Zero Emissions Vehicle Mandate and non-ZEV Efficiency Requirements Consultation-stage Cost Benefit Analysis

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ZEV Mandate Cost Benefit Analysis: Executive Summary

1. The UK is committed to delivering our legal obligations to achieve net zero CO_2e emissions by 2050 and deliver on upcoming carbon budgets as laid out in the Net Zero Strategy. These will require the rapid decarbonisation of the UK economy, requiring a 68% reduction in greenhouse gas (GHG) emissions by 2030 and a 78% reduction by 2035 (including international aviation and shipping emissions) from 1990 levels. Transport is the UK's largest GHG emitting sector, and cars, and vans make up two-thirds of transport emissions. Ultimately, delivering zero exhaust emissions from cars and vans requires a move to zero emission vehicles.

The problem under consideration

2. There are several causes of market failure which warrant government intervention. Greenhouse gas emissions are a negative externality – as the costs of GHG emissions from vehicles impact wider society. There is also a coordination market failure as delivering zero emission vehicles also requires deployment of the charging infrastructure and investment in power sectors at the same time. Providing greater certainty on zero emission vehicle deployment will provide a clear signal to invest in these interlinked markets.

Policy objectives

3. The key objective of this policy is to deliver substantial carbon savings, enabling the UK to transition to a zero-carbon economy by 2050, and supporting our industry in this transition. This will be achieved by increasing the share of new vehicle sales made up by zero emission vehicles. Simultaneously, the policy aims to strengthen the business case for chargepoint investment, by reducing uncertainty over short- and medium- term demand for charging. This is intended to catalyse private investment in chargepoints and develop a widespread charging network. Certainty over zero emission vehicle uptake in the UK also helps to build the case for investment in the wider UK zero emission auto sector and ecosystem.

Options considered

4. Several policy options were considered; a number being discounted at the long-list stage as they were not deemed to meet the policy's critical success factors. The baseline do-nothing option is deemed to deliver insufficient carbon savings and other benefits; increasing ambition of the current carbon-efficiency regulatory framework was deemed to have the potential to deliver significant savings, however it fails to support investment in the charging infrastructure network; fiscal measures such as EV grants also offer substantial savings, however are unlikely to be affordable at the scale required to meet net zero by 2050.

5. Of the short-list options, low, medium, and high ZEV trajectories are tested, alongside policy options which require efficiency improvements to the non-ZEV fleet. These options are presented in greater detail in Table 1. The Preferred Option was selected as it is deemed to strike the best balance between driving ZEV uptake and chargepoint investment, achievability for businesses, and affordability.

Table 1 Summary of short-list options appraised in this Cost Benefit Analysis

Policy option	Detail
0 (Do-nothing baseline)	The baseline 'do-nothing' policy option would maintain current retained EU CO_2 regulations. This would lead to some improvements in car and van emissions efficiency, which could be achieved through a mix of efficiency gains for non-ZEVs and increasing ZEV sales. This is the option against which the following options are appraised.
1 (Central ZEV; Preferred)	This option sets mandatory annual ZEV sales targets, coupled with manufacturer-specific non-ZEV CO_2 baselines, to ensure there is no regression on non-ZEV fuel efficiency. Targets ramp-up to 80% ZEV sales in 2030 for cars and 70% for vans. These are broadly aligned with those presented in the technical consultation, although the van trajectory has been increased, based on technical consultation feedback.
2 (Low ZEV)	This option is as above, however the ZEV sales targets are substantially lower. The car sales targets are based on SMMT's 'low' ZEV uptake trajectory and represents a very low level of ambition (with ZEV sales reaching 59% for cars and 38% for vans, in 2030), which in certain years falls below the expected baseline level of ZEV uptake.
3 (High ZEV)	This option is as above, however with substantially higher ZEV sales targets, which are broadly based on recommendations put forward by the Climate Change Committee. These represent a significant increase in the level of ambition, with ZEV sales shares exceeding 95% for both cars and vans in 2030.
4 (Central ZEV; incremental efficiency improvements)	This option is similar to the Preferred Option (Option 1), however it would also require manufacturers to make efficiency improvements of 2% per year to their average non-ZEV sales. As in option 1, ZEV sales shares ramp-up to 80% for cars and 70% for vans, in 2030.

Expected impacts

6. The Preferred Option is expected to achieve emissions savings of 31, 81, and 415 $MtCO_2e$ in carbon budgets 5, 6, and 2020-2050, respectively. It offers high value for money, with a social Net Present Value ranging from £44bn - £96bn, as well as supporting growth and employment in the low-carbon economy.

Notes

7. These proposals are treated as imputed tax and spend, and therefore outside the remit of the Regulatory Policy Committee.

Summary: Analysis & Evidence

Policy Option 1 (Preferred Option) – Central ZEV Trajectory with Flat CO_2 standard for non-ZEVs

Price Base	PV Base	Time Period	Net Benefit (Present Value (PV)) (£m)		
Year 2021	Year 2022	Years 50	Low: £-31bn	High: £184bn	Best Estimate: £44bn

COSTS (£m)	Average Annual (Constant Price)	Total Cost (Present Value)
Low	£2.2bn	£112bn
High	£1.4bn	£72bn
Best Estimate	£2.0bn	£101bn

Description and scale of key monetised costs by 'main affected groups'

Key monetised costs include capital (£27bn and £11bn for the marginal capital cost of vehicles and infrastructure, respectively); operational expenditure (opex) costs of operating and maintaining the infrastructure network (c.£2bn); and costs associated with potentially greater road usage (£52bn in congestion and £5bn in accidents). There are also social costs relating to increased traded emissions (emissions generated through the increased demand for electricity) and administrative costs (<£35m). There is significant uncertainty regarding induced demand and associated costs, and these are likely to be conservative over-estimates.

Other key non-monetised costs by 'main affected groups'

There may be costs associated with the electricity grid, to the extent that the policy leads to greater peak demand for electricity and requires grid reinforcement; there may be indirect costs to downstream businesses (e.g. car dealers); finally differences in the production emissions of ZEVs and ICEVs are not quantified. These impacts are highly uncertain, however future analyses will aim to expand the evidence-base ahead of the Government Response Cost Benefit Analysis.

BENEFITS (£m)	Average Annual (excl. Transition) (Constant	Total Benefit (Present Value)
Low	£1.6bn	£81bn
High	£5.1bn	£257bn
Best Estimate	£2.9bn	£145bn

Description and scale of key monetised benefits and negative costs by 'main affected groups'

There are very significant social benefits attributed to non-traded emissions savings (c.£103bn) which far outweigh the cost of increased traded emissions. Households are expected to benefit by more than £35bn in reduced running costs (c.£20bn and c.£15bn in reduced fuel costs and maintenance costs, respectively); in addition there are anticipated to be significant indirect tax (c.£4bn), air quality (c.£1bn), and consumer surplus benefits (c.£1bn).

Other key non-monetised benefits by 'main affected groups'

The employment impacts of the policy are not monetised. These include domestic ZEV manufacturing, as well as significant employment opportunities in the supply chain, installation, and maintenance of the chargepoint network.

Key assumptions/sensitivities/risks

Standard STPR:	3.5%
Long-term STPR:	3.0%
Health discount	1.5%
Long-term health	1.3%

This analysis is highly sensitive to the assumed 'rebound effect', of induced traffic. This leads to very significant social costs. It is likely an over-estimate; impacts excluding the rebound effect are presented in 'Section 2.0: Sensitivity Analysis'.

There are also risks relating to supply constraints, uncertainty around carbon savings, and the future cost of ZEVs relative to ICEVs. These assumptions are varied in 'Section 2.0: Sensitivity Analysis' and discussed in Section 3.0: Risks and unintended consequences.

Policy Option 2 – Low ZEV Trajectory with Flat CO_2 standard for non-ZEVs

Price Base Year 2021	PV Base Year 2022	Time Period Years 50	Net Benefit (Present Value (PV)) (£m)		
			Low: NA	High: NA	Best Estimate: £17bn

COSTS (£m)	Average Annual (Constant Price)	Total Cost (Present Value)
Low	NA	NA
High	NA	NA
Best Estimate	£0.4bn	£18bn

Description and scale of key monetised costs by 'main affected groups'

Key monetised costs include capital (£6bn and £3bn for the marginal capital cost of vehicles and infrastructure, respectively) and opex costs of operating and maintaining the infrastructure network (c.£0.5bn). There are also social costs relating to increased traded emissions (emissions generated through the increased demand for electricity) and administrative costs (<£35m). There may be greater fuel costs, caused by the interaction between lower-than-baseline non-ZEV efficiency and low ZEV uptake, of up to £5bn. However, there is significant uncertainty regarding induced demand and associated costs.

Other key non-monetised costs by 'main affected groups'

There may be costs associated with the electricity grid, to the extent that the policy leads to greater peak demand for electricity and requires grid reinforcement; there may be indirect costs to downstream businesses; finally differences in the production emissions of ZEVs and ICEVs are not quantified. These impacts are highly uncertain, however future analyses will aim to expand the evidence-base ahead of the Government Response Cost Benefit Analysis.

BENEFITS (£m)	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	NA	NA
High	NA	NA
Best Estimate	£0.7bn	£35bn

Description and scale of key monetised benefits by 'main affected groups'

There are social benefits attributed to non-traded emissions savings (c.£21bn) which far outweigh the cost of increased traded emissions. There may be reduced congestion and accident costs under this option (due to changes in average non-ZEV sales efficiency and much lower ZEV uptake; of potentially £7bn in congestion and £0.6bn in accidents); in addition there are anticipated to be maintenance (c.£6bn) significant indirect tax (c.£1.6bn), air quality (c.£0.2bn), and consumer surplus benefits (c.£0.3bn).

Other key non-monetised benefits by 'main affected groups'

The employment impacts of the policy are not monetised. These include domestic ZEV manufacturing, as well as significant employment opportunities in the supply chain, installation, and maintenance of the chargepoint network.

Key assumptions/sensitivities/risks

This analysis is highly sensitive to the assumed 'rebound effect', which leads to very significant social costs. It is likely an over-estimate; impacts excluding the rebound effect are presented in 'Section 2.0: Sensitivity Analysis'.

Standard STPR:	3.5%
Long-term STPR:	3.0%
Health discount	1.5%
Long-term health	1.3%

There are also risks relating to supply constraints, uncertainty around carbon savings, and the future cost of ZEVs relative to ICEVs. These assumptions are varied in 'Section 2.0: Sensitivity Analysis' and discussed in Section 3.0: Risks and unintended consequences.

Policy Option 3 – High ZEV Trajectory with Flat CO_2 standard for non-ZEVs

Price Base Year 2021	PV Base Year 2022	Time Period Years 50	Net Benefit (Present Value (PV)) (£m)		
			Low:	High:	Best Estimate: £67bn

COSTS (£m)	Average Annual (Constant Price)	Total Cost (Present Value)
Low	NA	NA
High	NA	NA
Best Estimate	£3.9bn	£193bn

Description and scale of key monetised costs by 'main affected groups'

Key monetised costs include capital (£51bn and £18bn for the marginal capital cost of vehicles and infrastructure, respectively); opex costs of operating and maintaining the infrastructure network (c.£4bn); and costs associated with potentially greater usage of road transportation (£105bn in congestion and £10bn in accidents). There are also social costs relating to increased traded emissions (emissions generated through the increased demand for electricity) and administrative costs (<£35m). There is significant uncertainty regarding induced demand and associated costs, and these may be likely to be conservative over-estimates.

Other key non-monetised costs by 'main affected groups'

There may be costs associated with the electricity grid, to the extent that the policy leads to greater peak demand for electricity and requires grid reinforcement; there may be indirect costs to downstream businesses; finally differences in the production emissions of ZEVs and ICEVs are not quantified. These impacts are highly uncertain, however future analyses will aim to expand the evidence-base ahead of the Government Response Cost Benefit Analysis.

BENEFITS (£m)	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	NA	NA
High	NA	NA
Best Estimate	£5.2bn	£260bn

Description and scale of key monetised benefits by 'main affected groups'

There are very significant social benefits attributed to non-traded emissions savings (c.£183bn) which far outweigh the cost of increased traded emissions. Households are expected to benefit more than £35bn in reduced running costs (c.£41bn and c.£23bn in reduced fuel costs and maintenance costs, respectively); in addition there are anticipated to be significant indirect tax (c.£5bn), air quality (c.£2bn), and consumer surplus benefits (c.£4bn).

Other key non-monetised benefits by 'main affected groups'

The employment impacts of the policy are not monetised. These include domestic ZEV manufacturing, as well as significant employment opportunities in the supply chain, installation, and maintenance of the chargepoint network.

Key assumptions/sensitivities/risks

This analysis is highly sensitive to the assumed 'rebound effect', which leads to very significant social costs. It is likely an over-estimate; impacts excluding the rebound effect are presented in 'Section 2.0: Sensitivity Analysis'.

Standard STPR:	3.5%
Long-term STPR:	3.0%
Health discount	1.5%
Long-term health discount rate:	1.3%

There are also risks relating to supply constraints, uncertainty around carbon savings, and the future cost of ZEVs relative to ICEVs. These assumptions are varied in 'Section 2.0: Sensitivity Analysis' and discussed in Section 3.0: Risks and unintended consequences.

Policy Option 4 – Central ZEV mandate, Incremental CO_2 Improvements on non-ZEVs

Price Base Year 2021	PV Base Year 2022	Time Period Years 50	Net Benefit (Present Value (PV)) (£m)		
			Low:	High:	Best Estimate: £44bn

COSTS (£m)	Average Annual (Constant Price)	Total Cost (Present Value)
Low	NA	NA
High	NA	NA
Best Estimate	£2.1bn	£106bn

Description and scale of key monetised costs by 'main affected groups'

Key monetised costs include capital (£31bn and £11bn for the marginal capital cost of vehicles and infrastructure, respectively); opex costs of operating and maintaining the infrastructure network (c.£2bn); and costs associated with potentially greater usage of road transportation (£53bn in congestion and £5bn in accidents). There are also social costs relating to increased traded emissions (emissions generated through the increased demand for electricity) and administrative costs (<£35m). There is significant uncertainty regarding induced demand and associated costs, and these may be likely to be conservative over-estimates.

Other key non-monetised costs by 'main affected groups'

There may be costs associated with the electricity grid, to the extent that the policy leads to greater peak demand for electricity and requires grid reinforcement; there may be indirect costs to downstream businesses; finally differences in the production emissions of ZEVs and ICEVs are not quantified. These impacts are highly uncertain, however future analyses will aim to expand the evidence-base ahead of the Government Response Cost Benefit Analysis.

BENEFITS (£m)	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	NA	NA
High	NA	NA
Best Estimate	£3.0bn	£150bn

Description and scale of key monetised benefits by 'main affected groups'

There are very significant social benefits attributed to non-traded emissions savings (c.£110bn) which far outweigh the cost of increased traded emissions. Households are expected to benefit more than £32bn in reduced running costs (c.£19bn and c.£13bn in reduced fuel costs and maintenance costs, respectively); in addition there are anticipated to be significant indirect tax (c.£4bn), air quality (c.£1.5bn), and consumer surplus benefits (c.£1bn).

