Survey) to estimate the benefits experienced just outside the zones as a result of the policy.

Fraction of vkms spent within the zones

The fraction of vkms travelled within the network varies by vehicle type, and this data is provided by Ricardo Energy & Environment. The average time spent within the proposed restricted zones is presented as a percentage of total km driven. This data is used to calculate the impact on emissions inside and outside zone.

Unique vehicle entries

Vehicle-entries into zones by vehicle type are provided by Trafficmaster, sourced from DfT GPS Journey information. Only a sample of these figures was provided and so they were scaled based on empirical data on unique vehicles from one location. Vehicles, which enter more than one zone, are only counted once to mitigate double counting (a driver will only need to upgrade a vehicle once). The aim of this calculation is to calculate unique vehicle-entries into each zone. Unique vehicle-entries are then calculated over the assessment period. Over the assessment period, the fleet of vehicles that enter the zones is assumed to exhibit change similar to that of the national fleet and the vehicle entries are altered accordingly.

Days in network

The Trafficmaster dataset also enables the average number of days spent in the zones for each vehicle-type to be calculated. This is used to estimate costs that are based on the number of days a vehicle would enter the zone in each year.

Box **B.5** outlines all inputs that are not defined under vehicle characteristics or local authority characteristics but which are used to calculate impacts within the model.

Box B.5 Additional inputs used within the Fleet Adjustment Model

Fuel costs

Petrol and diesel fuel costs are annual average values. Fuel costs up to 2013 are observed, whereas values from 2014 onwards are projections based on the central fossil fuel price scenario published in October 2014 by the Department of Energy and Climate Change (DECC). These are used to estimate the fuel efficiency savings when using the 'financial cost' approach (for more details see Section **B.4**)

Fuel consumption

Fuel consumption is broken down by vehicle type and Euro standard. WebTAG guidance provides data on light vehicle fuel consumption. All other vehicle types are assumed to have no change in fuel consumption across Euro standards; this is in line with DfT fuel consumption analysis. These are used to estimate the fuel efficiency savings when using the financial cost approach method (for more details see Section **B.4**)

Air quality damage costs

NO_X and PM damage costs (£/tonne) are sourced from Green Book and Defra guidance[149]. These vary depending on location to reflect population density. As far as possible, the damage costs have been matched to the location of the emissions. For example inside zones, the inner conurbation damage cost is used (or 'London, inner' cost for London)., whereas for outside-zone emissions, the rural transport average is used. Damage costs are assumed to remain constant in real terms and are therefore not adjusted for inflation. However, the calculation applies a 'health uplift' of 2% per annum to account for higher willingness to pay for healthcare.

Greenhouse gas abatement costs

Vehicle emissions are not included in the European Trading Scheme (ETS). To calculate the impact of a change in CO_2 emissions the calculation uses an average CO_2 non-traded central carbon price for the assessment period (£71.6/tonne in 2015 prices), published by DECC in October 2014.

Fleet emission factors

Emission factors are split by each vehicle type and emission standard for carbon dioxide (CO_2) and particulate matter (PM) as shown in Table **B.6**. The PM factors are derived by the NAEI based on the most recent dataset of vehicle composition. These are estimated from vehicle sales, survival rates, age-related vehicle mileage, and information from Automatic Number Plate Recognition (ANPR) data. Emission rates are taken from COPERT 5 as implemented in the National Atmospheric Emissions Inventory.

[149] www.gov.uk/government/uploads/system/uploads/attachment_data/file/460398/air-quality-econanalysis-damagecost.pdf

The CO_2 emission factors are provided by Transport Research Laboratory (TRL). CO_2 is the only greenhouse gas (GHG) that is produced by vehicles considered within DECC guidance[150] published in December 2015. As a result, no equivalent tonnes of CO_2 need to be accounted for.

Table B.6 Vehicle emission factors

Emission factors	Petrol cars	Diesel cars	Petrol LGVs	Diesel LGVs	RHGVs	AHGVs	Buses	Coaches
PM (mg%/km)								
Euro 3	2.40	70.63	2.33	87.86	193.08	256.00	245.48	245.48
Euro 4	2.40	42.93	2.33	87.86	125.73	239.26	137.29	137.29
Euro 5	1.07	32.92	1.06	58.87	93.45	139.59	127.41	127.41
Euro 6	1.07	25.45	1.06	30.75	24.49	33.68	31.21	31.21
CO_2 (g/km)								
Euro 3	163.19	149.25	220.27	236.34	619.39	978.36	686.29	686.29
Euro 4	150.37	141.52	220.27	236.34	579.35	908.23	647.83	647.83
Euro 5	131.91	123.70	220.27	236.34	587.79	922.00	662.75	662.75
Euro 6	116.34	108.61	220.27	236.34	587.79	922.00	662.75	662.75

Note: the NO_x vehicle emission changes are taken directly from the PCM model but equivalent figures for PM and CO_2 are not included in the PCM model.

B.4 Modelling changes in the fleet

This section sets out how changes in the fleet have been modelled to reflect measures taken. Assumed behavioural responses of vehicle owners are applied to model the resulting change in fleet. Changes in total annual distance travelled by each vehicle type and vehicle kilometres travelled within and outside the zone are then estimated. More details on the behavioural assumptions are given below.

150 www.gov.uk/government/uploads/system/uploads/attachment_data/file/360316/20141001_2014_DECC_HMT_Supplementary_Appraisal_Guidance.pdf

Behavioural response of owners with vehicles subject to charge

The consumers (households/businesses) who own vehicles subject to the charge are assumed to have the following choices within the model (Figure **B.7**):

- **Replace current vehicle with a vehicle exempt from the charge**: this will enable the new vehicle's owner to continue to drive in restricted areas without charge.

- **Cancel journeys**: some owners will choose to cancel trips into the zone where restrictions apply. (This includes consolidation of deliveries etc. into fewer journeys.)

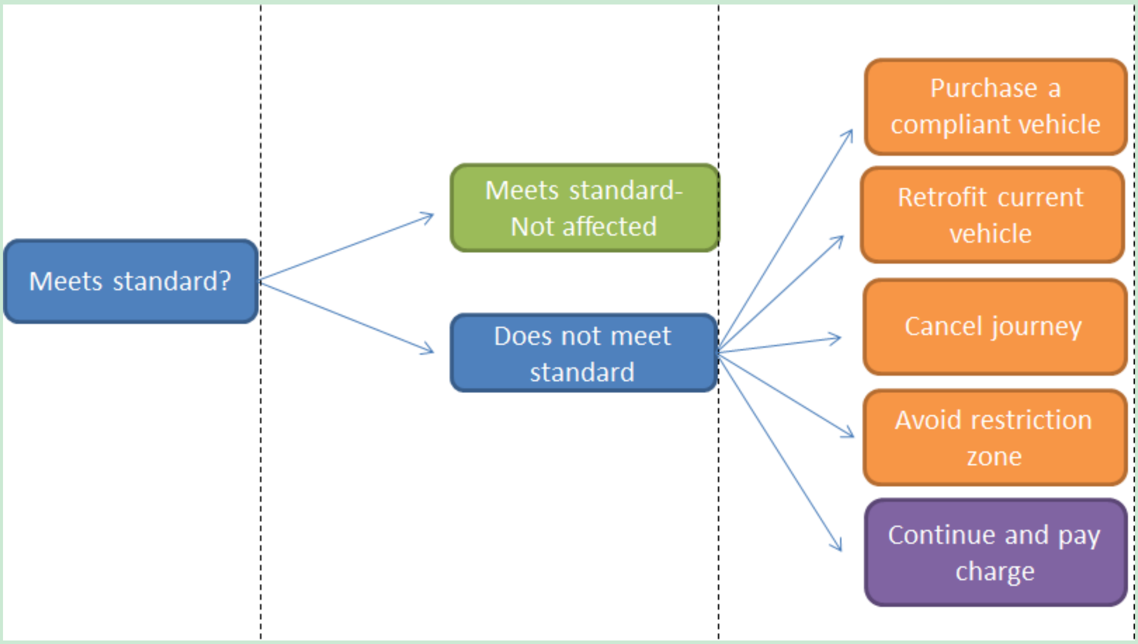
- **Avoid restriction zones**: some owners may divert their journeys around the zone.

- **Pay a charge for entering the zone**: some drivers will choose to pay a charge for entering restricted zones instead of one of the actions listed above. This may be the most cost-effective option for drivers that enter these zones infrequently.

- **Redeployment of existing fleet**: users with multiple vehicles may be able to redeploy their fleet to use cleaner vehicles within restricted areas. The costs of such changes are assumed to be negligible and therefore not considered in the model.

It is also possible that vehicle owners will choose to retrofit their vehicles in order to make them compliant with the CAZ standards. However, this has not been modelled due to a lack of strong evidence. It is likely that vehicle owners will only choose to retrofit if the cost of doing so is lower than the cost of upgrading their vehicle. Therefore, it has been conservatively assumed that all who choose to upgrade their current vehicle will replace rather than retrofit.

Figure B.7 Decision tree for road transport users



The behavioural response choices apply to vehicles that are subject to the charge. They are based upon a survey that was carried out by Transport for London when considering implementing the Ultra-Low Emissions Zone. This survey did not cover all vehicle types and it was expected that some behaviours would be different outside London, so expert opinion was used to fill these gaps. Given the limited data and the assumption that drivers response functions may vary from zone to zone, there are large and unquantifiable uncertainties surrounding these responses, which may have a big impact on the costs and benefits. However, it is assumed that if a Local authority were to implement a charging Clean Air Zone, it would conduct a detailed scoping study to identify the optimal charge to yield a behavioural change response equivalent to that laid out in Table **B.8**.

The assumed proportions of non-compliant vehicle owners who respond according to the different options available are summarised in Table **B.8**.

Table B.8 Proportions of non-compliant vehicle owners which choose certain behavioural responses

	Cars	LGVs	HGVs	Buses	Coaches
Pay charge	17%	48%	34%	0%	23%
Avoid zone	26%	24%	0%	0%	0%
Cancel trip	43%	14%	34%	41%	18%
Replace vehicle	14%	14%	33%	59%	59%

It is also assumed an additional 25% of those vehicles that are upgraded will be scrapped. The charge is estimated to lead to 17% of unique cars entering the zone choosing to pay the charge. As these are the least frequent zone users, this translates to only 7% of car vehicle kilometres travelled within the zone and therefore 93% of non-compliant car vehicle kilometres are expected to be altered in some way by the imposition of a charge.

B.5 Quantifying the impacts

The model assesses several impacts resulting from the modelled change in the fleet. The following costs and benefits are calculated:

- **Loss of consumer welfare/ financial cost of upgrading:** Consumers who upgrade their vehicle as a result of traffic restrictions will incur a cost by doing so. The model calculates this via two alternative methods.