Other key non-monetised benefits by 'main affected groups'

The employment impacts of the policy are not monetised. These include domestic ZEV manufacturing, as well as significant employment opportunities in the supply chain, installation, and maintenance of the chargepoint network.

Key assumptions/sensitivities/risks

This analysis is highly sensitive to the assumed 'rebound effect', which leads to very significant social costs. It is likely an over-estimate; impacts excluding the rebound effect are presented in 'Section 2.0: Sensitivity Analysis'.

Standard STPR:	3.5%
Long-term STPR:	3.0%
Health discount	1.5%
Long-term health	1.3%

There are also risks relating to supply constraints, uncertainty around carbon savings, and the future cost of ZEVs relative to ICEVs. These assumptions are varied in 'Section 2.0: Sensitivity Analysis' and discussed in Section 3.0: Risks and unintended consequences.

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1.0 Policy Rationale

Policy Background

1. The UK is committed to delivering our legal obligations to achieve net zero by 2050 and deliver on upcoming carbon budgets as laid out in the Net Zero Strategy. These will require the rapid decarbonisation of the UK economy, requiring a 68% reduction in GHG emissions by 2030 and a 78% reduction by 2035 (including international aviation and shipping emissions) from 1990 levels.

2. Transport represents the largest share of greenhouse gas emissions (GHGs) in the UK, and cars and vans, which are overwhelmingly powered by fossil fuels, represented two-thirds of domestic transport emissions in 2019. The Government has committed to end the sale of new petrol or diesel cars or vans by 2030, with all new car and van sales being composed of zero emission vehicles (ZEVs) by 2035. Between 2030 and 2035, new cars and vans can only be sold if they have significant zero emission capability.

3. In recent years, government has published multiple consultations[1] and engaged extensively with stakeholders about the appropriate policies to ensure that goal is met. This includes the 2035 delivery plan, published in July 2021, which lays out policies to make ZEVs more affordable, improve consumer awareness, accelerate infrastructure rollout, transition fleets, develop a UK supply chain, and maximise the sustainability of ZEVs.

4. However, it is also critical to set binding regulations to set the pace of the transition, with mandated targets ensuring the ZEV supply that is needed to deliver the significant carbon savings that are required to support our interim legally binding carbon budgets on the pathway to net zero. Other benefits will also include supporting the growth of our UK automotive sector, and providing investment certainty for charging infrastructure.

5. The UK's exit from the European Union provides an opportunity to re-examine the system for regulating vehicle emissions in light of the government's 2030 and 2035 targets. To this end, the government published a Green Paper on options for a new CO_2 regulatory framework for consultation in July 2021.

6. Based on the responses to consultation and the government's analysis, the government announced that it would adopt a ZEV mandate while continuing to regulate the emissions of the non-ZEV portion of the new car and van fleets to make sure they do not increase (hereafter referred to as ZEV mandate).

7. Initial views on the design of the ZEV mandate were set out for consideration in a Technical Consultation in April 2022. Based on the feedback and additional analysis, a third consultation with the full proposed policy has been published alongside this cost-benefit analysis.

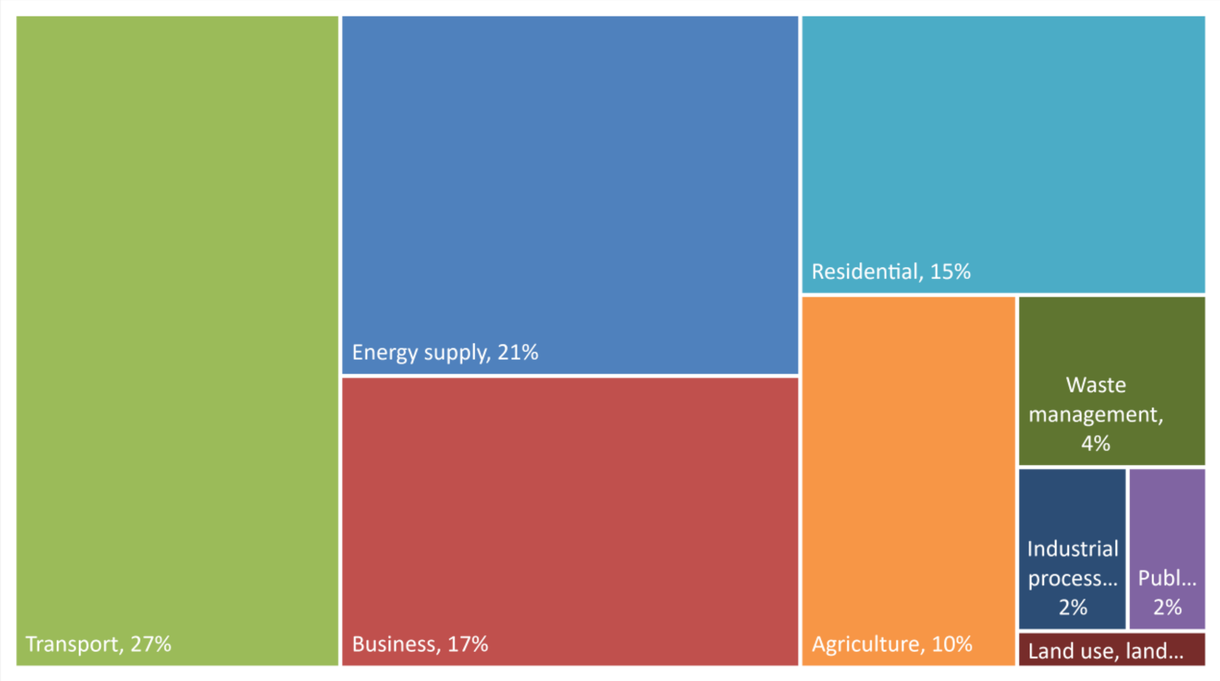
Problem Under Consideration

8. Transport is the UK's single biggest emitting sector. The final UK greenhouse gas national statistics show that in 2019, transport emissions amounted to roughly 122 $MtCO_2e$, or nearly 30% of total domestic emissions. In addition, the same data show over the 10 years to 2019, domestic emissions fell by roughly 25%, however transport emissions have fallen by less than 5%. Following COVID-19, transport emissions were suppressed by 28% in 2020 but have more recently bounced back in 2021 as restrictions eased. Although COVID-19 restrictions persisted into 2021, 2021 emissions rose somewhat to sit only 11.2% lower than 2019 levels, and provisional traffic statistics for Q1 2022 show road traffic on an upward trend back to pre-pandemic

[1] Green Paper; Technical Consultation.

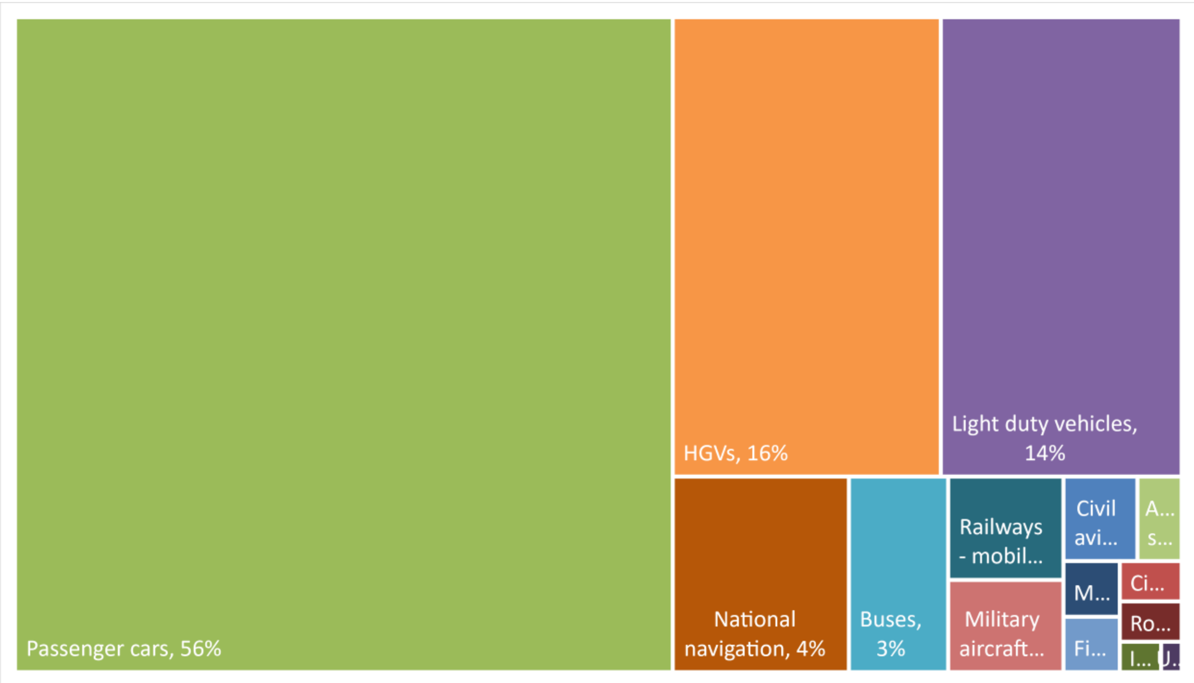
levels. This indicates that more needs to be done to decarbonise the transport sector, if the UK is to meet its stretching, legally binding emissions reductions targets.[2]

Figure 2 UK emissions breakdown by sector, 2019[3]



9. Within transport, cars and taxis are by far the single greatest source of emissions; as shown in Figure 3, these modes accounted for more than half of all UK domestic transport emissions in 2019. Light vans contribute an additional 16%, meaning that together these modes make up nearly three-quarters of UK domestic transport emissions; these equate to roughly 86.9 MtCO2e in 2019.

Figure 3 UK domestic transport emissions breakdown by type, 2019[4]



[2] In 2020, this figure fell to roughly 98.8 $MtCO_2e$, although transport activity was heavily affected by the Covid-19 pandemic and subsequent lockdowns. Car and van transportation continued to constitute more than two-thirds of domestic transport emissions. Source: Final UK greenhouse gas emissions national statistics: 1990 to 2020 - GOV.UK (www.gov.uk)

[3] Final UK greenhouse gas emissions national statistics: 1990 to 2020 - GOV.UK (www.gov.uk)

[4] Final UK greenhouse gas emissions national statistics: 1990 to 2020 - GOV.UK (www.gov.uk)

10. Furthermore, overall emissions from cars, taxis, and light vans have fallen by just 1.5% over the last decade. Car and taxi emissions fell by 7%, however light van emissions rose by more than 20%. Although efficiency gains have been driven by retained EU regulations, these are almost entirely offset by increased numbers of vehicles in the fleet, increased sales of heavier vehicles, and increased mileage. Therefore, it is clear that within transport, more needs to be done to decarbonise cars, taxis, and vans.

Rationale for Intervention

11. There are several key market failures which underpin the rationale for intervention in the car and van market and justify this type of intervention; they are set out in detail in the sub-sections below.

External costs

12. Externalities are costs and/or benefits of the production or consumption of a good, which are not directly experienced by the agents in a transaction. These external costs and benefits lead to allocations of resources and consumption of goods which differ from the socially optimal level. Where this occurs, government intervention is justified to bring the consumption of goods into line with the optimal level.
13. In the context of climate change, over-consumption of hydrocarbon fuels and associated carbon emissions will lead to increased average global air temperatures, with wide-ranging environmental impacts. This may include increased risk of extreme weather events, fires, water shortages, and rising sea levels, many of which may be irreversible and lead to severe environmental and economic damage.[5]
14. Road transport is currently heavily dependent on these hydrocarbon fuels; petrol and diesel cars and vans emit harmful greenhouse gas and air quality emissions from their exhausts, which impose external costs onto wider society both through their contribution to climate change but also through their impact on air quality, for instance.
15. These external costs are not currently reflected in the price paid by consumers, and there is therefore an over-consumption of petrol and diesel cars and vans, and associated fuel use relative to the socially optimal level. As of today, the Worldwide Harmonised Light Vehicles Test Procedure (WLTP) test cycle suggests that an average car emits 119.8 gCO_2/km and 198.5 gCO_2/km for vans (although there is conclusive, widespread evidence of a gap between WLTP-judged efficiency and real-world performance).[6,7]
16. DESNZ (the department for Energy Security and Net Zero) produce estimates for the value of carbon on society. As of 2021, this value sits at around £245 per tonne of carbon equivalent emitted in 2021 (in 2020 prices), reflecting a rough scale of externalities due to greenhouse gases borne by society due to CO_2e emitted by today's cars and vans. Electric cars and vans (or other zero emission technologies) in comparison produce zero exhaust emissions (and a fraction of the emissions on a lifecycle basis), which means they can dramatically reduce external costs.
17. One common approach to address external costs is to 'internalise' them by imposing taxes on the consumption of these products such as fuel duty. This is intended to align the private and social costs of consumption, thereby moving equilibrium consumption towards the socially optimal level. In 2020, using DESNZ carbon values, the carbon externalities on petrol fuel consumption is estimated at ~50 pence per litre meanwhile fuel duty is set at 59 pence per litre. There are,

5 What are the risks? - Climate Change Committee (theccc.org.uk)

6 VEH0156: Provisional average reported carbon dioxide (CO2) emission figures of vehicles registered for the first time by body type, fuel type and measure: Great Britain and United Kingdom

7 https://theicct.org/wp-content/uploads/2022/01/FactSheet_FromLabToRoad_ICCT_2016_EN.pdf; https://theicct.org/wp-content/uploads/2022/06/real-world-phev-use-jun22-1.pdf

however, many other significant externalities of fuel consumption such as air quality, congestion, accidents, road wear and tear which DESNZ carbon valuations do not include.

18. Furthermore, there are behavioural considerations which may undermine the effectiveness of policy levers such as this. Most notably, there is widespread evidence that economic agents have a preference to delay costs and realise benefits sooner. In many instances, ZEVs are expected to offer drivers considerable savings, over relatively short periods; however, they currently come at a premium. The greater salience of these up-front costs, despite the potential for significant medium-term savings, is a barrier to investment for many.
19. As a result, it is unclear whether policy levers which look to internalise the social costs of driving Internal Combustion Engine Vehicles (ICEVs) are able to deliver the level of emissions reduction required to meet the UK Government's legally binding targets. Therefore, this consultation includes several additional policy levers which are expected to be more effective at addressing these externalities, thereby reducing emissions while supporting economic growth.