- **Loss of asset value:** A certain proportion of the oldest vehicles in the fleet will be scrapped as their value falls to zero. This will correspond to a loss of asset-value as their value was greater than zero in the baseline.

- **Cost of cancelling trips or avoiding the zone:** Consumers who cancel trips or avoid the zone will incur a loss of welfare as a result.

- **Infrastructure implementation and running cost:** Costs are incurred by local authorities in setting up the infrastructure of Clean Air Zones and running them.

- **Emission change impacts:** A change in emissions will change the health and environmental impacts on society.

These impacts are assessed consistently with the baseline modelling. The detailed inputs to the model are set out in Section **B.2** with headings corresponding to those in the calculation flow-charts within Section **B.4**.

Cost of upgrading

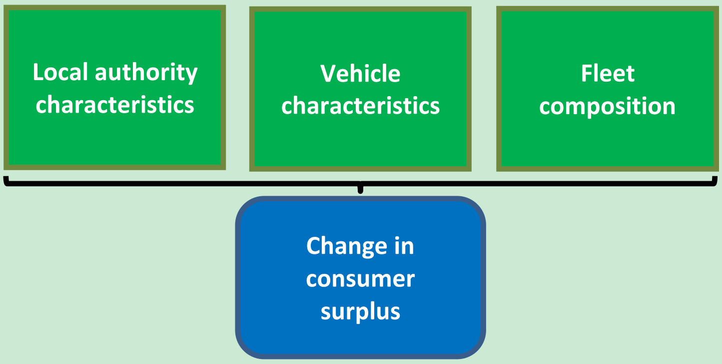
The different vehicle response functions are explained in Section **B.3**. The response with the most significant impact on societal welfare is those consumers that choose to upgrade to a vehicle exempt from the charge, which leads to their old vehicle being either scrapped or sold on.

There are two ways in which the analysis has measured the societal cost of upgrading to a charge-exempt vehicle: the ‘consumer surplus’ approach and the ‘financial cost’ approach.

Consumer surplus approach

Figure **B.9** demonstrates the inputs that feed into the consumer surplus calculation (see Boxes **B.2** and **B.4** as well as Table **B.3** for a full list of inputs).

Figure B.9 Inputs to consumer welfare loss calculation



The consumer surplus approach is based on the following three assumptions.

- Owners of vehicles value them differently. It is assumed the levels at which the vehicles are valued is equally distributed between the minimum value (i.e. market price) and the maximum (i.e. minimum price of a vehicle one Euro standard above).

- The market price is the minimum price at which owners would value their vehicle. This is assumed on the basis that they would otherwise sell their vehicle in the baseline.

- The maximum value placed on a vehicle is the value of a vehicle one Euro standard above. This is because it is assumed that people always prefer newer vehicles, and if they are willing to pay more for a vehicle, they would purchase the higher Euro standard in the baseline.

The loss of surplus from selling old vehicles is calculated based on these assumptions (See Box **B.10** for an economic explanation of consumer surplus).

Box B.10: Consumer surplus – economic explanation

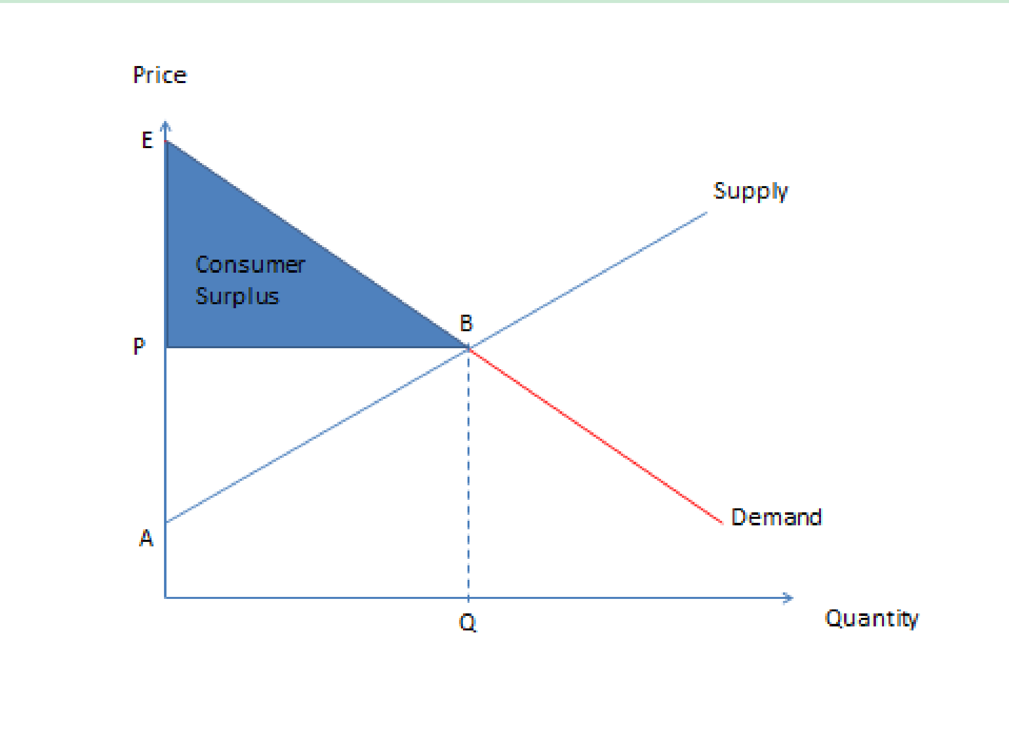
The value a consumer puts on a vehicle above the price they paid for it is called the consumer surplus. For example, if an owner perceives that they can make an extra £3,000 a year by owning a van as they can access more customers, while the costs of purchase loan repayments and running the van total just £2,000 a year, the van owner makes £1,000 consumer surplus from owning the van.

Given this, the loss to the business of getting rid of this van cannot be assessed as the value of their vehicle at the market price alone. It would be the difference between their valuation (£3,000 in this case) and the market price.

Graphically, this can be shown with a supply and demand graph (below). The value of consumer surplus can be estimated by identifying the maximum price consumers are willing to pay for the vehicle (point E, or £3,000 in the case of the van driver) and the market price (point P; or £2,000); this is then multiplied by the number of individuals affected (Q).

This figure would provide the aggregate consumer surplus if all owners valued the vehicle equally. However, as it is assumed owners of vehicles value them differently and the levels at which they are valued is equally distributed between the maximum (i.e. price of a vehicle one Euro standard above) and minimum value (i.e. market price) this total figure is then divided by 2 to attain the total consumer surplus for the market (the blue triangle below).

Figure B.11 Simplified illustration of consumer surplus



There is a transaction cost associated with searching for and buying a new vehicle. It is assumed any implementation of new vehicle emissions guidelines will be announced 4 years in advance, as households and businesses own cars for an average of 4 years. It is assumed that the effort required to purchase a new vehicle remains the same, regardless of whether or not a new measure is implemented.

It should be noted that there will be a shift in demand from vehicles subject to a charge to exempt vehicles. This will increase the number of available vehicles subject to the charge in the market, leading to a decrease in the value of such vehicles, which will negatively impact owners of vehicles subject to a charge. However, it is not possible to forecast this change in the market price and this impact is therefore not assessed. The degree to which this will affect the results will depend upon the percentage of the UK fleet that is affected by the traffic restrictions; this impact is expected to be relatively small.

Additionally, it is assumed in the model that no corresponding non-monetised benefits are accrued via retrofitting. Therefore, the cost of a retrofit is the entire financial cost (c. £17,000 to retrofit an HGV / bus). However, non-monetised benefits are incurred when vehicles are traded for newer vehicles. Therefore consumer surplus losses are much lower, and always below £17,000 for all vehicles. As a result, no drivers are assumed to choose to retrofit if the consumer welfare approach to valuation is taken.

Note that when using the consumer surplus approach we do not value the fuel savings separately as this saving is considered to be implicitly accounted for in the consumer welfare calculation.

Financial cost approach

Vehicle owners that upgrade will incur monetary costs from purchasing a newer (and therefore more expensive) vehicle. Therefore, the costs and benefits valued in the 'financial cost' methodology are the following:

a) The extra cost of purchasing a vehicle exempt from the charge (i.e. the cheapest second hand exempt vehicle, or new vehicle in 25% of cases)

b) The benefit gained by selling the baseline vehicle (residual value)

c) The benefit of fuel savings from owning a more efficient vehicle

If a vehicle is scrapped, the cost of the cheapest compliant vehicle is the cost that will be paid (as the owner receives no residual value for their vehicle). It is also assumed that 25% of vehicles will be bought new (to replace the scrapped vehicles), incurring the corresponding cost.

The cost of retrofitting is accounted for as the entire financial cost. While there may be an increase in running costs, these are considered to be negligible.

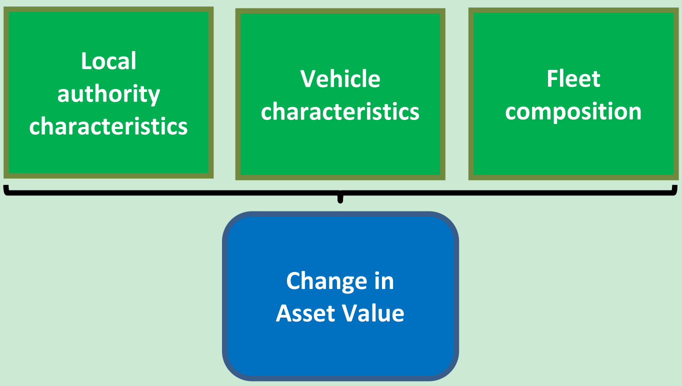
This approach does not estimate the additional impact on owners who operate outside the Clean Air Zones. These owners will be able to purchase vehicles that do not meet zone standards at a lower price, and sell vehicles that do for a higher price to those drivers who do enter such zones.

Vehicle owners will recoup some of the costs of purchasing a newer vehicle via fuel savings. As the measure will lead to a shift from older vehicles to newer, more fuel-efficient vehicles, consumers are likely to experience a fall in running costs due to savings on fuel expenditure. The final value for savings is based on the resource cost of fuel, which excludes duty and VAT. The total distance travelled by each vehicle is assumed to remain unaffected by Clean Air Zones, and any fuel efficiency savings incurred by vehicle owners from upgrading vehicles will be implicitly captured in the consumer welfare calculation. However, for the UK as a whole there will be a reduction in fuel use given that a proportion of the most fuel inefficient vehicles have been scrapped and left the fleet, and replaced with compliant vehicles. This translates into a resource saving from reduced expenditure on fuel.

Change in asset cost

Figure **B.12** demonstrates the specific inputs that are used as part of the change in asset cost calculation. A detailed breakdown of this calculation is laid out in the paragraphs below.