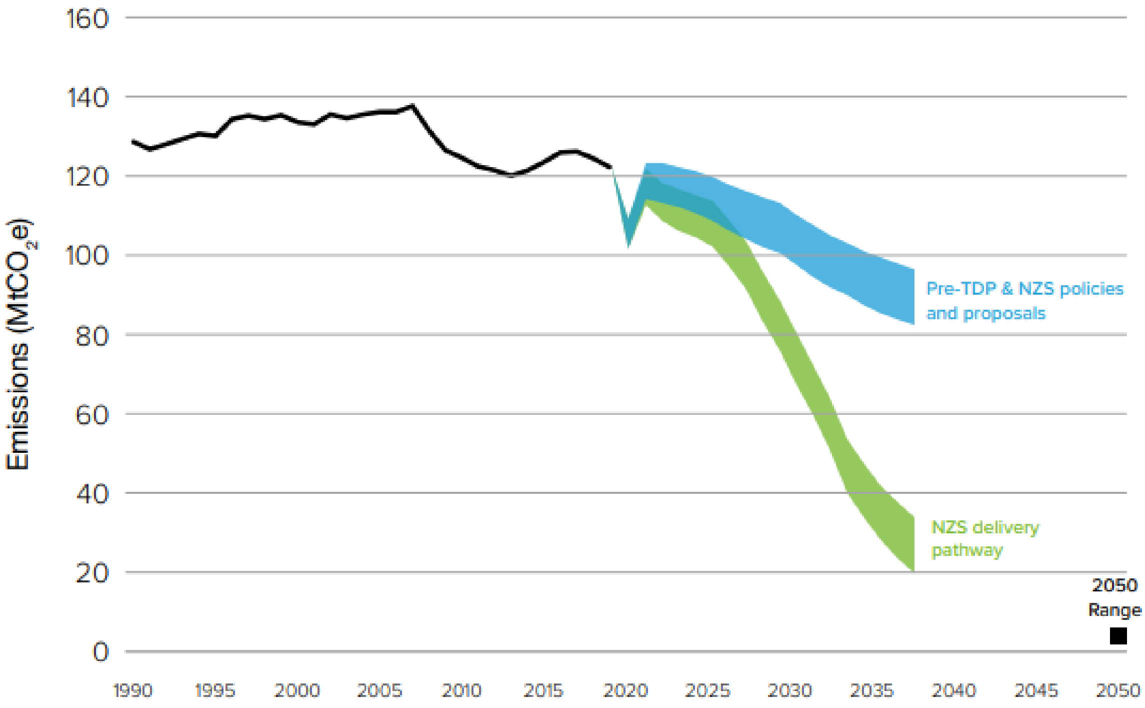
Legal rationale

20. The UK was the first major economy to legislate the requirement to reach net zero emissions by 2050 – to deal with externalities caused by GHG (Greenhouse gas) emissions and avoid the risk of catastrophic climate change. As part of this, the UK also set legally binding carbon budgets which set the economy-wide course for decarbonisation; these targets are among the most challenging globally.
21. Achieving net zero requires action from all sectors of the economy. For road transport it requires effectively all vehicles to be zero emission at the exhaust by 2050, combined with decarbonisation of upstream power. Regulatory intervention is critical to guaranteeing the rapid uptake of ZEVs to ensure contribution towards legally binding interim carbon reduction requirements on the pathway to net zero.
22. However, current baseline 'do-nothing' projections suggest roughly 42% car ZEV sales in 2030, and 12% for vans. Within this baseline, we expect 67% of car mileage to be zero emission by 2050, and 45% for vans. This is inconsistent with the UK Government's Net Zero Strategy and would risk compliance with its legally-binding carbon budgets and net zero 2050 commitment.
23. The effect of changing the car and van fleet takes many years; vehicles have an average expected functional lifetime of 14 years, but this can exceed 20 years. Because the baseline and proposed policies impact new car and van sales (rather than the stock of the fleet), further action is needed in earlier years (before 2035) to achieve these interim carbon budget targets.

Figure 4 UK emissions reductions commitments

Target	Carbon Budget 4	NDC	Carbon Budget 5	Carbon Budget 6	Net Zero
Target horizon	2023-2027	2030	2028-2031	2032-2037	2050

Figure 5 Indicative domestic transport emissions pathway to net zero 2050



Source: BEIS analysis

Information/coordination failure

24. There also exists a coordination challenge with regard to the transition to zero emission transport: ZEVs require a new refuelling network in order to ensure they become suitable substitutes for non-ZEVs, which already have access to a widely-distributed refuelling network. The required investment for battery electric vehicles may be lesser than other technologies, as existing electricity distribution infrastructure is already in place, nonetheless the investment required to develop adequate coverage for ZEVs is very significant, and private business cases for investment in chargepoints require certainty over levels of future demand.

25. Simultaneously, consumers base the decision on whether to buy a ZEV or non-ZEV on factors including anticipated range and whether access to charging is guaranteed – so-called 'range anxiety'. As a result, there is a 'chicken-and-egg' problem where uncertainty regarding the supply and demand for chargepoints inhibits investment in ZEVs and chargepoint infrastructure.

26. This coordination failure can be solved by sending a clear signal to industry that ZEVs will be required for the UK's transition to net zero emissions, as well as from 2050 onwards. This improves certainty for chargepoint investors, improving private business cases for chargepoint provision, which in turn is expected to alleviate consumer concerns regarding the availability of charging stations.

27. It should be noted that this certainty is not provided by the baseline scenario, in which incremental gains in average new sales gCO_2/km efficiency are required. This is because these requirements can be met either through technologies which *do* require chargepoints (e.g. the sale of ZEVs and Plug-in Hybrids), the sale of lighter vehicles (which are typically more efficient, and do not raise demand for chargepoints), or improvements in engine technology and full-hybrids (which also do not raise demand for chargepoints).

28. However, eventually more stretching incremental targets will only be achievable through increased sales of ZEVs. Under this option, where incentives for investment in chargepoints are weaker – it is possible that the chargepoint network will be insufficient to support the eventual increase in ZEV adoption as these efficiency targets reach 0 gCO_2/km. For this reason, policy options which send clearer signals to related industries are investigated.

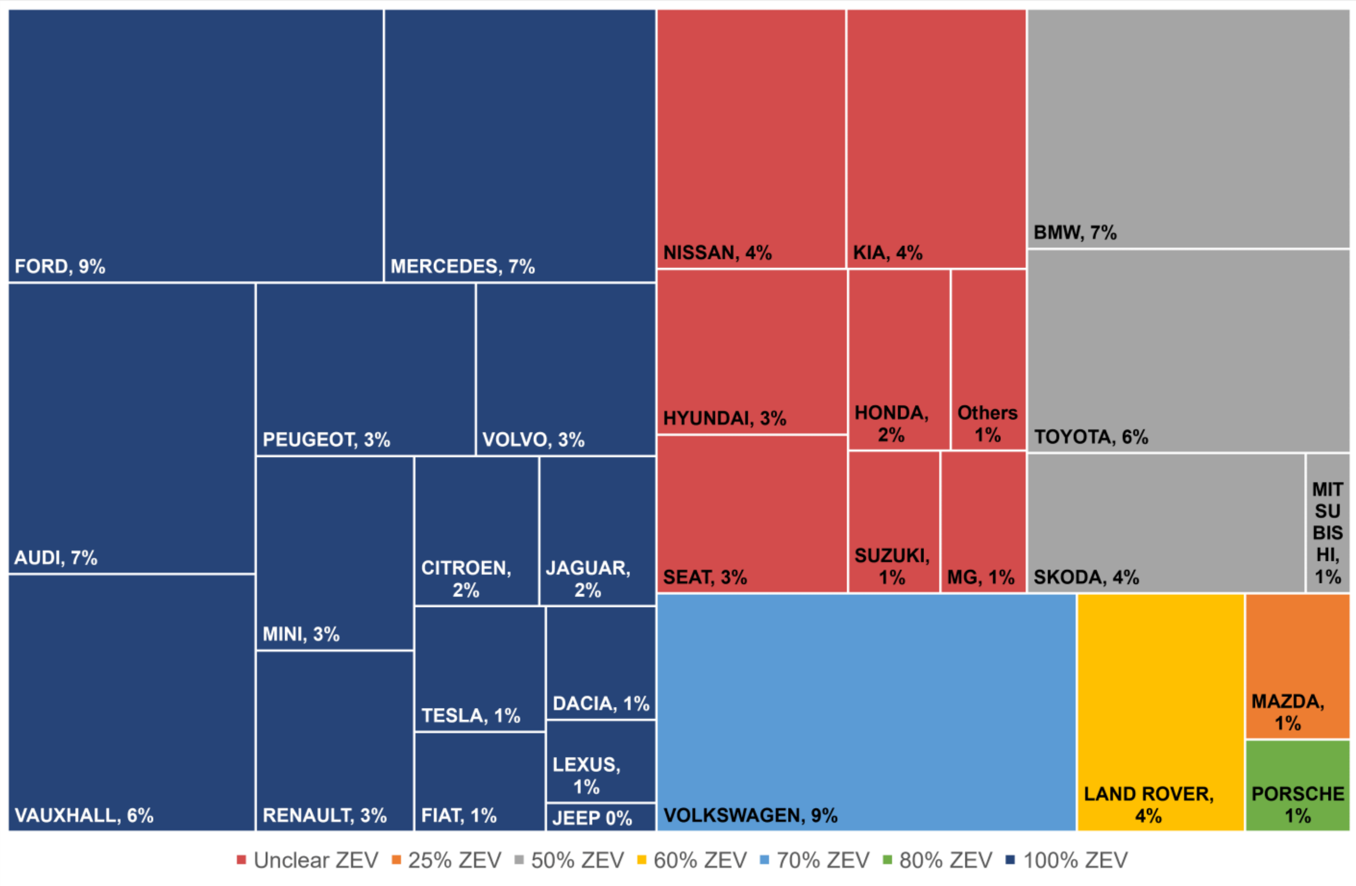
Regulatory failure – challenges of measuring CO_2 using test cycles

29. An additional challenge facing regulations to date has been the continuing disparity between measured car and van performance on a test cycle and their real-world emissions. ICCT research shows that this disparity has been increasing over time. Historically, this has made measuring CO_2 reductions difficult for vehicles with petrol and diesel engines, increasing the uncertainty regarding the success of CO_2 performance improvement policies.
30. The difference between the test cycle and real-world performance has been especially dramatic for Plug-in Hybrid Electric Vehicles (PHEVs) – where the latest evidence indicates that the real-world gap can be 5 times higher than the performance measured at the test cycle for company cars and 3 times for private cars.
31. This means regulations specifying future reductions in the emissions of vehicles with petrol and diesel engines are likely to result in much smaller real-world savings or do so with higher decarbonisation uncertainty. In comparison shifting to zero emission vehicles, given the increasingly large share of UK electricity supply which is generated by renewable technologies, means large and more certain CO_2 savings, whilst at the same time focussing investment in the destination zero emission technologies.

Rationale for government intervention rather than market forces

32. To ascertain whether Government intervention is necessary, evidence has been gathered from manufacturers on their ZEV commitments by 2030 (as of announcements made by March 2022). Figure 6 shows these commitments by the relative market share of each manufacturer within the UK car sales market.
33. This illustrates that ~65% of the total 2020 market share have already made commitments to be zero emission by 2030. However, we recognise these commitments are pre-emptive and reflect, to some degree, the early signal of previous combustion engine phase out announcements made by the UK Government.
34. Additionally, vehicle markets are highly globally connected. While the industry scales up its ZEV production capacity, failure to legislate levels of ZEV supply risks the diversion of a potentially finite supply of ZEVs away to other markets, leaving the UK behind in the global transition.
35. Furthermore, current ZEV production costs exceed those of ICEVs, which may disincentivise high levels of ZEV production (see Capital Cost section for cost projections). In the long-run, it might be expected to be economical (profit maximising and cost minimising) for manufacturers to produce ZEVs. Without further policy intervention, and because the market is very competitive (with a large number of firms in the market which compete on both price and quality through differing product segments) ZEV sales numbers are expected to fall below the required level to contribute towards meeting the required carbon budgets – as a result of a competitive penalty for being a first-mover in the market. As a result, in the short-run, further action is needed.

Figure 6 Zero emission car manufacturing expectations by 2030 (as of August 2022 announcements)[8]



Policy Objective

36. The ZEV mandate will set legally binding annual targets for the share of new cars and vans that are sold in the UK each year to ensure that these segments are on track to meet the government's decarbonisation goals. The mandate will be enacted as a trading scheme under the Climate Change Act of 2008.

37. The number of new non-ZEV vehicles that may be sold each year will be capped through the allocation of allowances. ZEV sales requirements will increase each year from 2024-2030, aligned with the high-level phase-out targets for 2030 and 2035. The policy will contain several flexibilities to accommodate small volume manufacturers and enable a smoother transition to the new regulatory framework in the initial years of the policy while preserving the certainty to industry afforded by a ZEV mandate.

38. The new regulatory framework is designed to shift manufacturers' efforts toward moving to ZEVs as quickly as possible rather than improving the efficiency of ICE vehicles. However, ICE vehicles will remain a substantial share of new vehicle sales for several years. Therefore, this legislation will also include a CO_2 standard to regulate the greenhouse gas emissions of the new vehicles which are not ZEVs. This standard, which will also operate as a trading scheme under the Climate Change Act, will be set as a baseline against performance in 2021, to ensure that ICE vehicles do not become less efficient over time.

39. Taken as a whole, this new regulatory framework is intended to significantly reduce emissions from cars and vans in the UK. In addition, we anticipate the policy will: encourage investment in infrastructure provision; bring increased consumer confidence; ensure we are less reliant on

[8] ZEV manufacturer expectations represent what manufacturers have publicly announced up to August 2022. The areas of boxes reflect the UK registration market share each manufacturer has based on the 2020 DVLA vehicle registration by make statistics.

imported fossil fuels; and ensure UK domestic manufacturing is well placed for a zero emission future delivering inward investment, growth and jobs.

Summary of Options Considered

40. This section sets out the policy options considered which address the problem under consideration. Per HMT Green Book guidance, the first option presented (Policy Option 0) represents the baseline/do-nothing counterfactual. The subsequent policy options present the key details of separate options, with particular focus on how they differ. Afterwards, additional policy details which apply to each of policy options 1-5 are presented.

Table 7 Summary of policy options considered in this appraisal

Category	Option	Details
Do Nothing – trajectory & non-ZEV CO_2 requirements	0 - baseline	In the do-nothing scenario, the UK maintains the existing retained EU CO_2 regulations. For cars, this results in a 15%, 37.5% gCO_2/km reduction in 2025, 2030 to a 2021 baseline. Manufacturers can comply via deploying ZEVs or more efficient non-ZEVs.
Central ZEV targets trajectory (preferred option)	1 – Central ZEV trajectory + Flat non-ZEV CO_2 requirements	A central trajectory of annual ZEV sales targets, plus a flat non-ZEV CO_2 requirement for each manufacturer, based on their 2021 average of new sales. Trading, banking, two-way credit transfers, and borrowing permitted, with payments for non-compliance.
Low ZEV targets trajectory	2 – Low ZEV trajectory + Flat non-ZEV CO_2 requirements	A low trajectory of annual ZEV sales targets, plus a flat non-ZEV CO_2 requirement for each manufacturer, based on their 2021 average of new sales. Trading, banking, two-way allowance transfers, and borrowing permitted, with payments for non-compliance.
High ZEV targets trajectory	3 – High ZEV trajectory + Flat non-ZEV CO_2 requirements	A high trajectory of annual ZEV sales targets, plus a flat non-ZEV CO_2 requirement for each manufacturer, based on their 2021 average of new sales. Trading, banking, two-way credit transfers, and borrowing permitted, with payments for non-compliance.
Non-ZEV CO_2 improvement, plus central ZEV targets trajectory	4 – Tightening non-ZEV CO_2 requirements (marginal improvement of 2% per annum) + central ZEV targets trajectory	The central series of annual ZEV sales targets, plus requirements for manufacturers to make incremental improvements to their non-ZEV CO_2 efficiency, at a rate of 2% per year. Trading, banking, two-way credit transfers, and borrowing permitted, with payments for non-compliance.

41. The options summarised in the table above relate to the *short-list* of policy options (those that were deemed to at least partially meet the policy's critical success factors [CSFs]). Other options were considered at the long-list stage; this includes options such as tightening the existing CO_2 efficiency regulatory framework. However, such options were discounted due to their inconsistency with one or more of the policy's CSFs.

42. In keeping with HMT Green Book guidance for economic appraisal, this cost benefit analysis covers the direct impact of this secondary legislation. For this reason, we model the first phase of the ZEV mandate which raises targets year-on-year until 2030, after which they are assumed to stay constant for modelling purposes. However, Government is clear that the second phase of the ZEV mandate (including subsequent annual targets from 2031 to 2035) will be implemented at a level no less ambitious than set out in the accompanying consultation on the full policy.

Option 0 – Do Nothing/Baseline

43. Under the current 'Do nothing' policy option, current retained EU CO_2 regulations remain in place; this is the baseline against which alternative policy options are appraised. These regulations impose a target for the average CO_2 emissions, measured in g/km, across the new car and van fleet. The targets apply to each manufacturer but are adjusted based on vehicle mass. Manufacturers can meet the requirement with any strategy through using ZEV sales or more efficient non-ZEVs. The regulations are tightened only every 5 years, meaning that no improvement in efficiency is required in the interim years.

44. The details of this option are set out in Table 8. As shown, they are expected to achieve a 15% reduction in the emissions of new cars and vans from 2025, and a reduction of 37.5% and 31% from 2030, for cars and vans, respectively. There are penalties which are intended to impose prohibitive costs of non-compliance, while several flexibilities, exemptions, and derogations are included in order to mitigate disproportionate impacts for smaller businesses and reduce costs.

Table 8 Baseline policy[9]

Baseline gCO_2/km target	2020-2024	2025-2029	2030
Car	95g (NEDC)	15% reduction, relative to 2021 levels	37.5% reduction, relative to 2021 levels
Van	147g (NEDC)	15% reduction, relative to 2021 levels	31% reduction, relative to 2021 levels
Incentive mechanism	2020	2021	2022
Car	2 certificates if <50g	1.67 certificates if <50g	1.33 certificates if <50g
Van	N/A	N/A	N/A
Flexibility mechanism			
Pooling	Manufacturers can group together and act jointly to meet their emissions target. In forming such a pool, manufacturers must respect the rules of competition law. Pooling between car and van manufacturers is not possible.		
Penalties	If the average CO_2 emissions of a manufacturer's fleet exceed its specific emission target in a given year, the manufacturer has to pay – for each of its vehicles newly registered in that year – an excess emissions premium of €95 per g/km of target exceedance.		
Exemption	Manufacturers responsible for fewer than 1,000 cars or fewer than 1,000 vans newly registered in the EU per year are exempted from meeting a specific emissions target, unless they voluntarily apply for a derogation target.		
Derogation	Manufacturers may apply for a derogation from their specific emission target at the following conditions: A small-volume manufacturer (responsible for less than 10,000 cars or less than 22,000 vans newly registered per year) can propose its own derogation target, based on the criteria set in the Regulation. A niche car manufacturer (responsible for between 10,000 and 300,000 cars newly registered per year) can apply for a derogation for the years until 2028 included. Between 2020 and 2024, the derogation target must correspond to a 45% reduction from its average emissions in 2007. In the years 2025 to 2028, the derogation target will be 15% below the 2021 derogation target.		
Zero and Low Emission Vehicle (ZLEV) Factor	From 2025, a bonus-only mechanism applies, whereby manufacturers registering above a set percentage of ZLEVs each year (defined as vehicles with CO_2 emissions < 50g CO_2/km) may see their overall CO_2 target relaxed by up to 5%. The percentages are 15% for 2025-2029, and 35% for 2030 onwards.		

[9] https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

ZEV uptake expected in the baseline

45. There is expected to be increased uptake of ZEVs in the baseline due to the existence of the current regulatory environment, falling costs and increasing diversity of ZEVs and the expanding infrastructure network. Recently SMMT have published the following short term projections for ZEV cars and vans presented in Figure 9 and Figure 10.

Figure 9 ZEV (car) uptake based on past ZEV recent statistics and forecasts

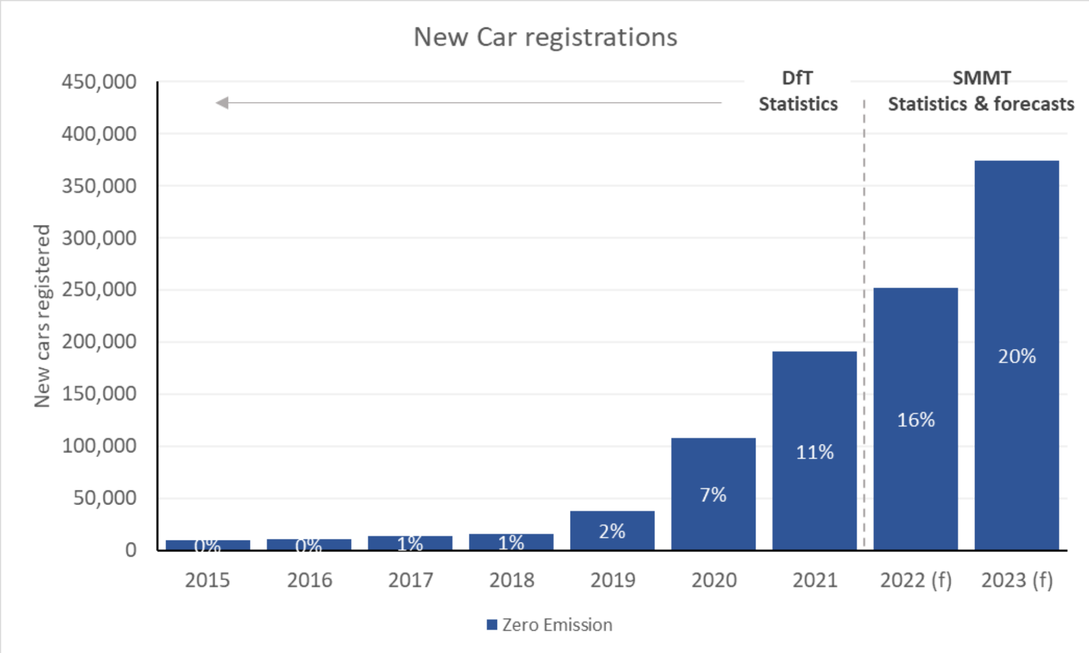
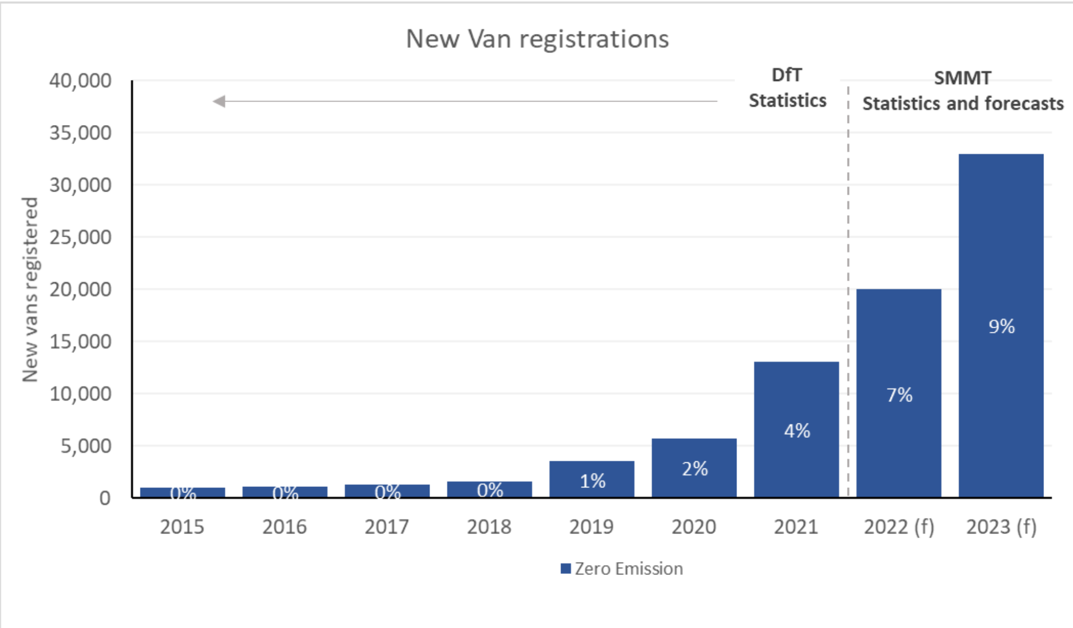


Figure 10 ZEV (van) uptake based on past ZEV recent statistics and forecasts



46. DfT produce bespoke projections of ZEV uptake, based on vehicle costs, battery price costs, and our consumer preference model. We estimate the amount of ZEV sales based on relative price differences of powertrains and consumer choices (more details presented in Annex A.1). These projections of ZEV uptake are produced below. This baseline projection results in an estimate of 42% car ZEV sales in 2030, 12% for vans. Since this forecast was last updated, van makes and models have come forward more quickly than previously expected with the SMMT now expecting 10% of van sales to be ZEV by 2023. We will review the baseline for the final stage Impact Assessment.

Table 11 Car and van ZEV uptake baseline forecast

	2024	2025	2026	2027	2028	2029	2030
Car	23%	26%	30%	33%	37%	40%	42%
Van	3%	4%	4%	5%	7%	9%	12%

Table 12 Average carbon intensity (gCO_2/km) of non-ZEVs in the baseline

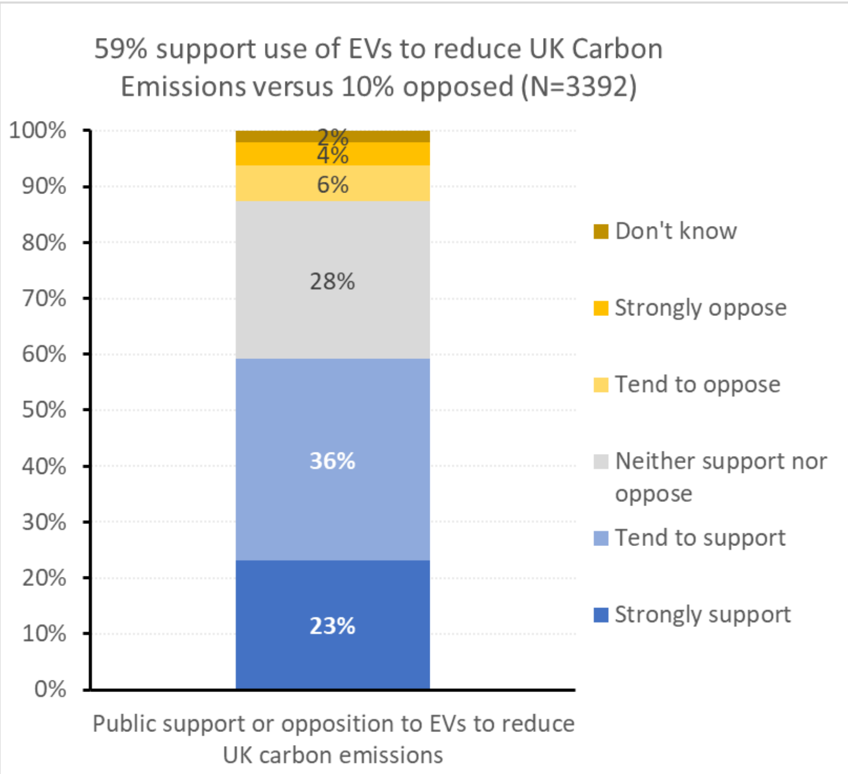
	2024	2025	2026	2027	2028	2029	2030
Car	157.91	154.95	154.23	153.48	153.11	152.80	152.66
Van	213.01	192.06	192.05	192.03	191.99	191.93	170.69

47. Within this baseline, we expect a significant proportion of mileage to come from ZEVs, with 67% of car mileage to be zero emission by 2050, and 45% for vans. However, this results in an inadequate contribution to the UK's legally binding net zero Target and interim carbon targets. For this reason, the 'do-nothing' baseline is deemed to be an unsuitable policy option.

48. Several further policy options are set out in the section below. These options are all based on minimum ZEV sales requirements, as opposed to the average CO_2 requirements used in the baseline policy. This is because zero emission vehicles are ultimately the technology required to deliver net zero, there is a need to provide greater certainty for recharging infrastructure provides, and the problems of measuring reductions in petrol and diesel emissions using the test cycle. These incentives are vital to ensuring a well-functioning, widely-available infrastructure network is in place to facilitate the transition to zero emission transport.

49. Additionally, there is expected to be widespread public support for the use of ZEVs to help reduce the UK's carbon emissions. Figure 13 is taken from the Department for Transport's Technology Tracker Survey, which finds that only 10% oppose the use of EVs to reduce carbon emissions, while nearly 60% support it.

Figure 13 Public attitudes to the use of EVs to reduce emissions



Option 1 – Central ZEV Mandate Option (Preferred Option)

50. This section sets out Policy Option 1 – the Preferred Option. For the car and van market this would set legally binding annual minimum sales proportions for ZEVs[10] , with this requirement placed on manufacturers. For cars the target rises from 22% in 2024 to 80% in 2030 and for vans from 10% in 2024 to 70% in 2030. These targets would be converted into a number of allowances manufacturers are required not to exceed each year.

51. These annual targets would raise ZEV take-up considerably above the expected baseline level of sales from 2024. This is intended to alter the composition of the car and van fleets, considerably reducing overall emissions as older ICEVs are replaced by zero exhaust emissions vehicles, whilst also providing certainty and strong incentives to invest in the chargepoint infrastructure network. The targets trajectories can be seen in Figure 14, Figure 15, and Table 16.