Figure B.12 Flow of inputs to change in asset value

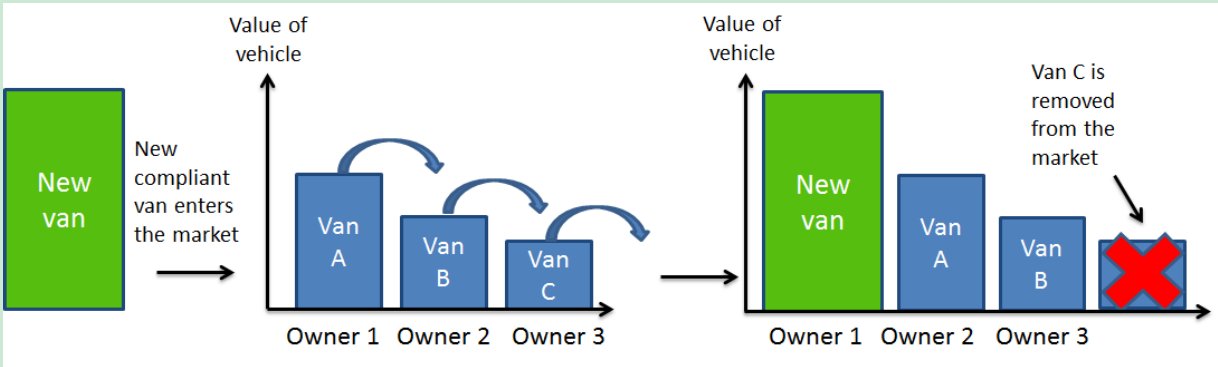


A proportion of the upgrading vehicle owners will buy a new vehicle, assumed to be 25%, with the remainder selling their current vehicle to a buyer largely unaffected by the access restriction and purchasing a second-hand exempt one. Assuming that the market for vehicles operates efficiently, given that the total fleet in operation will not increase, it follows that a similar number of the oldest, most polluting vehicles will exit the market and be scrapped. This is because demand for such vehicles has fallen to zero, resulting in a deterioration in value for these vehicles.

The entrance of new vehicles to the market and subsequent knock-on effects on the rest of the vehicles in the market is demonstrated in Figure **B.13**. For example, if van A is a Euro 5 diesel, owner 1 can sell this to owner 2, who does not travel frequently into the restricted area and owns van B, a Euro 4 diesel. Owner 2 in turn will sell on van B to owner 3, and van C (a Euro 2 diesel) will be scrapped, as its value would fall to zero.

However, if the access restriction had not been introduced, all vans of Type C in the market would have a value greater than zero, and would have remained in the market. The introduction means that this value is lost, as demand for this vehicle type would fall, and therefore there is an additional cost to society.

Figure B.13 Fleet turnover process



The number of vehicles scrapped depends upon the number of vehicles who face the charge and the behavioural assumption that a percentage, based upon the vehicle type, will be scrapped as a result of the Clean Air Zones.

The residual value of the vehicles scrapped prior to the introduction of the Clean Air Zones has been calculated based on the age of vehicle and depreciation rates over time. For example, a vehicle that has a limited operational life remaining but which is scrapped earlier is valued at the estimated price of a vehicle of that type and age. The total residual value of the vehicles scrapped is considered to be the loss of asset value to society as a result of the introduction of Clean Air Zones.

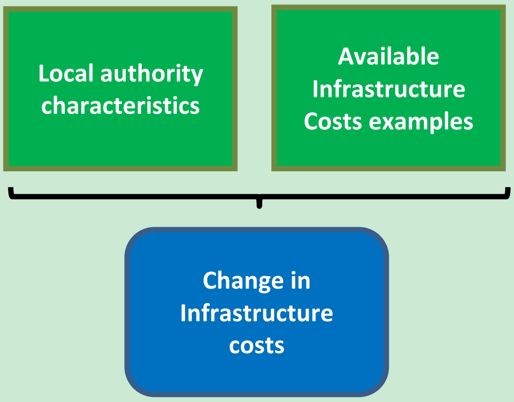
Cost of cancelling trips or avoiding zones

Non-compliant vehicle owners are assumed to cancel their trip or avoid the zones only if the cost of doing so is equal to or less than the cost of entering the zone. Since these incurred costs will range on a continuous scale from zero to the value of the fine for entering the zone, the assumption is that the average cost is equal to half of the fine value. Therefore, the overall cost of cancelling trips and avoiding the zones is equal to the total number of trips where this behaviour is expected multiplied by half the fine value.

Change in infrastructure costs

Figure **B.14** highlights the specific inputs that are used to calculate the change in infrastructure costs. The full process is detailed below.

Figure B.14 Inputs to infrastructure capital and running costs



Clean Air Zones that are included in the network will incur costs in both set-up and enforcement of vehicle emission standards. Such costs could include the following:

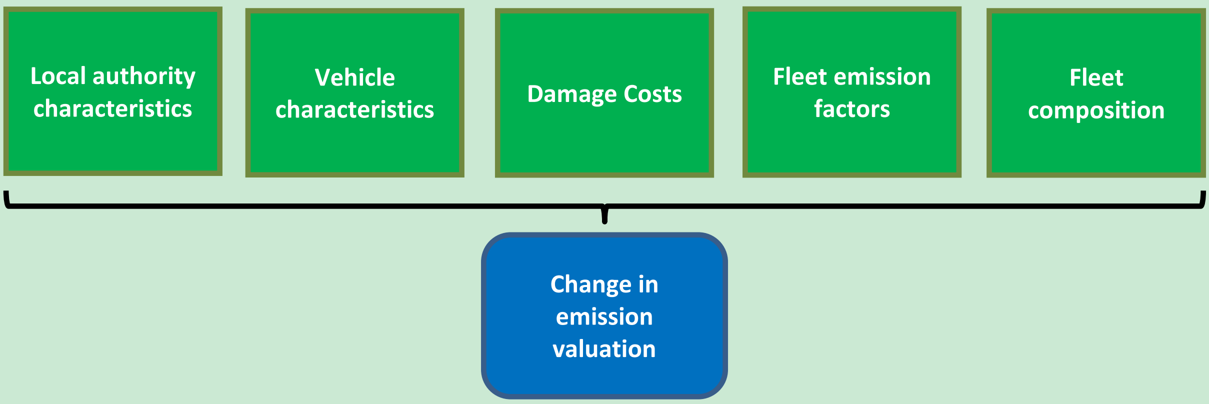
- General infrastructure and implementation costs (e.g. signage, monitoring compliance)
- Automatic Number Plate Recognition system (e.g. ANPR camera and installation costs, running costs, IT equipment) however, other systems may be more appropriate for the area in question
- Ongoing communication, enforcement, and staff costs

Defra have scaled costs of implementation from available data on similar schemes. To estimate the costs that will be incurred within the restricted areas considered in the model, these costs were scaled up depending on the total population and perimeter lengths of the zones to obtain the costs for each zone under assessment.

Emission change impacts

Figure **B.15** highlights the specific inputs that are used to calculate the emission changes as a result of Clean Air Zone implementation. The full process is detailed below.

Figure B.15 Inputs to emissions change



The tonnage of NO_X emission reductions inside zones is provided from the PCM model runs for 2020, 2025, and 2030 and extrapolated for other years. Reductions will decrease with time as the fleet naturally upgrades to cleaner vehicles exempt from the charge.

A change in NO_x and PM emissions is expected outside the zones. Some drivers subject to the charge will divert journeys to avoid the zone. This will increase the emission levels outside the zone. Other vehicles subject to the charge will be sold outside the zone when drivers upgrade to vehicles exempt from the charge; however it is assumed this would still be an upgrade from an older vehicle, therefore reducing the emissions outside of the zone. The overall change can be calculated by adding the vehicle kilometres of vehicles avoiding the zone and then subtracting the emissions savings produced from the newer vehicles bought outside the zone.

For those vehicles scrapped as a result of the traffic restriction zones, a calculation has been made to account for the emissions savings that would have been incurred over the ten-year assessment period. The distance travelled by each scrapped vehicle per annum and the emissions produced as a result, are multiplied by the remainder of each scrapped vehicles expected lifetime within the assessment period. This provides the expected emissions that are no longer produced on the roads by scrapped vehicles, as a result of the traffic restrictions.

The Clean Air Zones do not generally cover the entire built-up area for the city or town they are placed in. These built-up areas would have the same damage costs as the zone, which is higher than the national average used for outside zones. We would expect vehicles entering the zone to also travel through a built-up area on the journey and therefore there are additional benefits outside the zone to be realised from the behavioural changes. To estimate these additional benefits the NO_x emissions savings from upgrading for each zone are uplifted by a factor based on the ratio of the zone to built-up area modified by trip length distribution. This uplift factor is also applied to the congestion benefit for London.

The PCM does not provide estimates of CO_2 changes. CO_2 emission factors for different vehicle types and Euro standards are obtained from the Transport Research Laboratory. There will be a reduction in CO_2 emissions as the fleet upgrades to newer, more fuel-efficient vehicles and a proportion of the fleet is scrapped. From the data available on number of vehicles, Euro standard and distance travelled; it is possible to approximate the reduction on emissions due to the upgrade in fleet. It is also possible to calculate the fuel cost savings using projections of diesel and petrol prices from DECC[151].

B.6 Calculating Net Present Value

For ongoing benefits, a ten-year appraisal period is used from 2020 (when the policy is assumed to be fully implemented). For analysis purposes, costs incurred with implementation and upgrading are upfront costs and are assumed to be incurred in 2020. Fuel, $NO_{X,}$ and carbon impacts associated with local measures are incurred over the ten-year period.

As outlined previously, total benefits include emission damage cost reduction and fuel savings, while total costs include asset loss, consumer welfare loss and infrastructure costs.

After obtaining the total quantified cost and benefit figures, the present value of the differences between the costs and benefits is calculated to provide the NPV discounted to 2015 prices.

[151] Department for Energy and Climate Change, Fossil fuel price projections: 2014, <www.gov.uk/government/publications/fossil-fuel-price-projections-2014>.

Annex C – Theoretical maximum technical potential

C.1 Introduction

To help prioritise and shape the options considered in full in this report, first a high level assessment was undertaken of the theoretical maximum technical potential (MTP). The MTP indicates in absolute terms the maximum reduction that could be expected if a policy was to be implemented at its highest rate. **This assessment does not reflect the technical and implementation challenges in delivering such an outcome**, nor does it provide a full financial impact analysis, but it does provide an indication of the full potential of different policies to improve NO_2 concentrations.

To make such an assessment meaningful it also uses the same indicative assumptions to calculate the potential costs to Government of such an outcome. In this way, it can help prioritise and shape the options considered in the full analysis. The assessment is explained for each option including:

- A brief description
- An outline of key assumptions
- The projected air quality impact
- The estimated cost to government

For ease of comparison, the projected air quality impacts have been estimated for 2020 for each option because this is the earliest year of data in the SL-PCM model that has been used to model these impacts. A summary of the results of the theoretical maximum technical potential assessment for each of the shortlisted options is presented in Table **3.8** of the technical report.

C.2 Clean Air Zones

A Clean Air Zone (CAZ) is a geographically defined area bringing together immediate action to improve air quality. CAZs can include a charging element for vehicles which enter a CAZ but that do not meet the required standard. To consider the maximum technical potential of CAZs, the following hypothetical scenario has been investigated:

- All vehicles will be restricted within each CAZ (equivalent to Class D under the 2015 Plan)

- CAZs are implemented in 27 zones in 2020.
- The impact on ambient NO_2 concentrations has been modelled in the five most polluted cities within the UK, which are expected to exceed the legal limits for NO_2 in 2020.
- Assuming the mean of these five cities is the representative mean of all non-compliant cities, the impact on emissions was scaled up to estimate the total impact of implementation across all the cities. This assumption will be refined for the final Plan based on assessment of feasible zone perimeters.
- London implements the Ultra-Low Emission Zone (ULEZ), while also tightening restrictions in the wider London area to the same extent.

As with all the options, this is a theoretical assessment to understand the maximum technical potential and does not incorporate consideration of deliverability. Sections **4-6** describe the options that have been analysed fully.

Air quality impacts

It is estimated that this option will reduce NO_2 concentrations by an average of 11.0µg/m^3 and emissions of NO_x by 29,000 tonnes (51,000 tonnes within the zones[152]).

Government cost

Costs to government will be around £595m. This includes the costs to government of setting up and running the 27 CAZs over a ten-year period.

Table C.1: Maximum technical potential impact of CAZs	
Impact	**Result**
AQ impact	11.0µg/m^3 reduction
Government cost	£600m

[152] The reduction within zones is partially offset by increases outside the zones because some journeys lengthen to avoid the zone

C.3 Retrofit

Retrofitting vehicles can reduce the amount of NO_x emitted. This policy considers retrofit schemes for buses, HGVs, and black taxis. The maximum technical potential scheme assumes that all pre-Euro 6 buses, black cabs, and HGVs will be retrofitted.

Retrofit installs two technologies: selective catalytic reduction (SCR) for buses and HGVs, and Liquid Petroleum Gas (LPG) retrofit for taxis. SCR is the technology used in the latest Euro 6 buses and HGVs to minimise NO_x emissions. LPG retrofit for black taxis has been undertaken within the clean vehicle technology fund (CVTF). The evaluation evidence suggests that emissions after retrofit are equivalent to a petrol engine.

The assessment for the retrofit measure was carried out using the Scrappage/Retrofit model.

Air quality impacts

The maximum technical potential option estimates the impact of retrofitting all pre-Euro 6 buses, black cabs, and HGVs at an average reduction of 1.5µg/m^3 in concentrations of NO_2 in 2020. This would result in around 70 percent of taxis, 50 percent of HGVs and 60 percent of buses (around 300,000 vehicles in total) being retrofitted in 2018.

Government cost

The total cost to Government is estimated at £4,500m to retrofit all vehicles. We have not estimated the costs of administering the scheme at this stage. Based on similar schemes these costs are unlikely to be significant in comparison to the costs of retrofitting vehicles, and therefore excluding these is unlikely to materially affect the conclusions.

Government is assumed to incur the full cost of retrofit, estimated at £4,500m. The modelled costs of retrofit are as follows:

- Cost of SCR: £17,000
- Cost of LPG: £8,000

Costs have been estimated based on existing retrofit schemes undertaken by Government. The cost of retrofitting HGVs is assumed to be the same as the cost for retrofitting buses. Total costs were estimated by multiplying the cost of retrofit by the number of vehicles retrofitted. The modelling assumes that all retrofit takes place in 2018 for the MTP option.

Table C.2: Maximum technical potential impact of retrofit	
Impact	**Result**
AQ impact	1.5µg/m^3 reduction
Government cost	£4,500m

C.4 Scrappage

This option estimates the impact of scrapping all pre-Euro 6 diesel cars and vans in 2019. It is limited to diesel vehicles because they emit substantially more NO_2 than petrol vehicles. The hypothetical scenario modelled is that:

- Around eight million diesel cars will be scrapped and replaced with new Euro 6 cars.
- Around two million diesel vans will be scrapped and replaced with new Euro 6 diesel vans.

As with all the options, this is a theoretical assessment to understand the maximum technical potential of scrappage and does not incorporate consideration of deliverability. Sections **4-6** describe the options that have been analysed fully.

A scrappage scheme is expected to improve air quality by increasing fleet turnover and therefore reducing the average age of the vehicle fleet.

Air quality impacts

The maximum potential option illustrates the potential first order impacts of scrapping all pre-Euro 6 cars and vans (around ten million vehicles) and replacing them with new Euro 6 vehicles. The condition on the replacement for this option is a new Euro 6 vehicle, the modelling has assumed that it is equally likely that cars will either be replaced by diesel or petrol Euro 6 vehicles, and that vans will likely be replaced with a new diesel Euro 6 vehicle on the basis that diesel vans dominate the market.

It is estimated that there could be around 35 million cars and vans on the road in 2019. The option modelled could result in around 30% of the total stock (of cars and vans) or around 60% of the total diesel stock (of cars and vans) being scrapped and replaced with a newer vehicle (Euro 6).

The modelling suggests that this measure could reduce NO_2 concentrations by 6.3µg/m^3 in 2020. However, it is important to note that this policy could lead to an increase in average NO_2 concentrations of 1.1µg/m^3 by 2030. This is because a scrappage scheme in 2019, by bringing forward the replacement of the oldest vehicles in the fleet, would mean a spike in the purchase of current Euro 6 vehicles.

This increased number of early, dirtier Euro 6 vehicles[153] will remain in the fleet until the end of their working life whereas under business as usual the pre Euro 6 vehicles would naturally be replaced with newer Euro 6 vehicles over a longer timescale.

Government cost

The costs of administering the scheme have not been considered at this stage. The main cost to government that has been quantified is the cost of the grants paid to participants of the scheme. Under this scheme, pre-Euro 6 cars and vans are replaced with new Euro 6 vehicles. The grant levels that have been estimated for this option are:

- £6,000 for diesel cars
- £6,500 for diesel vans

These values were estimated based on the maximum estimated residual values of the vehicles expected to be scrapped (based on a Euro 5 vehicle) in 2019.

The discounted costs to government are estimated to be approximately £60,000m (2017 prices and base year). It assumes the policy is introduced in 2019 and runs for one year.

Table C.3: Maximum technical potential impact of scrappage

Impact	Result
AQ impact	6.3µg/m^3 reduction
Government cost	£60,000m

C.5 Ultra-low emission vehicles

This measure provides additional support to purchasers of ultra-low emission vehicles (ULEV's). There is one basic assumption made for the maximum technical potential scenario for ULEV's:

- 100% of the new car purchases (or 2.6 million vehicles) in 2019 will be Battery Electric Vehicles (BEVs).

[153] The Euro 6 standard is continually improving over time reflecting better enforcement and testing against the standard. See Section **8.2.2** for more details.

This would mean around five million new BEV purchases over three years, this estimate includes a ramp up period up until 100per cent take-up is achieved in 2019.

Given the current incentive structure, and the additional cost of an average BEV above a conventional car, the baseline scenario is that most of these 2.6 million vehicles in 2019 would have otherwise been newly purchased conventional cars (Euro 6 standard), split equally between petrol and diesel variants.

Air quality impacts

As BEVs have zero emissions, the air quality improvements stem from the assumption that each additional BEV is replacing a conventional car. Therefore, the total level of emission reduction from this policy is equal to the total emissions generated by those five million vehicles being replaced (over the three-year period).

This measure is estimated to reduce NO_2 concentrations by an average of 2.99µg/m^3 in 2020.

Government cost

For this scenario, the cost to Government is the value of the grants that would be required to incentivise car buyers to purchase these five million BEV's. To understand the potential cost it has been assumed that, in order to get all car buyers to convert to BEVs, the government would have to pay the full price differential between a Euro 6 vehicle and a BEV.

These grants would be paid as the BEVs are purchased over the next three years and the minimum discounted costs would be around £90,000m.

Table C.4: Maximum technical potential impact of ULEVs

Impact	Result
AQ impact	2.99µg/m^3 reduction in 2020
Government cost	£90,000m

C.6 Speed limits

COPERT speed emission curves suggest that vehicles travelling at higher average speeds should emit more NO_x the faster they go (Fig. **6.1** of the technical report).

Different engine types and standards produce different emission speed curves so the optimum speed (from a NO_x perspective) is different for each type of vehicle. Table **C.5** shows that it is not possible to define a single optimum speed limit for all vehicle types.

Table C.5: Approximate optimum speeds (mph) for lowest NO_x emissions by vehicle type and Euro standard						
	Euro 1	**Euro 2**	**Euro 3**	**Euro 4**	**Euro 5**	**Euro 6**
Petrol cars	30	30	60	70	50	50
Diesel cars	40	40	40	40	80	50
Petrol LGVs	40	40	40	40	30	30
Diesel LGVs	40	40	40	40	40	40
HGVs	55	55	55	55	55	55

The air quality impacts of reducing speed limits on motorways to 40mph, 50mph and 60mph have been simulated by modelling lower average speeds on motorways (by 10, 20 and 30mph respectively). A reduction of 20mph is the most effective in terms of NO_x emissions, so a 50mph limit is presented as the maximum technical potential option. Modelling was based on the following assumptions:

- The effect of reducing the speed limit from 70 to 50mph can be simulated by modelling a reduction in the average speed (by 20mph) on motorways with a national average speed of ~70mph.
- For motorways with a national average speed of ~60mph the effect of reducing the speed limit to 50mph can be simulated by subtracting the impact of reducing average speeds by 10 mph from the impact of reducing them by 20mph.
- Effects to flow of traffic and congestion can be ignored
- Speed would be controlled via variable signs on gantries over the carriageway

The impact of this measure is calculated on the assumption that traffic on failing motorway links is travelling at the same speed as the national average (for the type of motorway). It is possible that failing motorway links tend to be busier and more heavily congested, and that average speeds on them are lower. In this case, a change in the speed limit may have little impact on air quality - because cars are already travelling at speeds below the limit.

Air quality impacts

Initial modelling suggests a mean reduction of up to 4.5µg/m^3 in 2020 across failing motorway stretches. Impacts are expressed as ‘up to *x*’ because there is uncertainty over the modelling approach in relation to vehicle speed and the interplay between speed and congestion (Box **6.3** of the technical report). Highways England’s (HE’s) approach would not give a reduction in NO_2 concentrations or congestion following speed limit reduction.