Figure 14 Car manufacturers' annual targets

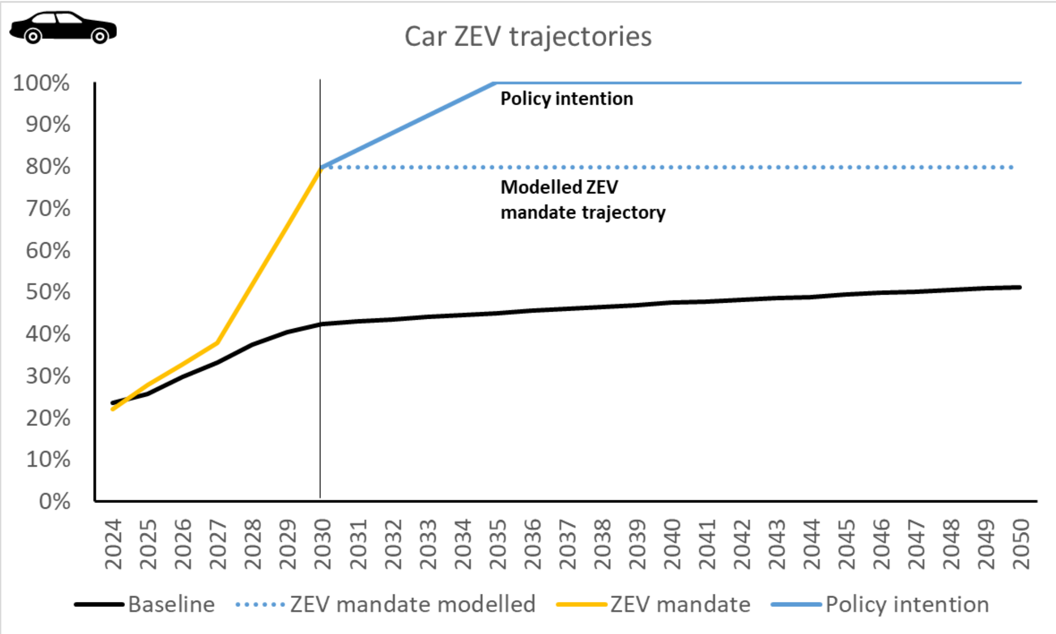
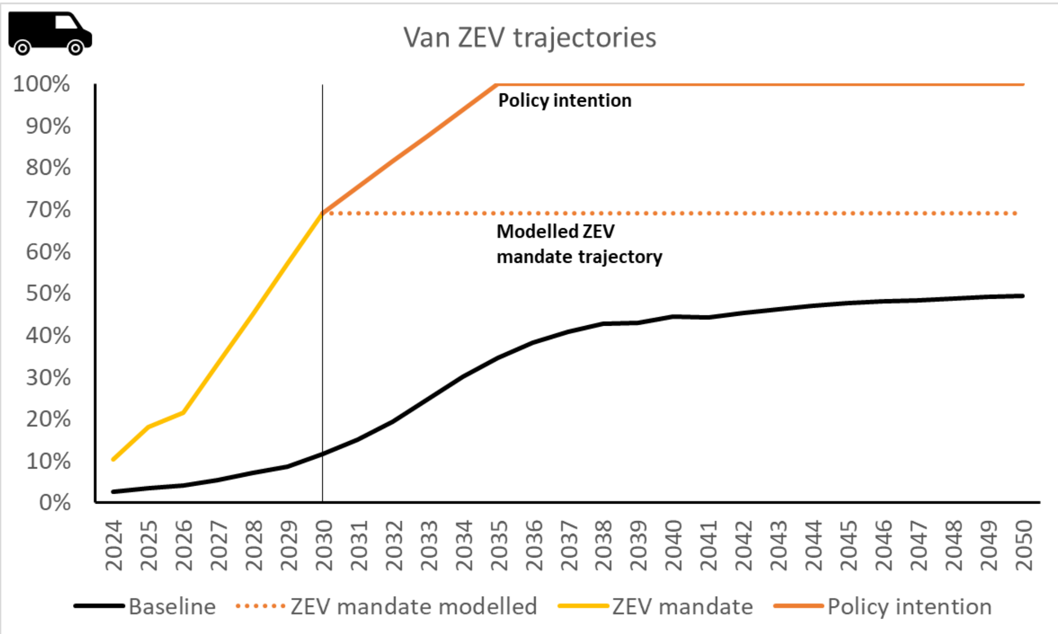


Figure 15 Van manufacturers' annual targets



[10] ZEVs are defined as vehicles which have zero exhaust emissions, such as battery electric hydrogen fuel cell vehicles.

Table 16 Central ZEV uptake targets for each manufacturer

	2024	2025	2026	2027	2028	2029	2030
Car	22%	28%	33%	38%	52%	66%	80%
Van	10%	19%	22%	34%	46%	58%	70%

52. In addition, in order to maximise the additionality of carbon abatement achieved by these proposals, manufacturers would be set a baseline average CO_2 emissions (gCO_2e/km) for the non-ZEV sales in each year. This would be set based on manufacturers' average sales emissions in 2021 (excluding ZEVs) and remain constant out to 2030. 2021 is chosen as to give necessary time to process emissions performance data by the intended implementation date of 2024.

53. Under these proposals, manufacturers would be permitted to meet their targets through a mix of selling ZEVs and by purchasing allowances from other manufacturers. They would also be permitted to 'bank' surplus allowances to be redeemed in subsequent years or 'borrow' a number of allowances from future years, with some limitations. Finally, manufacturers will be permitted to transfer over-delivered credits between the ZEV and non-ZEV elements of the scheme, subject to certain limitations. These flexibilities are expected to mitigate risks associated with product cycles, uncertainty e.g. regarding sales volumes, and support competition.

54. Manufacturers failing to meet their targets through this mix of opportunities would be required to make a payment for each vehicle sold which is not covered by an allowance or credit. This payment may lead to additional costs to business, however it is required in order to provide sufficient incentives for firms to comply with the regulations. It should be noted that, as set out in Table 8, similar payments exist in the current baseline regulations.

Changes to the Central Option since the Technical Consultation

55. These proposals have been amended, based on feedback provided through ZEV Mandate Technical Consultation, published in April 2022. Many stakeholders suggested that higher van targets were preferred and feasible. Furthermore, they supported a lesser focus on van hybrid technology as these technologies are not widespread and are not expected to be widely developed before the phase-out of non-ZEV technologies. Additionally, modelling undertaken by the CCC which underpins the Sixth Carbon Budget also follows this low expectation of van PHEV technology. The proposed central van trajectory has therefore been adjusted to 70% by 2030, with corresponding increases from 2024 – 2029, to reflect this feedback (see Annex D.2. for more information).

56. In addition, the technical consultation discussed the potential for some incremental improvements to non-ZEV average emissions. However, additional research and development into further incremental improvements to combustion engine efficiency technologies is no longer a key objective. For this reason, in the central scenario no efficiency improvements are imposed on manufacturers' non-ZEV fleets. They are, however, appraised in Policy Option 4.

Option 2 – Low ZEV Mandate Option

57. This policy option is identical to Policy Option 1, except that the level of ambition, as determined by the annual ZEV targets, is lower. This reflects feedback received by a small proportion of technical consultation respondents that the proposed targets would be difficult and/or costly to meet.

Table 17 Low ZEV uptake targets

	2024	2025	2026	2027	2028	2029	2030
Car	21%	21%	21%	26%	33%	44%	59%
Van	4%	6%	8%	16%	20%	28%	38%

58. For cars, the low trajectory reflects the relative % ZEV sales ambition stated in the SMMT Low (unsupported) scenario. For vans, the central van trajectory is adjusted to proportionately adopt the same level of delivery ambition as for cars relative to their respective baseline starting point. Because vans start at a much lower baseline, the lower trajectory is therefore proportionately lower than the car low trajectory. These less ambitious targets are expected to result in significantly lower carbon savings.

Option 3 – High ZEV Mandate Option

59. As above, this policy option matches the details of Policy Options 1 and 2, except that a higher set of annual targets is imposed. This reflects the fact that several technical consultation respondents suggested that more action is required in order to safeguard the UK Government's progress against its legally binding emissions reductions commitments. It is also broadly consistent with the most ambitious targets of a number of manufacturers to only sell zero emission vehicles from 2030.

Table 18 High ZEV uptake targets

	2024	2025	2026	2027	2028	2029	2030
Car	26%	41%	46%	50%	62%	77%	97%
Van	14%	25%	30%	46%	63%	80%	96%

60. The targets used in this scenario are based on recommendations set out in the CCC's 'The Sixth Carbon Budget: Surface Transport' report. These are significantly more ambitious than those presented in the central scenario (of which the vans targets have been increased since the technical consultation) and the low scenario. It is possible that the targets are not achievable without significant trading and payments made by some individual manufacturers; nonetheless, this option is included as a point of reference.

Figure 19 Comparison of car trajectories under Policy Options 1, 2, and 3

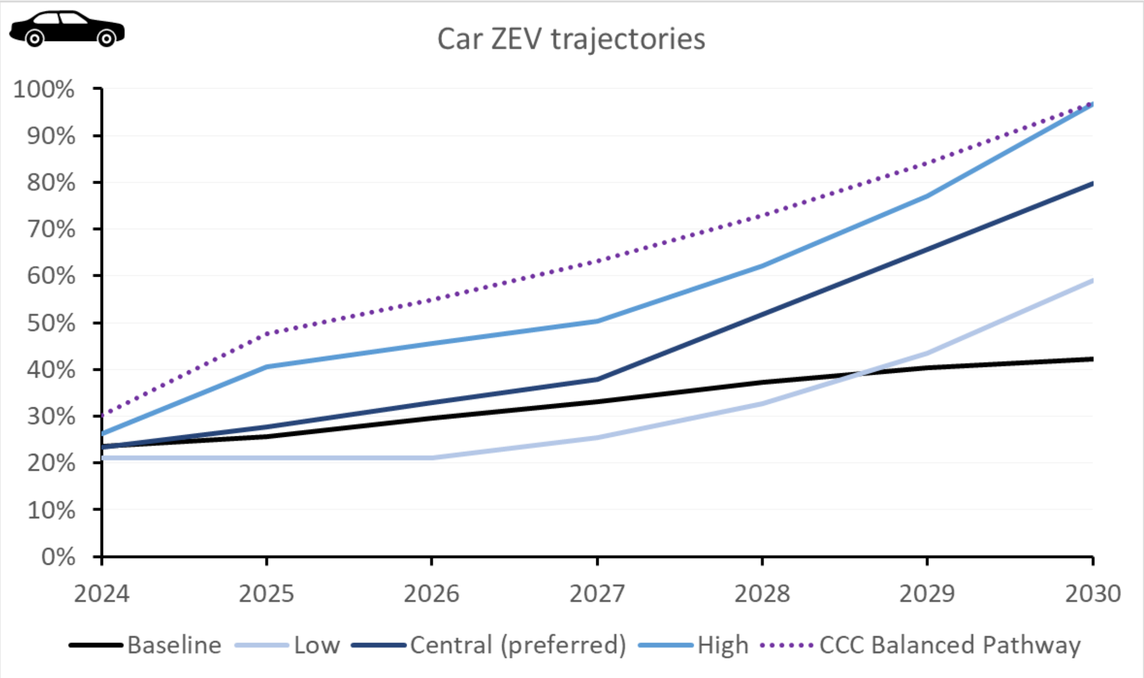
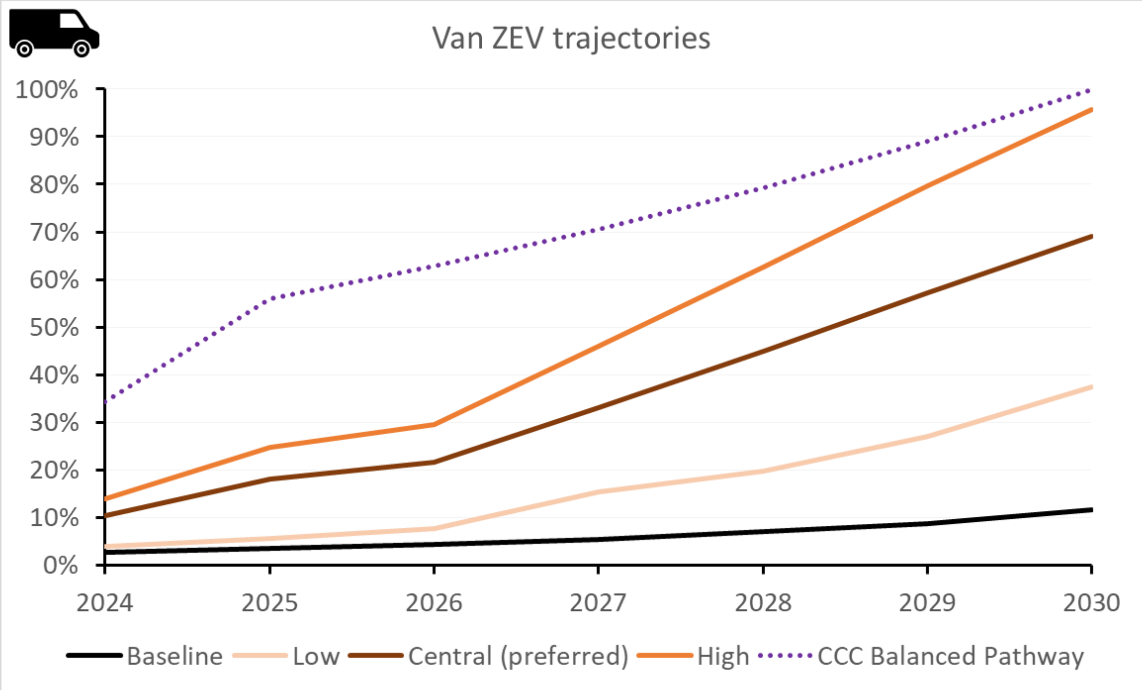


Figure 20 Comparison of van trajectories under Policy Options 1, 2, and 3



Option 4 – Central ZEV Mandate with Incrementally Tightening non-ZEV CO_2 Requirements

61. The technical consultation suggested that incremental improvements to manufacturers' non-ZEV CO_2 efficiency may be required. This is explored in this option, as it offers the potential to achieve additional carbon savings through non-ZEV sales. This is modelled in conjunction with the 'central' ZEV mandate annual sales targets, presented in Policy Option 1.

62. In this option, manufacturers would be required to make incremental efficiency gains of 2% per year against the WLTP test cycle. This would apply to non-ZEV sales only and would apply to their baselines as determined on 2021 sales. This means that individual manufacturers' efficiency targets would vary, but the overall estimated market gCO_2/km requirements are presented in Table 22.

63. Under option 4, we assume manufacturers opt for the strategy to use PHEVs to deliver the 2% non-ZEV efficiency improvements in line with SMMT's Central long term PHEV uptake outlook. As a result, the WLTP non-ZEV average is achieved up to 2027 and exceeded past 2027. However, when accounting for the real-world emissions of ICEVs/HEVs/PHEVs, the real-world improvement is not as pronounced and is less than 2% per year. This is illustrated in Figure 21 and Table 22 below.