Government cost

Costs for upgrading and operating 45km of motorway, to cover every section of motorway projected to be in NO_2 exceedance in 2020, have been estimated based on advice from HE.

Costs for installing and maintaining the equipment on the motorway links projected to be in exceedance in 2020 (about 48km) are estimated to have a 10 year NPV cost of about £60m. These estimates are based on a high-level average unit cost for the equipment and its maintenance. They should not be used to develop a standard cost for every scheme. It is also likely to be an underestimate, as it does not include the cost of software maintenance and other sundry costs.

Table C.6: Maximum technical potential impact of speed limits

Impact	Result
AQ impact	Up to 4.5µg/m^3 reduction in 2020
Government cost	£60m

C.7 Government vehicles

Adherence to Government Buying Standards for transport (GBS-T) is mandatory for central government. Currently, air quality impacts are not included in the standards. This policy measure would involve updating GBS-T to include air quality impacts. Updating the GBS-T for central government would be relatively straightforward given it does not require any new legislation but the resulting change in purchasing behaviour is uncertain. This is because air quality would be one of a number of factors used to select a new vehicle.

Whilst all Government Buying Standards are mandatory for central government, they are only a recommendation for the wider public sector. Thus, a change to GBS-T would not automatically lead to a change in wider public sector behaviour. Defra is exploring how GBS-T could be rolled out across the wider public sector. At this stage however, analysis is presented for central government only. The maximum technical potential scenario is based on the following assumptions:

- The modelling inputs used do not vary over the appraisal period.
- The vehicles referenced in Section **8.2.1** of the technical report stay representative of their given segments.

- The GBS-T would be updated to mandate that all central government new car purchases will be petrol from 2018.

Air quality impacts

The maximum technical potential of this measure would result in all new vehicle purchases switching from diesel to petrol. New Euro 6 diesel vehicles emit around 10 times more NO_x than new Euro 6 petrol vehicles.

Only cars are included given the uncertainty in the availability of petrol variants of other vehicle types.

As a result of this measure 23% of the total central government car fleet will be a Euro 6 petrol car in 2020, 61% in 2025, and 76% in 2027. This leads to a mean NO_2 concentration reduction of 0.004µg/m^3 in 2020.

Government cost

The maximum technical potential of this measure would have a present value cost to Government of £5.6m over the appraisal period. This cost reflects the capital switching cost and running cost, the methodology of which can be found in Section **6.3.4** of the Technical Report**.**

Table C.7: Maximum technical potential impact of Government vehicles

Impact	Result
AQ impact	0.004µg/m^3 reduction in 2020
Government cost	£5.6m

C.9 Vehicle labelling

Vehicle labelling looks to provide consumers with the information they require in order to make an informed purchasing decision. Historically air pollution has not been reflected in vehicle labelling because of the way Euro standards were introduced. This policy would put air quality information in an easy to understand labelling scheme for all new vehicles sold.

The maximum technical potential option is based on the following assumptions:

- The measure will have some behavioural impact behaviourally ammounting to a maximum technical potential of a 5% shift in purchasing decisions from new diesel vehicles to new petrol vehicles. This behavioural impact is what was judged to be the maximum change that could be seen.

- This would impact annually from April 2018.

Air quality impacts

As a result of this measure, an additional 0.6% of the national car fleet will be Euro 6 petrol in 2020, 1.6% in 2025, and 1.8% by 2027. This will lead to a mean NO_2 concentration reduction of 0.13µg/m^3 in 2020.

Government cost

It is assumed that the government cost of implementing this measure is negligible over the appraisal period.

This is because a review of the labelling system is already funded and the addition of NO_x impacts is considered unlikely to result in additional costs. It is also assumed that running costs for this scheme will be negligible.

Table C.8: Maximum technical potential impact of vehicle labelling

Impact	Result
AQ impact	0.13µg/m^3 reduction in 2020
Government cost	Negligible

C.10 Influencing driving style

This policy would seek to improve a driver's style of driving with the aim of reducing vehicle emissions. Excessive speed, maintaining high engine revolutions, and accelerating hard are all known to increase fuel consumption as well as NO_x emissions. Through this policy, Government would seek to promote driver training and best practice in order to reduce NO_x emissions.

For the maximum technical potential scenario, it is assumed Government would fund a programme to train all car and LGV drivers and provide them with telematics (a device which can be fitted into cars and has the ability to measure how well the car is being driven) to ensure that they adhere to their training.

Air quality impacts

This scenario is estimated to reduce NO_2 concentrations by an average of 4.2µg/m^3 in 2020 following the assumptions highlighted in Section **6.4.3** of the technical report**.**

Government cost

The maximum technical potential of this option would have a present value cost to government of £5,300m over the appraisal period. This reflects the estimated cost of training and the cost of installing telematics for all drivers.

Table C.9: Maximum technical potential impact of influencing driving style	
Impact	**Result**
AQ impact	4.2µg/m^3 reduction in 2020
Government cost	£5,300m

Annex D – Clean Air Zones

D.1 Modelling charging Clean Air Zones

The Government has undertaken modelling of charging Clean Air Zones (CAZs) at a national level to estimate their possible impacts. This modelling is still subject to further updating based on newer data.

For the purposes of this modelling, assumptions have been made about the type of charging CAZ that could be implemented to deliver compliance in the shortest possible time. In the modelling it is assumed that there will be 27 charging CAZs (Section **4.3.1**), which is felt to be a reasonable assumption given the level of uncertainty in how exceedances at a local level could translate into numbers of charging CAZs. While national modelling (Annex L to the draft Plan) shows that more than 27 local areas are projected to have annual mean NO_2 concentration exceedances in 2020 (the year it is assumed that CAZs are introduced), not all local areas with persistent exceedances will require a separate charging CAZ. There are broadly three reasons for this:

- **Overlap:** where it might be possible to address exceedances in multiple local areas through a single charging CAZ.
- **Not suitable for a charging CAZ:** where a charging CAZ is not possible because no reasonable alternative routes are available by road. In such areas, specific local solutions will be needed.
- **Upcoming development:** expected infrastructure changes are expected to address the exceedance.

D.2 Impact of Clean Air Zones on estimated number of vehicles

Estimates of the potential number of cars regularly entering CAZs have been produced, based on modelling undertaken for this consultation. These were produced by forecasting the number of cars owned nationally, identifying the proportion that would be non-compliant, and then estimating the proportion that might enter a CAZ area.

The forecast of national cars in 2020 is based upon DfT statistics on the vehicle stock projected forward using the historic change in stock (using a 5 year rolling average). The UK car fleet is estimated to be 32m in 2020.

The proportion of non-compliant vehicles uses estimates of the split of the vehicle stock by Euro standard at a national level used as inputs in the PCM. Because information on Euro standards is not collected these are estimated using DfT statistics on vehicle ages and information on the introduction dates of Euro standards. The age mix of the fleet is projected forwards to understand the mix of vehicles by Euro standard in future years. In total it is estimated that 8.5m cars could be non-compliant in 2020 (the earliest year that CAZs are expected to be introduced).

Estimates of the number of cars entering CAZs are then made using GPS data.

- GPS data tracks vehicles and can be used to identify the numbers that enter different local authorities. The data is provided by Trafficmaster. The data captures the movements of approximately 90,000 cars over the course of a year.

- The number of cars in the dataset that enter the original 5 CAZ areas and the London ULEZ was based on the existing assumed boundaries produced for the 2015 Plan.

- As no decisions have yet been made on the how many CAZs of each type will be needed, or what their boundaries would be, this number was then scaled up to provide an estimate of the number of vehicles that might be expected to enter an assumed 15 car CAZ areas. This was based on potential CAZ boundaries in additional cities, to understand the marginal impact of adding extra cities, which was then scaled up to estimate the number of cars captured in 15 cities.

- Because the Trafficmaster data captures only a sample of cars, this was in turn scaled up to provide an estimate of the total number of cars affected.

Finally, GPS data is also used to track the number of times that cars enter the assumed CAZ boundaries. This was used to estimate the proportion of cars that might enter the assumed 15 CAZ areas more than once a week (estimated as greater than 51 times per year) and more than once a month (estimated as greater than 11 times per year).

There is significant uncertainty regarding the number of cars that will be impacted, due to uncertainty around the number of CAZs, their boundaries, and the number that will cover cars. Furthermore, there is also uncertainty in the methodology as it relies on GPS data, which covers only a sample of newer vehicles and may not accurately reflect vehicles on a national basis. It also does not take account of local differences in the age of vehicles, or travel patterns. Finally, these calculations only estimate the number of non-compliant cars that might be expected to enter the areas where a CAZ may be implemented and do not take account of the behaviour change that would result from CAZ charging.

To reflect this uncertainty a significant range is placed around these estimates, from -50% to +100% in the estimates of cars that regularly enter the CAZs. Estimates of the number of cars impacted will be refined for the final Plan. The results of the assessment are presented in Table **D.1**.

Table D.1 Cars that enter CAZs regularly (millions)

	Low	Central	High
> 51 times per year	0.6	1.1	2.2
> 11 times per year	1.1	2.2	4.4

These numbers have been compared to the number of cars registered in local authorities that could be affected by car CAZs. DfT publishes vehicle registration data which, following the approach set out above, has been forecast forward to 2020 and limited to those that would be non-compliant. In total, it is estimated that in 2020 there could be 0.8m non-compliant cars registered in local authorities in England that could have charging CAZs.

- As the CAZ areas would be smaller than the area covered by the local authority this estimate does not represent the number of registered cars within CAZs: some of the cars included may never enter CAZ areas.
- Many cars that are registered in other local authorities will enter CAZs, so this should not be used as an estimate of the number of cars affected.
- The estimate does not capture the frequency with which cars would enter CAZs.

Annex E – Guidance on calibrated uncertainty language from the Intergovernmental Panel on Climate Change

E.1 Introduction

Following the Air Quality Review group meeting on 2nd March 2017 (Annex **F**), it was recommended that the Technical Report should assess and present uncertainties in line with Intergovernmental Panel on Climate Change (IPCC) guidance. In order to characterise key findings, calibrated uncertainty language should be used that conveys the most information to the reader. As per the commitment made in Section **9.1.3**, work is ongoing to adopt an approach in line with the IPCC's guidance[154].

The following section explains the criteria used in the IPCC guidance to help determine how to present uncertainty, recognising that in all cases traceable accounts of relevant evidence and agreement should be included when describing uncertainties.

E.2 Criteria used by the IPCC

If a variable is ambiguous, or the processes determining it are poorly known or not amenable to measurement: confidence should not be assigned; summary terms should be assigned instead for evidence and agreement (Fig. **9.2**). The governing factors, key indicators, and relationships should also be explained. If a variable could be either positive or negative, the pre-conditions or evidence for each should be described.

If the sign of a variable can be identified but the magnitude is poorly known: Confidence should be assigned when possible (Table **9.3**); otherwise summary terms for evidence and agreement should be assigned. The basis for this confidence evaluation and the extent to which opposite changes would not be expected should also be explained

If the order of magnitude can be given for a variable: confidence should be assigned when possible; otherwise, summary terms for evidence and agreement should be assigned. The basis for estimates and confidence evaluations made should be explained, and any assumptions should be indicated. If the evaluation is particularly

---

[154] Mastrandrea, M.D. et al., '*Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*' (2010) Intergovernmental Panel on Climate Change <https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf>.

sensitive to specific assumptions, then the confidence in those assumptions should also be evaluated.

If a range can be given for a variable, based on quantitative analysis or expert judgement: likelihood or probability for that range should be assigned when possible; otherwise only confidence should be assigned. The basis for the range given should be explained, noting factors that determine the outer bounds. Any assumptions made should be stated and the role of structural uncertainties should be estimated. The likelihood or probability for values or changes outside the range should be explained, if appropriate.

If a likelihood or probability can be determined for a variable, for the occurrence of an event, or for a range of outcomes (e.g. based on multiple observations, model ensemble runs, or expert judgment): a likelihood for the event or outcomes should be assigned, for which confidence should be “high” or “very high”. In this case, the level of confidence need not be explicitly stated. Any assumptions made should be stated and the role of structural uncertainties should be estimated. Characterizing the likelihood or probability of other events or outcomes within the full set of alternatives, including those at the tails should be considered.

If a probability distribution or a set of distributions can be determined for the variable either through statistical analysis or through use of a formal quantitative survey of expert views: the probability distribution(s) should be graphically presented and/or a range of percentiles of the distribution(s) should be provided, for which confidence should be “high” or “very high. In this case, the level of confidence need not be explicitly stated. The method used to produce the probability distribution(s) and any assumptions made should be explained, and the role of structural uncertainties should be estimated. Quantification of the tails of the distribution(s) should be provided to the extent possible.

Annex F – Report on the outcomes of the Air Quality Review meeting

F.1 Introduction

An Air Quality Review meeting was held on 2nd March 2017. Chaired by Defra's Chief Scientific Adviser Professor Ian Boyd and attended by the members of the technical review group including independent academic experts[155], this meeting sought to review the draft technical report that would be published alongside the draft Plan. This annex sets out the comments and recommendations provided in the meeting. These have been addressed as far as possible in this technical report, and will continue to be considered for the final Plan.

F.2 Structural comments

The document presented to the technical group was structured as follows:

- Introduction and the challenges.
- Air quality assessment and national monitoring network and projections for concentrations as far as the model can go.
- How to make improvements: identifying options available, describing how these options have been assessed and assessing theoretical maximum technical potential without any constraints.

Based on this, theoretic potential feasible options were developed. The next three sections provide more detailed assessments of each of these options split into three groups

- Implementation of Clean Air Zones (CAZs)
- National CAZ supporting measures; intended to be targeted in areas where a CAZ is required to aid the transition.

---

[155] **Attendees**: Professor Ian Boyd (Chair, Department for Environment, Food and Rural Affairs), Professor Frank Kelly (Kings College London), Professor Paul S Monks (University of Leicester), Professor Charles Godfray (Science Advisory Council), Professor Phil Blythe (Department for Transport). **Apologies**: Professor Chris Whitty (Department of Health), Professor Sir Mark Walport (Government Chief Scientific Adviser), Professor Angela McLean (University of Oxford).

- National measures to supplement CAZs either by targeting different sources or by operating in different areas.

- Distributional analysis, assessing how different groups are affected by the feasible options.

- Sensitivities and uncertainties assessing, and where possible quantifying, the range around the estimates.

- Future steps - how do we improve air quality including finalising the plan and the wider interests in air quality beyond NO_2.

- Summary of all the results for potential measures to address NO_2.

Following the presentation of this structure, comments were sought. In summary these were:

- The process of describing technical potential then narrowing to potential that is possible may lose the focus and the attention of reader.

- Theoretical maximum might be confusing and we need to be realistic about actual real life reductions. Also during the movement from theoretical to practical, the definition of practical is unclear.
    - Practicality could be judged on economics, social, political, technical aspects.
        - It was clarified that the selection of the technically feasible option had been defined through collaboration between the policy and evidence teams.

- The document should seek to better clarify and define jargon in order to make it more accessible.

- The document should avoid making a judgement of political sensibilities, as this was the role of the draft Plan. If necessary, a summary of why technical options may not be politically acceptable sourced from the covering document would be a better course of action.

- Whilst it is understandable that given the scope of the document the main focus will be on a single pollutant, this should not limit the scope of the assessment. A better course of action would be to include considerations of the effects of other pollutants and potential co-benefits possibly within the introduction and conclusion.

    - It was noted that undertaking a multipollutant analysis would not be expected to substantially change the order of the options. It was also noted that this multipollutant analysis is expected for the next stage of the analysis.

- Regarding the overall structure, it was concluded that this should be largely unchanged but there should be an extended executive summary that could stand alone.

- There should be a clear distinction between CAZ measures, national measures, and supporting measures.

F.3 Comments on uncertainties and presentation

Comments were also sought regarding uncertainties and the presentation of data, charts, and graphs. The responses were:

- It was noted that the technical report included the best available evidence and one of the biggest challenges is to understand and narrate the uncertainty.

- Given this challenge, it was recommended that vocabulary with regards to uncertainty should be consistent and form a narrative, using the IPCC method with expert assessment of uncertainty as an example.

- It was noted that error bars can be a spurious exercise when error is not quantitative or meaningful. It is essential the narrative of uncertainty is strong throughout the document. This means that where figures are quoted the uncertainty should be explicitly identified. This also means that where trends are suggested, (for example ‘can increase’) a measure such as ‘is likely to increase’ should be used where possible.

- Uncertainty in the document with regards to the measurement system, modelling, and cost-benefit analysis should be recognised upfront. It should also be noted what has been completed to minimise uncertainty, for example the models tested are the best model available. To deal with each aspect of uncertainty a table explaining where the uncertainty comes from could be presented at the beginning of the report.

- Graphs and figures should be as clear and transparent as possible. Where applicable, figures should have an R squared value, n value, and explanation of where the data points have come from.

- The terminology used regarding electric vehicles should be consistent and clear.

- It was reflected that a number of options that are widely suggested are not present for good reason, such as NO_x eating paint.

- It should also be noted that a key assumption in this modelling is that current vehicle emission standards deliver the expected reduction in emissions over time.

F.4 Comments on monitoring and evaluation of the effectiveness of future air quality policies

Finally, comments were sought regarding the monitoring and evaluation of the effectiveness of future air quality policies. The responses were:

- Given the presence of uncertainty, the report should articulate the fact that work will be conducted in the near future to investigate the national monitoring system.

- The principles of the monitoring system should be outlined in the technical report; however, details of the monitoring system and evaluation should be developed by another group.

- The principles of the monitoring system should enhance the measurement strategy prior to the introduction of these policies to provide a baseline. Focus of monitoring could be CAZs and the surrounding areas.

    - It is noted that CAZs will be variable with different geographies and networks, and so multiple representative CAZs should be measured.

- It was suggested that to get a reasonable baseline we should look to get the new monitoring system operational around 12 months before the policies are active.

- It was also agreed that it was necessary for the new monitoring network to be operated nationally rather than locally. This creates independence between the operator and the reviewer, addressing the need to monitor in areas that do not take action (as controls on the results).

- It was also suggested that personal monitoring (otherwise known as exposure modelling) was in the longer term an important part of the picture especially in considering the health impacts.

F.5 Closing comments

This is the start of the process rather than a single meeting. Written comments from an independent objective perspective would be valued before the document was opened for consultation. During the consultation period, another meeting could be convened. The panel also accepted that it was useful to document and include this process within the documents including a brief summary of this session.

Annex G – Reporting zone NO_2 concentrations

Table G.1 Average annual concentration of NO_2 on the highest road link in each reporting zone ($\mu g/m^3$)[I]

Zone name	2017	2018	2019	2020	2021
London	**103**	**96**	**90**	**84**	**78**
West Midlands Urban Area	**60**	**59**	**58**	**57**	**54**
Greater Manchester Urban Area	**52**	**50**	**48**	**46**	**44**
West Yorkshire Urban Area	**60**	**59**	**59**	**58**	**55**
Tyneside	**54**	**52**	**50**	**48**	**45**
Liverpool Urban Area	**47**	**45**	**44**	**42**	40
Sheffield Urban Area	**53**	**50**	**48**	**45**	**43**
Nottingham Urban Area	**57**	**55**	**53**	**51**	**48**
Bristol Urban Area	**50**	**47**	**45**	**42**	40
Leicester Urban Area	**46**	**45**	**45**	**44**	**43**
Portsmouth Urban Area	**50**	**47**	**45**	**43**	**41**
Teesside Urban Area	**60**	**56**	**51**	**47**	**45**
The Potteries	**52**	**49**	**45**	**42**	40
Bournemouth Urban Area	**45**	**44**	**42**	**41**	39
Reading/Wokingham Urban Area	**45**	**44**	**42**	**41**	40
Coventry/Bedworth	**48**	**46**	**43**	40	38
Kingston upon Hull	**47**	**44**	40	36	34
Southampton Urban Area	**57**	**54**	**51**	**48**	**46**
Birkenhead Urban Area	**42**	40	38	36	35
Southend Urban Area	**51**	**49**	**47**	**46**	**43**
Glasgow Urban Area	**61**	**56**	**51**	**46**	**44**
Edinburgh Urban Area	**45**	**43**	**42**	40	38
Cardiff Urban Area	**49**	**47**	**46**	**44**	**42**
Swansea Urban Area	**44**	**43**	**42**	**41**	38
Belfast Metropolitan Urban Area	**51**	**48**	**45**	**41**	40
Eastern	**54**	**53**	**52**	**50**	**47**
South West	**47**	**45**	**44**	**42**	40
South East	**52**	**50**	**47**	**45**	**43**
East Midlands	**57**	**55**	**53**	**51**	**48**
North West & Merseyside	**58**	**55**	**52**	**48**	**46**
Yorkshire & Humberside	**52**	**50**	**48**	**45**	**43**
West Midlands	**53**	**50**	**48**	**45**	**43**
North East	**53**	**51**	**49**	**46**	**44**
Central Scotland	**45**	**43**	**42**	40	38
North East Scotland	**45**	**43**	40	38	37
South Wales	**56**	**54**	**52**	**50**	**47**
North Wales	**49**	**46**	**44**	**41**	39

Note: results in bold indicate concentrations that are above average annual NO_2 limits
[I] Only reporting zones that are projected to be in exceedance of the NO_2 limit in 2020 are shown

The air quality modelling from the Streamlined PCM model estimates the average annual NO_2 concentration for over 9,000 road links in the UK. The links with the highest average annual concentration in each reporting zone are then used to determine which zones are in compliance with annual NO_2 concentration limits. Compliance is therefore determined on a zone-by-zone basis.