Figure 21 Policy Option 4 non-ZEV gCO₂/km averages

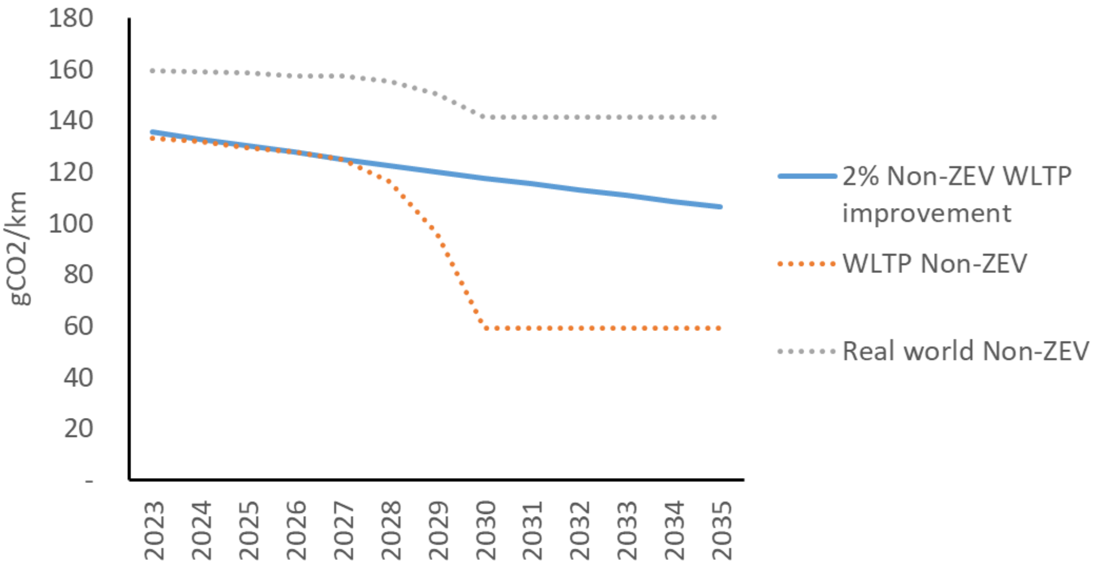


Table 22 Estimated new sales real-world gCO_2/km efficiencies for Policy Option 4

Vehicle type	Drive train	2024	2025	2026	2027	2028	2029	2030
Car	Petrol ICE / HEV	165	165	164	164	165	165	165
Car	Diesel ICE / HEV	187	187	186	187	187	1871	187
Car	Petrol PHEV	137	137	137	137	137	137	137
Car	Diesel PHEV	134	134	134	134	134	134	134
Van	Petrol ICE / HEV	145	142	140	137	134	131	129
Van	Diesel ICE / HEV	209	205	201	197	193	189	185
Van	Petrol PHEV	169	165	162	159	156	152	149
Van	Diesel PHEV	159	155	152	149	146	143	140

64. With regard to other policy details, this option matches Policy Option 1. Therefore, the ZEV uptake targets align with those presented in Table 16.

Additional Policy Details

65. There are several additional policy details which are proposed to apply to each of the policy options under consideration. These elements of the policy intend to ensure that manufacturers have sufficient flexibilities in place and incentives to comply with the proposals.

Banking and Borrowing

66. Several technical consultation respondents suggested that manufacturers would benefit from some flexibility, particularly in early years of the scheme. It was proposed that allowing manufacturers to bank (‘carrying over’) or borrow (‘carrying under’) allowances from their delivery in other years would help manufacturers deal with year-to-year uncertainty and better align targets with their shorter-term production plans.

67. Recognising these concerns, it is proposed that manufacturers are allowed to borrow up to a fixed number of allowances from previous or subsequent years. This would apply for the years 2024-2026, with any deficit to be repaid by the end of 2027 at the latest, and be limited to 75%, 50%, and 25% of the ZEV trajectory targets in 2024, 2025, and 2026 respectively. Recognising that early delivery does not lead to social costs in the same way as late delivery, banking will be permitted in all years of the scheme, but banked allowances will expire after 3 years (I.e., an allowance allocated in 2024 would expire if not used following the 2027 trading period) in order to encourage trading and limit the potential for unintended consequences.

68. For borrowing, it is important to reflect the benefits to society foregone due to the late delivery of each allowance. For this reason, it is proposed that ‘interest’ is charged on each allowance

borrowed from subsequent years, at a rate of 3.5% per year. This value is the HMT Green Book social time preference rate (over 1 – 30 years) which aims to reflect society's preference for a benefit in the present period, compared to in one year's time.

69. This flexibility may pose some risk to the policy's emissions impacts, if all manufacturers were to maximise their borrowing from subsequent years, despite the proposed limitations to borrowing. Risks are identified in Section 3 and the downside consequences estimated in 'Section 2: Sensitivity Analysis'.

70. However, there is significant uncertainty with regards to individual manufacturers' strategic behaviour relating to ZEV production and sales, and banking and borrowing. Per HMT Green Book guidance, in the central scenario we assume full, on-time compliance, and estimate a maximal borrowing scenario in 'Section 2: Sensitivity Analysis'.

Trading

71. A tradeable element of the scheme is required under the Climate Change Act (2008). In accordance with these powers, in order to promote healthy competition between manufacturers, and to mitigate the potential for disproportionate costs for businesses and consumers, manufacturers will be permitted to trade ZEV allowances and non-ZEV allowances under the non-ZEV regulatory framework.

72. There are no proposed limits to the proportion of individual manufacturers' targets that can be met through trading. This is expected to significantly reduce the risk of under-delivery and excessive costs for manufacturers whose ZEV delivery falls below the annual targets and are unable/unwilling to offset this through borrowing. It also provides incentives for manufacturers to overachieve against targets, as they can trade excess allowances with other manufacturers.

Closed Pooling

73. Some manufacturers may be considered to be a group of connected entities; if a manufacturer has voting rights, inter alia, over another manufacturer's or more business, these are then considered to be connected undertakings. These groups of connected entities may share design facilities, technology, R&D, and other costs. In recognition of this, manufacturers within the same connected entity may enter into a closed pool together and be treated as a single participant under the scheme rather than multiple individual entities.

74. Companies may decide to create a pool where one manufacturer within the group has a much higher ZEV trajectory, increasing their overall credit yield and providing allowances which can be used by other manufacturers within the closed pool. Equally, a manufacturer may choose not to pool all manufacturers in its connected undertaking together, for example leaving out a small or micro volume manufacturer which could then receive a derogation instead. This flexibility enables companies to take a holistic approach to the scheme, preventing the risk to manufacturer's using group-wide resources without compromising policy objectives.

Payments for Under-Delivery

75. The above flexibilities are expected to de-risk and mitigate the challenge of the proposed targets for manufacturers. However, to incentivise ZEV uptake, some level of financial payment is required.

76. In setting this payment, it is important to avoid setting a payment which is too low, which would be expected to lead to preferring to make payments over selling ZEVs by some manufacturers; it is also important to avoid setting the payment too high, which could lead to disproportionate costs for under-delivering manufacturers (if, for instance, a manufacturer fails to meet their target and is unable to offset this with borrowing and trading).

77. There are several key determinants of the optimal payment level. From society's point of view, each ZEV delivers benefits, for instance in the form of reduced emissions and fuel savings. If the payment is less than the lifetime discounted value of these benefits, society would be worse off if

a manufacturer under-delivered and made the payment. If the payment exceeds this value, then society as a whole would also be worse off, as the cost to society would exceed the benefit to society.

78. Through the lens of guaranteeing manufacturers' delivery of ZEVs, the key consideration is the cost of delivering the last ZEV, compared to delivering one more ICEV. If the payment is less than the difference in cost between producing a ZEV versus an ICEV, then a cost minimising manufacturer would have a financial incentive to under-deliver and pay the payment. If the cost were significantly greater than the cost differential, under-performing manufacturers which are unable to meet their obligation through borrowing and trading may face disproportionate costs.

79. Finally, in an open economy, it is important to consider the interaction between connected markets. Vehicle emissions regulations and compliance frameworks in other, connected markets could jeopardise the delivery of these proposals, if manufacturers are unable to meet all requirements and the financial incentives to comply with these regulations are lesser than those in other economies. For this reason, there is a rationale to set the payment to be no lower than those in other markets with which the UK has a linked vehicle market.

80. With these considerations in mind, the proposed payment is £15,000 for cars and £18,000 for vans. This payment would apply per allowance deficit in each year and is effectively the price of purchasing an allowance from Government, instead of borrowing or trading to meet targets in a given year. This is therefore expected to function as a 'price cap' on the allowance market, preventing under-delivering manufacturers from facing costs which exceed the cost difference of manufacturing a ZEV and the social cost of the failure to deliver one ZEV.

81. We propose to retain the same payment structure for the non-ZEV CO_2 portion of the regulation, namely that manufacturers would be required to make a payment of £86 per gram of CO_2 above their target, evaluated as an average of all new non-ZEV vehicles sold, multiplied by the number of non-ZEV vehicles sold. This would be calculated separately for new cars and for vans but with the same cost per gram.

Allowance Transfers

Transfer of ZEV allowances to non-ZEV allowances

82. Given that the shift to ZEVs is the core priority of this framework, we propose that manufacturers exceeding their ZEV mandate targets may use extra ZEV allowances to comply with their non-ZEV CO_2 target. Specifically, allowances from the car ZEV mandate may be converted into allowances for the car non-ZEV CO_2 scheme; and van ZEV mandate allowances may be converted into allowances for the van non-ZEV CO_2 scheme. The rate of conversion shall be determined based on the average CO_2 emissions (using the WLTP standard) from non-ZEV cars and vans (respectively) in 2021.

Transfer of non-ZEV allowances to ZEV allowances

83. Some manufacturers may require additional flexibilities in the early years of the policy because production plans can be set 5-7 years in advance. For this reason, it is proposed that manufacturers which over-perform against their non-ZEV CO_2 targets may count this excess performance against their ZEV allowances, for the years 2024-2026.

84. In order to count non-ZEV over-performance against ZEV delivery targets, a conversion rate is required. This rate is currently proposed to be determined based on the CO_2 emissions exceedance (WLTP) from non-ZEV cars relative to the CO_2 emissions savings of a ZEV. For example, if Manufacturer A sells 100 non-ZEV cars, emitting 90 gCO_2/km (WLTP) where the non-ZEV target is 135 gCO_2/km (WLTP) they will accrue 4,500 excess non-ZEV allowances [(135-90)*100]. Assuming a ZEV saves 166 gCO_2/km (real-world) compared to the average non-ZEV alternative, a manufacturer then can choose to transfer these to minimise their ZEV allowance target by 27 [4,500/166].

85. Manufacturers will only be able to transfer their non-ZEV over-delivery to their non-ZEV allowance; therefore, they will still need to comply with their non-ZEV targets. Additionally, to safeguard certainty in ZEV uptakes and associated infrastructure investment, we propose to cap this transfer such that only 25% of a manufacturer's ZEV allowances can be redeemed using transferred non-ZEV certificates.

2.0 Costs and Benefits

Summary of Cost Benefit Analysis

Scope of analysis

86. The scope of analysis covers the impacts delivered by these proposed regulations. These proposals implement a ZEV mandate which begins in 2024 and rises to 2030 (and after this it is fixed at the 2030 level) and requirements for the non-ZEV fleet to either make limited improvements or to maintain the current level of efficiency.

87. For the purposes of the CBA, as we are solely considering proposed legislation, trajectories are assumed flat after 2030. As per the accompanying consultation document, we will introduce legislation for post-2030 at a future date, although it is anticipated the trajectories will be at least as ambitious as those set out in the consultation document. Decisions are yet to be finalised on the definition of a vehicle with 'Significant Zero Emission Capability' (SZEC) in the wake of new evidence on technological and environmental uncertainty of PHEVs (see 'Section 2: Sensitivity Analysis: Real-world emissions' for more detail).

Scope of zero emission technologies modelled

88. For simplicity and proportionality, this analysis monetises the costs and benefits of the deployment of zero emission vehicles assuming all ZEVs are BEVs. This is appropriate as currently, ZEV cars and vans deployed into the UK are almost exclusively EV. Furthermore, manufacturer strategies for future deployment of zero emission vehicles in the UK and Europe are also dominated by electric vehicles.

89. The evidence base on BEVs is also the most well developed and therefore it is easiest to quantify the impacts of these powertrains. However, we remain technologically neutral in terms of decarbonisation and will ensure that all ZEV powertrains are supported as we move to net zero.

Appraisal Periods

90. This analysis covers the environmental impacts of car sales from 2024 – 2050, resulting from the targets set in these regulations, which ramp-up to 80% in 2030. This is intended to reflect the direct impact of the proposals in this consultation on the UK's progress against its emissions reductions targets, up to net zero in 2050.

91. The policy's costs and benefits are appraised over 2024-2071 to count the impacts of a vehicle (a capital asset) through its lifetime as they drive on the roads. That is, an additional ZEV on the roads in 2050 will deliver significant mileage and impacts years after 2050. Given DVLA statistics on mileage by age, and survival rates of vehicles, a period of 21 years after the vehicle has been placed onto the roads is assumed, as this will capture over 99.5% of the expected lifetime impact of the last vehicle.[11]

[11] By this point, because fewer miles are driven by the oldest vehicles, and only few vehicles make it to the oldest ages, a vehicle of 21+ years of age is expected to account for <0.5% of the lifetime mileage of the average vehicle.

92. This methodology is consistent with Green Book and Transport Analysis Guidance and aligns with rationale for appraisal periods in other published Government analyses such as Clean Heating policies.

Modelling time horizon assumptions	Year
Policy development + consultations + laid in parliament	2020 – 2023
First Year policy is in force	2024
Switching the composition of the car and van sales to more ZEVs	2024 – 2050
Counting the impact of new sales (this extends out to 2071 to account for the lifetime impact of the capital asset. i.e. a new ZEV sale in 2050 will exist on roads for many years – 21 years counted in our fleet modelling. This is intended to capture long-tails of the distribution of the vehicles lifetime instead of using expected or mean age)	2024 – 2071

Summary of Impacts

Approach of impact analysis

93. Our analysis separates quantified costs and benefits from the ZEV mandate into two categories of impacts. Direct impacts relate to the impacts assuming no behaviour change from those impacted. It measures the costs and benefits of replacing ICEVs with ZEVs, the cost of recharging infrastructure plus the costs of administering the scheme.

94. In addition, some impacts can be identified as 'indirect', as they result from behaviour change which may result from the policy. For instance, the transition to electric vehicles may result in additional traffic caused by the lower per mile cost of driving electric vehicles. Projecting increased traffic from electric vehicles is clearly relatively uncertain (as the technology is still new) and is also dependent on the future tax system (currently electric vehicles do not pay fuel duty).

95. While most analyses of the transition to electric vehicles focus on the direct impacts only, our analysis also covers the indirect impacts to provide a more comprehensive picture of potential costs and benefits. We also provide the direct costs and benefits only to ensure comparability with other analysis. This also shows the costs and benefits if future policy were designed to mitigate the potential congestion impacts of electric vehicles.

96. Impacts were identified through stakeholder engagement through the July 2021 Green Paper, April 2022 technical consultation and workshops. Cross-government working groups were used with relevant departments to long-list policy impacts to ensure a government-wide, holistic analysis.

97. Table 23 sets out the direct, monetised costs of the proposals. These include costs to society, business, and Government, and both transitional and ongoing costs. Tax transfers are also included; although these are net neutral on society, they represent a reduction in tax revenues to Government and should therefore be quantified for public accounting purposes. This analysis assumes current vehicle taxation policy, including changes to Vehicle Excise Duty outlined in the 2022 Autumn Statement.

98. It should be noted that capital costs are categorised as both direct, monetised costs and benefits, because in scenarios where BEV capital costs fall below those of their ICEV equivalents, the greater uptake of ZEVs relative to the baseline achieves net cost savings to society.

Table 23 Summary of direct, monetised costs of the proposals

Impact	Transition/On-going	Impact on	Description
Capital cost[12]	On-going	Business	The additional up-front cost of vehicles in early years as battery electric vehicles (BEVs) are expected to be more expensive to buy than conventional vehicles.
Energy costs	On-going	Social	The additional electricity cost of driving electric vehicles, £/km.
Traded carbon	On-going	Social	Additional emissions due to additional electricity demand, and the traded-carbon cost of these.
Infrastructure (CAPEX)	Transition + On-going	Social/ Business/ Government	Cost to install necessary charging infrastructure.
Infrastructure (OPEX)	On-going	Social/ Business/ Government	Cost to operate and maintain charging infrastructure.
Administrative	Transition	Business	Cost to business of familiarisation and adjusting regulation compliance teams.[13]
Administrative	Transition + On-going	Government	Cost of setting up a tradable ZEV scheme Cost to run this scheme.
Tax Transfers	Transfer	Government	Lost tax duty and VAT revenues as a result of lower petrol/diesel fuel consumption.

Indirect Monetised Costs

99. Table 24 shows the indirect, monetised costs of the proposals. Energy system and traded carbon costs appear both as direct and indirect costs; this is because a some of these social costs originate from the direct effect of replacing ICEV mileage with ZEV mileage, and an additional proportion originate from additional transport demand induced by lower ZEV running costs. See 'Indirect Costs and Benefits: Rebound Effect Costs' for a more detailed discussion of this induced demand.

Table 24 Summary of indirect, monetised costs of the proposals

Impact	Transition/On-going	Impact on	Description
Congestion	On-going	Social	The time and reliability externality impact of higher road congestion due to induced demand from more ZEVs.
Energy system – additional consumption	On-going	Social	As above, however this relates to the additional social cost caused by induced demand for travel using ZEVs.
Traded carbon – additional consumption	On-going	Social	As above, however this relates to the additional social cost caused by induced demand for travel using ZEVs.
Accidents	On-going	Social	The damage cost externality of higher frequency of accidents on the roads due to induced demand from more ZEVs.
Additional Tax	On-going	Government	Changes in tax revenue caused by changes in driving behaviour and subsequent changes in fuel duty/VAT revenue.[14]

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[12] Capital costs are found in both benefits and costs as the price of the battery electric technology is expected to fall over time – this can lead to benefits in the long-term.

[13] Ongoing costs are assumed to be no different to the costs faced by manufacturers in complying with current regulations. For this reason, the marginal effect of these regulatory proposals on *ongoing* costs is expected to be negligible.

[14] Changes arising from the use of electricity instead of petrol/diesel are not included in the social NPV as this is a transfer from Government to consumers; changes arising from **additional mileage** due to the lower cost of electricity for ZEVs are included in the social NPV as this represents a benefit to both Government (in the form of increased tax revenues) and consumers (in the form of utility, valued at the retail price of fuel, which includes VAT).

Unmonetised Costs

100. Table 25 shows the unmonetized impacts of the proposals. These impacts have not been monetised due to gaps in the evidence-base on the scale or social cost of their effects, or in the interests of proportionality. Where possible and proportionate, these impacts will be estimated in the Government Response cost benefit analysis.

Table 25 Summary of unmonetised costs of the proposals

Impact	Transition/On-going	Impact on	Description
Road investment costs	On-going	Social/ Government	The cost of road wear and tear due to heavier vehicles on the road (electric vehicles could become heavier due to battery sizes) and additional induced driving demand.[15]
Life-cycle emissions	On-going	Social	The additional emissions due to zero emission vehicle: manufacturing, maintenance and servicing, and end-of-life activities (re-using, re-purposing, disposal, etc). [16]
Garages, traders, dealerships	On-going	Business	Additional training required to sell ZEVs. Additional training required to maintain, repair, and service ZEVs.
Energy system impacts	Transition + On-going	Social + Business	There may be costs associated with increasing the capacity of the electricity generation network and reinforcement of the distribution network.

Direct Monetised Benefits

101. Table 26 presents the direct, monetised benefits of the policy. As set out above, capital costs feature as both benefits as well as costs. Several benefits (e.g. operating cost savings, fuel savings) are identified as 'social' benefits, however these will also have a material benefit on individual households, in the form of greater disposable income due to overall vehicle costs savings, in many cases. These net savings are discussed in greater detail in 'Section 4.0: Cost of Living' and Annex E.

Table 26 Summary of direct, monetised benefits of the proposals

Impact	Transition/On-going	Impact on	Description
Carbon savings	On-going	Social	Benefits to society of reducing environmental pollution and global warming due to greenhouse gases.
Fuel savings	On-going	Social	The fuel cost savings from using more efficient vehicles, paying less for each £/km.
Capital cost savings[17]	On-going	Business	The additional up-front benefit of vehicles in later years as battery costs are expected to fall making BEVs less expensive than conventional vehicles.
Operating cost savings	On-going	Social	The additional ongoing cost savings of maintaining ZEVs.
Air quality improvements	On-going	Social	Quantified health benefits of lower particulate matter and NOx emissions from ZEVs.

[15] It was not deemed proportionate to quantify this impact given the TAG marginal external cost is ~1/100 the scale of the congestion cost per km. It was not deemed proportionate to quantify the impact of EVs making the fleet heavier, and the impact this has on road wear and tear.

[16] It was not deemed proportionate to quantify this impact as evidence suggests that the incremental emissions, compared to those associated with ICEVs, are relatively small. See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1062603/lifecycle-analysis-of-UK-road-vehicles.pdf

[17] Capital costs are found in both benefits and costs as the price of the battery electric technology is expected to fall over time – this can lead to benefits in the long-term.

Indirect Monetised Benefits

102. Table 27 presents the monetised, indirect benefits stemming from potential induced travel demand. Although indirect benefits are typically excluded from policy cost benefit analysis, they are presented alongside the monetised indirect costs for completeness. Unlike tax transfers, indirect tax generated by induced travel demand is a net benefit to society; for more detail on this rationale please see 'Costs: Tax Impacts', below.

Table 27 Summary of indirect, monetised benefits of the proposals

Impact	Transition/On-going	Impact on	Description
Consumer Surplus	On-going	Social	Additional benefit of the increased demand trips taken because ZEVs are cheaper to run than alternatives.
Indirect tax	On-going	Social	Additional benefit of increased tax revenue from additional ZEV trips.

Unmonetised Benefits

103. Finally, Table 28 sets out the unmonetised benefits of the proposals. As with the unmonetised costs, these are excluded because there is significant uncertainty regarding the magnitude or social benefit of the impact, or in the interests of proportionality. As above, these impacts will be further analysed and may be included in the Government Response CBA, if it is feasible and proportionate to do so.

Table 28 Summary of unmonetised costs of the proposals

Impact	Transition/On-going	Impact on	Description
Jobs/Growth	On-going	Social	Additional jobs in the UK economy / additional gross-value added to the UK economy.
Noise	On-going	Social	Lower noise (the damage cost value of noise on health) because ZEVs are quieter at speeds below 30mph.
Time spent refuelling	On-going	Social	Reduction in time required to refuel/recharge vehicles.

Quantified Impacts

104. Table 29, Table 30, and Table 31 present the central modelled impacts for the four policy options under consideration. For each option, the estimated impacts are net of the baseline, Policy Option 0.

105. Table 29 shows the expected carbon savings for the short-listed policy options. Policy Option 1 delivers significant carbon savings over all carbon budget periods. Policy Option 2 delivers lower carbon savings (and even negative savings in some years) as the ZEV trajectory is closer to the baseline and there are no non-ZEV efficiency improvements which are included in the baseline. Policy Option 3 delivers higher carbon savings as the ZEV trajectory is much more ambitious. Policy Option 4 delivers additional carbon savings to the central option as it requires CO_2 reductions from non-ZEVs alongside the ZEV central trajectory.

106. It should be noted that there is some uncertainty over how manufacturers would meet the additional non-ZEV efficiency improvements required under Option 4. This analysis assumes that manufacturers make improvements to the efficiency of all their non-ZEV drivetrains, however in practice it is likely that at least some of this improvement in average efficiency would be achieved by altering their product mix to favour more efficient (as assessed at WLTP) drivetrains such as PHEVs.

107. The key issue is that there is a significant gap in the efficiency of PHEVs between their WLTP assessment and their real-world emissions (this is discussed in greater detail in 'Section 2: Real-world emissions' and Annex G). The performance gap is estimated to be greater for PHEVs than for ICEVs. Therefore, if manufacturers were to meet required efficiency improvements by increasing their share of PHEV sales, relative to ICEV sales, the actual improvement in real-world efficiency and carbon savings would be significantly smaller. As a result, the carbon savings presented for Policy Option 4 below are expected to be an upper-bound, with potentially significantly lower savings.

Table 29 Expected carbon savings for the short-list policy options (MtCO₂e)

	Policy Option 1	Policy Option 2	Policy Option 3	Policy Option 4
CB4	0	-1	8	1
CB5	31	5	61	35
CB6	81	20	139	88
2020 – 2050	415	89	732	443

108. Table 30 shows the direct monetised impacts for the short-list policy options when excluding the rebound effect. All options deliver significant net benefits from a social cost benefit analysis perspective. The combined benefits for cars and vans in the Preferred Option delivers a Net Present Value (NPV) of £96 billion. This includes Present Value Benefits (PVB) of £145 billion and Present Value Costs (PVC) of £49 billion. Both the cars and van markets deliver positive Net Present Value over the appraisal period.

109. The remaining ZEV trajectories also show they are cost effective. Option 3 is estimated to deliver a higher NPV than the Preferred Option. This option is not preferred as it is considered that this trajectory is at a high risk of being undeliverable and may result in manufacturers not being able to ramp up production in time to meet targets – this could lead to delivery challenges for manufacturers which would erode social benefits, particularly carbon savings, while potentially raising costs.

110. As above, there is uncertainty over the likely level of efficiency gains and associated social impacts under Policy Option 4. In addition to reduced carbon savings, increased PHEV sales would lead to lower monetised carbon, air quality, and fuel benefits. In addition, it could lead to greater infrastructure costs (as PHEVs are still partly fuelled by electricity) and capital costs, because PHEVs typically cost more than their ICEV counterparts. For these reasons, the estimated NPV and cost-effectiveness of carbon abatement are also likely to be upper limits for this option.

Table 30 Expected present value direct monetised impacts for the short-list policy options only, does not include rebound effect (£m, 2021 prices)

	Impact (present value, discounted; 2021 prices)	Policy Option 1	Policy Option 2	Policy Option 3	Policy Option 4
Car	Benefits	115,315	30,504	189,298	116,082
Car	Costs	-42,429	-11,488	-72,536	-45,623
Car	Net present value	72,857	18,986	116,732	70,430
Van	Benefits	29,752	19,133	70,400	33,630
Van	Costs	-6,447	-27,138	-13,621	-7,299
Van	Net present value	23,301	-8,010	56,774	26,327
Both	Benefits	145,068	34,689	259,698	149,712
Both	Costs	-48,875	-23,713	-86,157	-52,921
Both	Net present value	96,158	10,976	173,506	96,757

111. Table 31 presents the same impacts but includes the indirect impacts associated with induced demand – the most significant of which is increased congestion. Again, all options deliver significant positive impacts on society represent by the large Net Present Values. The Preferred Option delivers a social NPV of £44 billion over the lifetime of the appraisal. The NPV is lower than that including direct impacts due to a number of factors including, most importantly, increased congestion. More detailed tables, which list each monetised social impact, are presented in Annex D (Table 105).

112. Policy Option 3 again delivers the highest NPV; however, as noted, it would entail significant delivery risks, given the very ambitious ZEV trajectory. Policy Option 4 delivers slightly higher NPV, while also carrying delivery/achievability risks.

Table 31 Expected monetised impacts for the short-list policy options, including rebound effect

	Impact (present value, discounted; 2021 prices)	Policy Option 1	Policy Option 2	Policy Option 3	Policy Option 4
Car	Benefits	115,315	30,504	189,298	116,082
Car	Costs	-82,744	-19,716	-139,739	-83,144
Car	Net present value	32,571	10,787	49,559	32,938
Van	Benefits	29,752	19,133	70,400	33,630
Van	Costs	-18,191	-12,774	-52,803	-22,619
Van	Net present value	11,561	6,359	17,597	11,011
Both	Benefits	145,068	34,689	259,698	149,712
Both	Costs	-100,935	-17,543	-192,542	-105,762
Both	Net present value	44,133	17,146	67,156	43,950

113. NPVs of the other policy options also are presented to illustrate the total magnitude of impact and value for money in line with Green Book guidance. As shown in Table 30 and Table 31, each of the policy options is expected to achieve a positive Net Present Value (NPV), with significantly greater positive impacts when the rebound effect is excluded.[18]

114. There is some uncertainty regarding the likely magnitude of any rebound effect; it is likely the figures presented in Table 31 are over-estimated. This is discussed in more detail in 'Indirect Costs and Benefits: Rebound Effect Costs', however in short this is primarily because this estimate is based on the price-elasticity of demand for transport, which corresponds to the change in demand stemming from an infinitesimal change in the price of transport. By comparison, the change in the price of transport from switching from ICEV to ZEV is significant (around 50% change in £/km cost). Typically, due to diminishing returns to consumption, the price-elasticity of demand falls as consumption rises – therefore the estimated demand-response to this change is likely upwardly biased.

115. Furthermore, non-transport costs (e.g. congestion, risk of accidents) rise with greater overall travel; this is indicated by the significant congestion and accident costs set out in Table 31. This analysis covers the direct, first-order effects only, however induced demand for transport would likely be reduced due to the second-order effect of these increased transport costs. The omission of these second-order effects is therefore also likely to upwardly bias the estimated rebound effect.

116. Nonetheless, the rebound effect is included to mitigate the risk of optimism bias and illustrate that – even in this pessimistic case – the policy is expected to achieve good value for money. The

[18] Excepting option 2, as set out above.

uncertainty regarding the magnitude of the rebound effect is discussed in greater detail in the 'Section 2.0: Rebound Effect Costs (Congestion/Accidents)'.

Non-Traded Cost Comparator (NTCC) Benchmark

117. In addition, due to the focus on carbon abatement of this policy, the abatement cost – the cost to offset one tonne of carbon dioxide equivalent – is presented as the environmental cost effectiveness indicator in line with DESNZ Valuation of energy use and greenhouse gas emissions appraisal guidance.

118. To assess cost effectiveness further, cost comparator indicators are calculated – weighting the emissions savings of the proposed central ZEV mandate trajectory by each year the emissions savings are realised to produce a weighted average of the DESNZ non-traded carbon values.[19] This reflects a benchmark comparison to an economy wide cost to decarbonise per tonne of carbon dioxide equivalent emissions.