Table **G.1** shows the reporting zone-level baseline projections for non-compliant zones from 2017-2021 if no further action is taken. This allows for a comparison to be made between the highest average annual concentration in each reporting zone and the expected improvement in concentrations as a result of each of the options set out in this report.

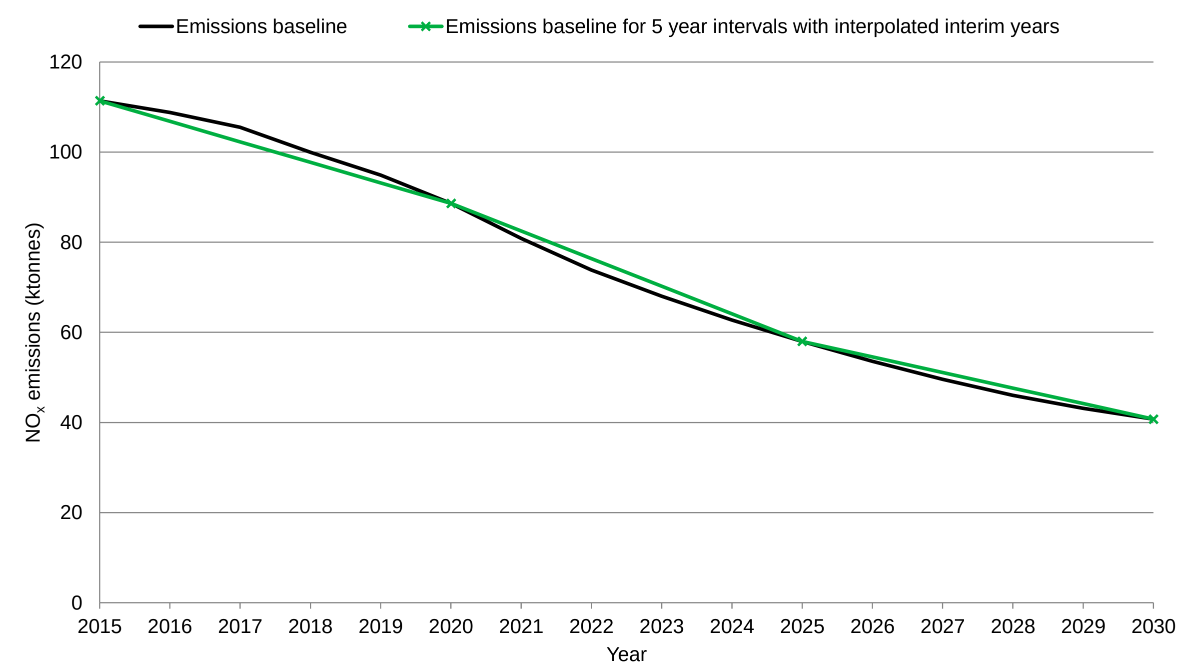
This comparison suggests that Clean Air Zones (CAZs, Section **4.3** of the Technical Report) are the only option that is able to deliver concentration improvements substantial enough to bring reporting zones into compliance within the time period shown. CAZs are therefore important in bringing about compliance with air quality limits in the shortest time possible. While the option of lowering speed limits (Section **6.2** of the technical report) could also bring about substantial concentration improvements, it is only able to do so on motorways. Because of this, only the Swansea Urban Area could be brought into compliance by the speed limits option in isolation.

Annex H – Assessment of methodologies for interpolating trends in NO_2 concentrations for non-modelled interim years

Defra’s air quality modelling currently produces concentration outputs for 2020, 2025 and 2030, and baseline concentration data is available for 2015. However, the concentrations for the years between these dates need to be estimated in order to determine which options bring areas into compliance in the shortest time possible. For the option analysis in this report, the concentration values for interim years have been estimated though a linear interpolation between the modelled years. Interpolation is a method of estimating values between a known set of values. In this case, the values at five-year intervals were known so the values for other years had to be interpolated from these.

In order to test the accuracy of this approach, baseline NO_x emissions data (which is available for all interim years) has been compared with linear interpolation estimates for the NO_x emissions data in interim years (Figure **H.1**). This is because it is assumed that the trend for emissions of NO_x is broadly the same as the trend for mean annual concentrations of NO_2. The correlation coefficient between these two results is 0.998. This indicates that the linear interpolation methodology gives values that are very close to the true values. Another key finding of this comparison is that interpolating interim values leads to an overestimation for values between 2020 and 2025, which is the key period in which the majority of zones are estimated to become compliant. This methodology can therefore be considered to be conservative as it is likely to slightly overestimate the number of roads that are non-compliant in the years 2020-2025.

Figure H.1: UK baseline emission projections: all years compared to five year intervals with interim years estimated by a linear interpolation (kt NO_x)



The accuracy of the linear interpolation methodology has also been tested by comparing against alternative methodologies for drawing lines of best fit between data points. Three estimates for interim year values have been calculated: a linear function, a square polynomial function, and a cubic polynomial function. The results of these methodologies are shown in Figures **H.2, H.3,** and **H.4**.

Figure H.2: UK baseline emission projections: all years compared to five year intervals with interim years estimated using a linear line of best fit interpolation (kt NO_x)

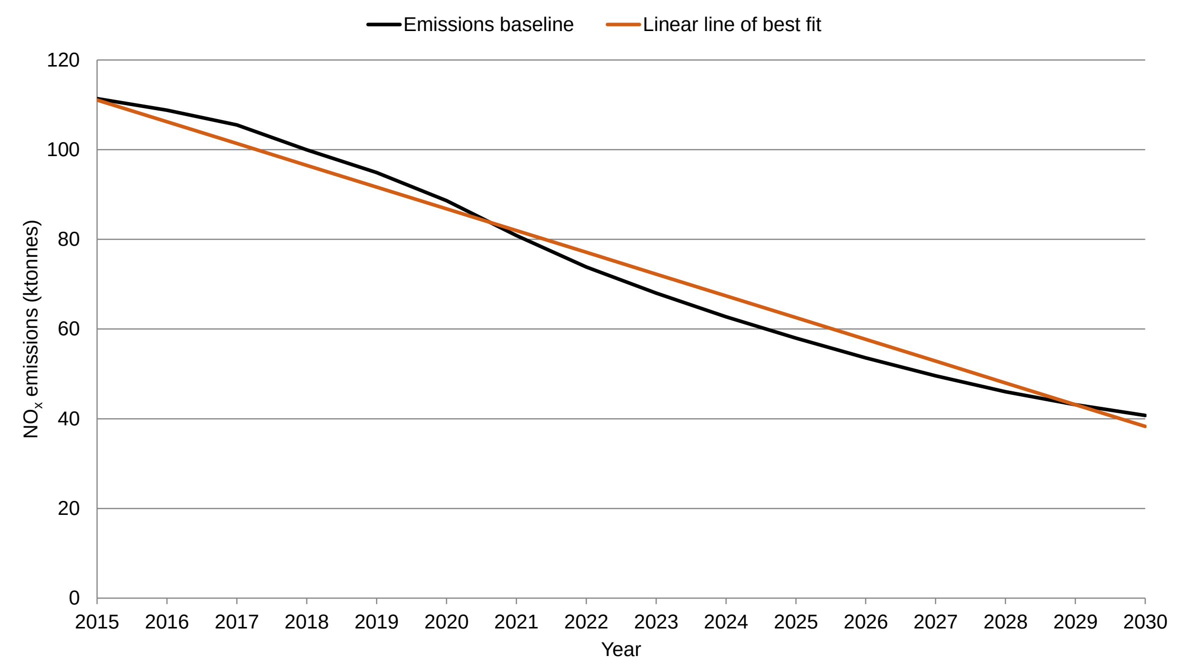


Figure H.3: UK baseline emission projections: all years compared to five year intervals with interim years estimated using a square polynomial line of best fit interpolation (kt NO_x)

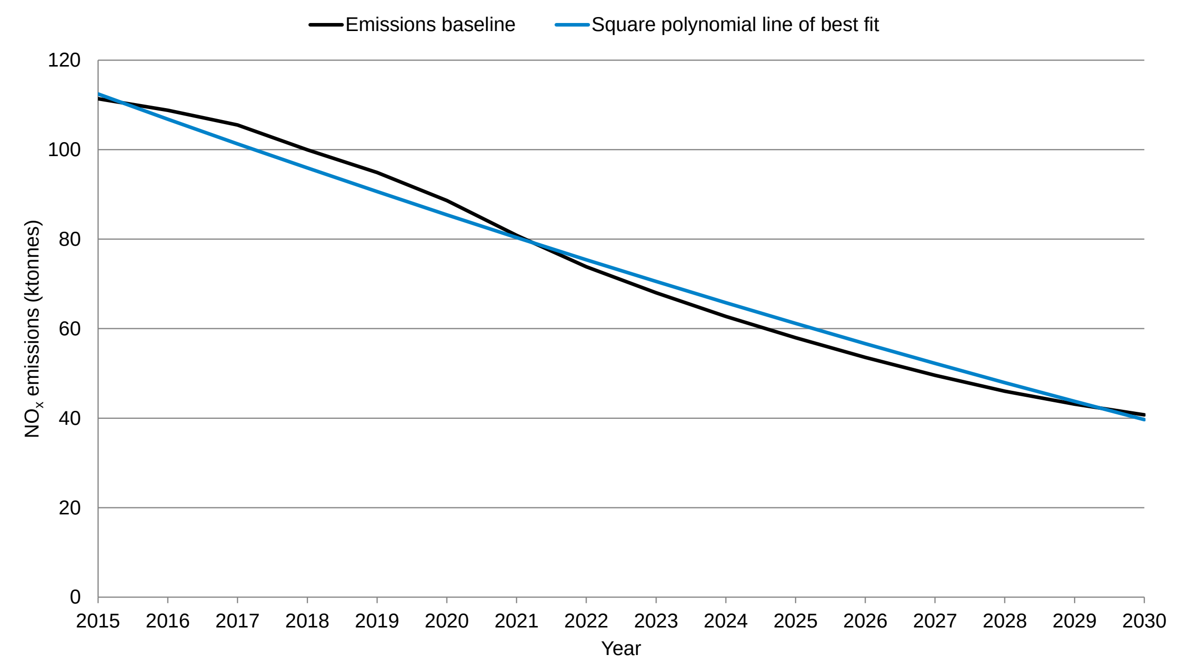
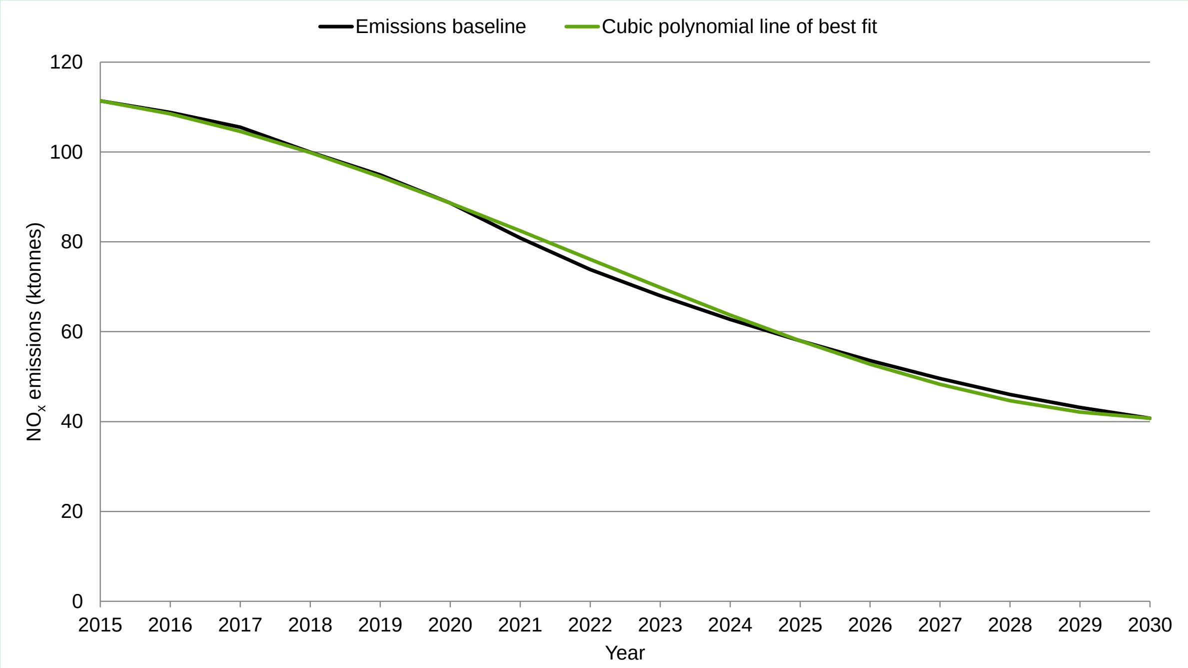


Figure H.4: UK baseline emission projections: all years compared to five year intervals with interim years estimated using a cubic polynomial line of best fit interpolation (kt NO_x)



Of these three alternative methodologies, only the cubic polynomial interpolation gives a more precise estimate than interpolating the interim years with a correlation coefficient to the actual baseline of 0.999 (Table **H.5**). Consequently, the linear interpolation methodology has been preferred for this report because it gives estimates that are likely to be extremely close to the actual values, and also gives a conservative estimate in the key years. The minor improvement in accuracy resulting from using a cubic polynomial function to interpolate interim years is not considered to be proportionate given the extra time required to calculate interim year values using this methodology.

Table H.5: Correlation between the modelled emissions estimates for all years and the estimates for emissions in interim years from four potential methodologies

Correlation coefficients	Interpolation of interim years	Linear line of best fit	Square polynomial line of best fit	Cubic polynomial line of best fit
Total correlation to modelled emissions	0.998	0.994	0.996	0.999
Correlation to modelled emissions for 2015-19	0.988	0.988	0.986	0.999
Correlation to modelled emissions for 2020-24	0.997	0.997	0.998	0.997
Correlation to modelled emissions for 2025-2029	0.997	0.997	0.998	0.999

It should be noted that estimating the concentration values in interim years will not be necessary for the final Plan because the SL-PCM model will be updated to generate additional outputs for these years

.

Annex I – Glossary of terms

Table I.1 : Table of terms		
Term	**Expanded form**	**Description**
ANPR	Automatic Number Plate Recognition	A technology used to automatically recognise vehicle number plates from a camera image
AURN	Automatic Urban and Rural Network	A network of automatic air quality monitoring stations measuring oxides of nitrogen (NO_x), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO) and particulate matter (PM_{10}, $PM_{2.5}$)
BCR	Benefit-Cost Ratio	An option's present benefits divided by its present costs. A ratio that is more than one represents an option with a positive net present value. A useful tool for comparing between different projects with different scales
BEIS	Department for Business, Energy and Industrial Strategy	Government department responsible for business, energy, and industrial strategy.
BEV	Battery Electric Vehicle	Vehicles powered by an internal battery
CAZ	Clean Air Zone	A policy designed to address areas of poor air quality. Within a localised geographical zone, clean-air initiatives will be encouraged and high-polluting vehicles may have to pay a charge.
CNG	Compressed Natural Gas	Methane gas stored at high pressure and a fuel that can be used in place of petrol, diesel, and liquefied petroleum gas.
COPERT	Computer Programme on Emissions from Road Transport	A computer program financed by the European Environment Agency to calculate the emissions of pollutants from road transport.
COPERT 5	Computer Programme on Emissions from Road Transport 5	The fifth and latest update of COPERT.
DECC	Department of Energy and Climate Change	Former governmental department responsible for energy and climate change, now part of BEIS

DfT	Department for Transport	Governmental department responsible for transport
DPF	Diesel Particle Filter	A device to remove particulate matter or soot from the exhaust gas of a diesel engine.
EV	Electric Vehicle	Vehicles powered by electricity, includes both hybrid and battery electric vehicles
FAM	Fleet Adjustment Model	The Fleet Adjustment Model quantifies the societal costs and benefits associated with changes in UK vehicle fleet
GBS	Government Buying Standards	A procurement standard used by all central government departments and their related organisations when buying goods and services for those product groups covered. The mandatory standards are encouraged for the wider public sector to specify in tenders.
GIS	Geographical Information System	A computer system for capturing, storing, analysing, and displaying data related to positions on Earth's surface.
HE	Highways England	The government company charged with operating, maintaining and improving England's motorways and major A roads, formerly the Highways Agency
HGVa	Articulated Heavy Goods Vehicles	Tractor units with a semi-trailer attached where part of the load is borne by the drawing vehicle
HGVr	Rigid Heavy Goods Vehicles	Heavy goods vehicles without a trailer attached
HGVs	Heavy Goods Vehicles	Larger vehicles constructed for transporting goods. Must have a gross weight more than 3.5 tonnes. This includes road tractors and curtain sided vehicles (with a gross weight of over 3.5 tonnes)
ICCT	International Council on Clean Transport	An independent non-profit organisation founded to provide first-rate, unbiased research and technical and scientific analysis to environmental regulators.
ICE	Internal Combustion Engine	An internal combustion engine is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit.

LGVs	Light Goods Vehicles	4-wheel vehicles constructed for transporting goods. Must have a gross weight of 3.5 tonnes or less. This includes road tractors and curtain sided vehicles (with a gross weight of 3.5 tonnes or less)
LowCVP	Low Carbon Vehicle Partnership	A public-private partnership, established in 2003, that exists to accelerate a sustainable shift to lower carbon vehicles and fuels and create opportunities for UK business
LPG	Liquefied Petroleum Gas	Alternative fuel for vehicles, as opposed to diesel or petrol
NEDC	New European Driving Cycle	The current laboratory test for measuring the level of CO_2 and pollutant emissions from vehicles so as to compare them against EU regulations. The standardised testing procedure allows comparison of emissions between different vehicle models.
NH_3	Ammonia	A gas that contributes to the formation of particulate matter in the atmosphere and can cause respiratory problems.
NM-VOCs	Non-methane volatile organic compounds	A variety of chemically different organic compounds, excluding methane, that easily become vapours or gases.
NO_2	Nitrogen Dioxide	A respiratory irritant that may cause respiratory problems and increase susceptibility to infections.
NO_x	Nitrogen Oxides	A respiratory irritant that may exacerbate asthma and possibly increase susceptibility to infections. The nitric oxide (NO) portion can form nitrogen dioxide in the atmosphere through oxidation.
NPV	Net Present Value	A calculation of the differences in the present value of an option’s cost and benefits streams. The NPV is the primary criterion for deciding whether government action can be justified.
NRMM	Non-Road Mobile Machinery	Any mobile machine, item of transportable industrial equipment, or vehicle - with or without bodywork - that is: 1. Not intended for carrying passengers or goods on the road. 2. Installed with a combustion engine - either an internal spark ignition petrol engine, or a compression ignition diesel engine. A generator is an example.

O_3	Ozone	A respiratory irritant: short-term exposure to high ambient concentrations can cause inflammation of the respiratory tract and irritation of the eyes, nose, and throat.
PCM	Pollution Climate Mapping model	A collection of models designed to fulfil part of the UK's EU Directive (2008/50/EC) requirements to report on the concentrations of particular pollutants in the atmosphere. It is consistent with the National Atmospheric Emissions Inventory (NAEI).
PM	Particulate Matter	A category of particles with a wide range of sizes and different chemical constituents.
PV	Present Value	The cost or benefit of an action in today's money. Future costs or benefits are discounted to the base year using Treasury guidelines
RDE	Real Driving Emissions	A test scenario to determine the emissions of vehicles in a road environment.
REVIHAAP	Review of evidence on health aspects of air pollution	A World Health Organisation document which presents answers to 24 questions relevant to reviewing European policies on air pollution and to addressing health aspects of these policies
SCR	Selective Catalytic Reduction	A means of converting emissions of NO_x from a stream of exhaust gases into water and other compounds by use of a catalyst
SL-PCM	Streamlined-PCM model	A simplification of the full Pollution Climate Mapping model.
SO_2	Sulphur Dioxide	A respiratory irritant that can cause constriction of the airways.
SRN	Strategic Road Network	Made up of the motorways and major trunk roads in England that are managed by Highways England, it comprises approximately 4,400 miles of road.
TfL	Transport for London	An integrated transport authority responsible for delivering the Mayor of London's strategy and commitments on transport. Runs the day-to-day operation of the Capital's public transport network and manages London's main roads.
TRL	Transport Research Laboratory	An independent transport consultant that provides innovative research, technology and software solutions for surface transport modes and related markets of automotive, motorsport, insurance and energy

UK-AIR	UK Air Information Resource	Defra's webpages that provide in-depth details on air quality and air pollution in the UK.
ULEVs	Ultra Low Emission Vehicles	New vehicles with pure electric engines, plug-in hybrid engines, or cars with CO_2 emissions below 75g/km at the exhaust pipe.
VED	Vehicle Excise Duty	An excise duty that must be paid to use a vehicle on the UK's public roads. The rate varies based on the car's quantity of CO_2 emissions.
WHO	World Health Organisation	A specialised branch of the United Nations (UN) that is concerned with international public health
WLTC	Worldwide Harmonised Light Vehicles Test Cycle	A means for determining the emissions and fuel consumption from light-duty vehicles.