Table 32 Non-Traded cost performance comparator benchmark versus policy cost-effectiveness, including and excluding rebound effects (2024-2071)

			Policy Option 1	Policy Option 2	Policy Option 3	Policy Option 4[20]
Car	Cost performance comparator benchmark (based on DESNZ carbon prices)	£/tCO2e	172	171	174	173
Car	Cost-effectiveness	£/tCO2e	22 – 105	42 – 98	25 – 111	35 – 108
Van	Cost performance comparator benchmark (based on DESNZ carbon prices)	£/tCO2e	185	149	178	186
Van	Cost-effectiveness	£/tCO2e	-32 – 77	NA[21]	-39 – 111	-40 – 91
Both	Cost performance comparator benchmark (based on DESNZ carbon prices)	£/tCO2e	175	177	175	175
Both	Cost-effectiveness	£/tCO2e	12 – 100	32 – 84	9 – 111	21 – 105

119. As shown in Table 32, in each policy option and each vehicle type, the emissions expected to be saved by these policy options are likely to be substantially more cost-effective than if the same amount of emissions were to be saved across the whole of non-traded emissions sector. This suggests that each policy option provides the opportunity to abate carbon at a much lower cost than average.

120. The abatement cost for vans in Policy Option 2 is not presented. This is because the combination of very low ZEV van uptake and efficiency requirements which are less stringent than the baseline may lead to *increased* van emissions. For this reason, the logic of the cost of carbon abatement calculation is not applicable to this option and vehicle type.

121. In each policy option, except Option 2, it is possible that carbon abatement costs are negative, when the rebound effect is excluded. The combination of lesser social costs (for instance, because van ZEV costs are expected to approach cost parity quicker than for cars[22]) and greater social benefits (for instance, because van ZEVs are expected to achieve high mileage and achieve greater fuel savings) leads to negative abatement costs for vans, which indicates a net benefit to society *excluding* non-traded carbon savings.

122. As shown, this is significantly lower than the NTCC benchmark calculated for all options, indicating that they are very likely to offer the opportunity to make significant, cost-effective carbon savings, relative to the decarbonisation of the broader non-traded economy. Comparing

[19] See Box 5.2 and Table 5.1 of DESNZ greenhouse gas emissions appraisal guidance for more details.

[20] As stated above, this is likely to be an upper limit of the cost-effectiveness of carbon abatement for this option.

[21] This value is not presented because this policy option is expected to lead to greater overall van emissions; the value of cost-effectiveness of carbon abatement calculation is not theoretically consistent

[22] See Annex C for more detail.

options 1, 3, and 4, when the rebound effect is included Policy Option 1 is likely to be most cost-effective for both cars and vans. When the rebound effect is excluded, Option 1 remains the most cost-effective for cars, however for vans it may be marginally less cost-effective. In each of these cases, when the rebound effect is excluded, we expect net social benefits even when carbon savings are excluded.

123. The cost-effectiveness of Option 2 is ambiguous; it may be more or less cost-effective than the other options, depending on the scale of the rebound effect. However, it is expected to lead to positive van emissions, and overall emissions savings up to 2050 are expected to be only around 20% of those achieved by the Preferred Option.

Justification For Selecting The Preferred Option (Policy Option 1)

124. This section explains the trade-offs considered between the short-listed policy options. Each policy option has been scored, based on their relative performance, against several criteria: environment, business, government/administration, and society. This scoring is set out in Table 33 forms the justification for the selection of the Preferred Option.

125. This approach is applied because, as set out in the HMT Green Book guidance for economic appraisal, the best policy option is not necessarily the one that achieves the greatest NPV or the one which performs best against the policy's primary objective (in this case, emissions reductions). Other contextual details such as deliverability, affordability, and impacts on industry are of significant strategic importance, and often difficult or impossible to monetise. As a result, although the monetised appraisal of the policy is useful in informing elements of policy design and should form part of the consideration of the Preferred Option, the balance of monetised and non-monetised impacts may support a policy option which does not achieve the maximal social cost-effectiveness.

126. Policy Option 2 sets a very low level of ambition, for which early years' required sales targets fall below the expected baseline.[23] These annual sales targets are based on the SMMT's 'unsupported' ZEV car sales trajectories, adjusted to align with ZEV van sales. For these years, a sales 'floor' is applied such that ZEV van sales never fall below what is expected in the baseline. Nonetheless, carbon savings expected to be achieved by ZEV van sales in this scenario are far lower than those expected of the other policy options, because in several years it does not differ from the baseline.

127. Like options 1 and 3, option 2 requires manufacturers' average new van sales efficiencies to not deteriorate. By contrast, in order to meet the retained baseline EU CO_2 regulations (Policy Option 0), vans would require significant ICEV efficiency improvements given DfT's baseline ZEV forecast.

128. This flat CO_2 baseline target and a low ZEV uptake contributes to the combination of less stringent non-ZEV efficiency requirements and ZEV van sales which often do not differ from the baseline. This results in significant losses of direct benefits relative to the baseline (especially fuel and carbon) and also additional indirect congestion and accident benefits which results in a worse net cost-effectiveness compared to other options receiving a score of 2 for society criteria. Given this policy's primary objective is to contribute to progress against the UK Government's stretching carbon budgets and net zero commitments, this option is given a score of 1 on the environment metric.

129. Between the other policy options, the choice is less clear. Each option is expected to deliver significant carbon savings, ranging from 81 $MtCO_2e$ – 139 $MtCO_2e$ in Carbon Budget 6, for Policy Options 1 and 3, respectively. As shown in Table 33, these options are scored as such: option 3

[23] Baseline sales are also expected to catch-up with and surpass the 2030-onwards target (38%) proposed in this option. A 'floor' is applied whereby policy scenario sales remain at least as high as the baseline. It should also be noted that the Government has committed to laying further legislation which sets the annual sales targets from 2031 – 2035, which will include the phase-out of petrol and diesel vehicles.

receives a score of 5 as it achieves the greatest carbon savings; option 4 receives a score of 4 as its impacts are somewhat lesser than option 3 but marginally greater than option 1, which receives a score of 3.5. Option 2 receives a score of 1 because its emissions savings are very low, and it may even raise emissions marginally over carbon budget 4.

130. Policy Option 3 also achieves the greatest NPV; although its cost-effectiveness is slightly lower than the other options, the trajectory is much more stretching, leading to greater overall net benefits. For this reason, option 3 receives a 'social' score of 5, while options 3 and 4 receive a score of 4 as their NPVs are broadly similar. Option 1 receives a score of 4.5, despite that its NPV is marginally lower than those of 4. This is because it is likely to impose lower costs to society than options 4 and full delivery is deemed to be at lower risk. Option 2 receives a score of 2, as its NPV is far lower than the other options.

Table 33 Scoring of policy options against performance indicators

	Criteria				Score
Option	Environment	Business/Deliverability	Government/Administrative	Society	Total
0	1	5	3	1	10
1	3.5	4	3	4.5	15
2	1	5	3	2	11
3	5	1	3	5	14
4	4	3	2	4	13

131. In the context of the ZEV mandate, there are several contextual features of the automotive industry which require a holistic view of the proposals' deliverability. These impacts are scored under the policy's impact on business. These issues have been identified through analysis of feedback received through the Technical Consultation, and extensive stakeholder engagement sessions with members of the automotive industry and other stakeholders.

132. In particular, some vehicle manufacturers may face challenges meeting stretching ZEV targets, particularly in the earlier years of the scheme, due to many cars and vans having product cycles of around 5-7 years. As a result of this, many manufacturers may have already made investment decisions which broadly determine their product mixes for the first years of the policy. Therefore, excessively high targets, particularly in early years, may be undeliverable, especially for manufacturers with 'locked-in' production plans for these years which are inconsistent with the ZEV mandate requirements.

133. In addition, the transition to ZEVs will require significant investment from the automotive industry. Several stakeholders suggested that 'double-regulation' (i.e. requiring CO_2 efficiency gains to new non-ZEV sales, alongside increasing ZEV sales requirements) may prohibit sufficient levels of investment in ZEV technology. The UK Government intends to send a clear signal to the automotive and related industries that ZEV technology is required to meet its legally-binding emissions reductions targets, therefore investment in these technologies should be prioritised over investment in other intermediary technologies which are not net zero consistent.

134. Finally, the automotive industry has faced unprecedented challenges in the wake of a microchip shortage, the Covid-19 pandemic, and Russia's invasion of Ukraine, all of which have impacts on investment, supply chains, and production plans. In order to drive significant additional carbon emissions reductions, while supporting the healthy functioning of the automotive industry and preventing prohibitive costs to consumers, policy options which achieve a balance between stretching targets and allowances for manufacturers may be preferable.

135. All these contextual features suggest there is a greater risk to full delivery of options 3 and 4, compared to Policy Option 1. For Option 3, this stems from ZEV sales targets which may be unachievable; for Option 4, this stems from the combined effect of stretching ZEV sales targets alongside additional efficiency improvements.

136. HMT Green Book guidance requires that central scenarios assume compliance with regulations, however the elevated risk to delivery indicates that manufacturers may be unable to fully comply, in which case the monetised impacts and carbon savings achieved may fall below those presented above. For these reasons, option 3 receives a score of 1 and option 4 is scored a 3, while option 1 is scored a 4. Option 2 is scored a 5 as it is the least stretching option for business.

137. Based on this scoring framework, Policy Option 1 (central ZEV targets, with a flat non-ZEV CO_2 requirement for non-ZEV sales) was selected as the Preferred Option. This option will require significant additional sales of ZEVs, compared to the baseline, and ambition on van sales has been significantly increased since the Technical Consultation. Simultaneously, requiring no further CO_2 efficiency improvements technologies for non-ZEV sales will allow manufacturers to focus their investment on ZEV technology. This is expected to raise the deliverability and affordability of the scheme, for both industry and consumers, and increase the likelihood that the expected social benefits are fully realised.

Detailed Analysis of the Preferred Option (Policy Option 1)

138. This section sets out a detailed explanation of the anticipated impacts of the proposals. In the interests of proportionality, the quantified impacts presented in detail here relate to the Preferred Option (Policy Option 1). More detail on the other policy options under consideration can be found in the annexes.

Costs

Administrative Costs

139. These proposals are likely to lead to small administrative costs for both business and Government. Vehicle manufacturers will be required to familiarise themselves with new regulations, set up new systems, monitor their progress against annual targets, and potentially adjust behaviour to ensure compliance.

140. In order to proportionately attribute costs and present the social cost-effectiveness specific to cars and vans separately, costs are distributed between the two vehicle types. A simplifying assumption is made that costs are distributed relative to each vehicle type's share of overall electricity demand.

Costs to Manufacturers

141. Manufacturer administrative costs are estimated using a bottom-up methodology, with labour cost data taken from the Annual Survey of Hourly Employment. Given the low value of these impacts, assumptions are made regarding the amount of labour required by each manufacturer to set up their compliance functions, to estimate the set-up administrative costs per manufacturer. These costs are multiplied by the number of manufacturers expected to be in-scope of the regulations, which provides an estimate of the industry-wide set-up costs. Manufacturers qualifying for an exemption are assumed not to incur these costs in the central scenarios.

142. Ongoing manufacturer administrative costs are not expected to materially differ from costs they would face in the 'do-nothing' scenario, in which they would be expected to comply with existing CO_2 regulations. Therefore, expected ongoing costs net of the counterfactual are £0. Consultation respondents are encouraged to provide evidence on likely administrative costs for manufacturers through this consultation; this evidence will be used to inform analysis presented in the Government Response to this consultation.

143. Uncertainty in administrative cost assumptions is reflected through sensitivity analysis. 'High' and 'low' scenarios, in which administrative costs vary by +/- 25%, are intended to reflect variance in labour requirements or costs.

Costs to Government

144. The UK Government will be responsible for meeting the costs associated with administering the scheme. This will require the development of an IT system and enforcement body to monitor manufacturers' compliance with the scheme, which is expected to lead to additional administration costs.

145. In the interests of proportionality, these costs are assumed to be in line with those of setting up and administering the Renewable Transport Fuel Obligation (RTFO). Cost assumptions are taken from published annual accounts and inflated to the correct price year. Unlike manufacturer administrative costs, ongoing costs are expected to be additional to the counterfactual. These assumptions are also taken from RTFO published accounts. As above, 'high' and 'low' scenarios, in which costs vary by +/- 25%, reflect potential variation in these costs.

146. These assumptions are expected to be conservative estimates of Government administrative costs, as there are differences between the two schemes which will likely lead to lower costs in administering the ZEV mandate. A more detailed costing will be presented in the Government Response to this consultation.

147. Central costs expected to be faced by manufacturers and Government are presented in Table 34. Also presented are the low and high estimates which vary administrative costs in the overall cost sensitivities.

Table 34 Net administrative costs for cars and vans in the central scenario for Policy Option 1 (present value, 2021 prices; £m)

		Set-up costs	Ongoing	Total
Manufacturer	Cars	8	-	8
Manufacturer	Vans	1	-	1
Manufacturer	Total	9	-	9
Government	Cars	7	15	22
Government	Vans	1	2	3
Government	Total	8	17	25

Capital Costs

148. A direct impact of the proposed ZEV mandate trajectory is the cost of supplying more ZEVs into the market. A price differential exists for ZEVs vs non-ZEVs currently on the market, and this is expected to persist, primarily due to the price of the battery pack of BEVs versus an ICEV (see assumptions in Annex C for more detail).

149. Any indirect effect – cost 'pass-through' – could occur through higher prices faced to consumers to purchase a vehicle as a result of the higher costs manufacturers face. However, this is contingent on manufacturers' price competition strategies within their respective segments in the market. It was deemed disproportionate – at this consultation stage – to model this second-order effect, and make an assumption on manufacturers competition strategies given the complexity and variety due to the range of vehicles, models, technologies, segments of the market, and number of firms within each segment, and what their optimum economic strategy would be.

150. However, we recognise the automotive market has an extent of competitiveness, with many firms in the market, and the market competes on different levels (quality and price) in different segments. The effect on disposable income of any potential cost pass-through to consumers (alongside operating cost savings) are assessed in 'Section 4: Cost of Living'. This analysis suggests that, on average, BEV owners are expected to realise net disposable income gains as a result of switching to BEVs. These savings are expected to grow over time as capital costs are expected to fall, and be even greater for those purchasing BEVs on the second-hand market. We

however welcome views from stakeholders on the likelihood and magnitude of cost-pass through occurring to consumers.

Cost Method

151. This sub-section briefly sets out the high-level methodology used to estimate capital costs for BEVs versus ICEVs. Full write-up of methodology can be found in the Cost and Performance modelling Section 2.3 of the April 2021 Element Energy report.

152. UK vehicle price data (P11D prices) is gathered for 2020 vehicles and prices are projected forward by Element Energy Ltd modelling. The chassis cost is assumed the same across ZEVs and non-ZEVs given their respective vehicle segment. Additional electric vehicle specific costs, such as bottom-up non-chassis costs like cabling/wiring harness, are estimated from Element Energy and Ricardo 2016 published information. Battery energy density assumptions are combined with Bloomberg's battery price forecasts and expected electric battery sizes into the future to provide the total cost of the electric vehicle (see details and sources in Annex C).

153. In the proposed central ZEV mandate scenario, this results in electric vehicles remaining more expensive than conventional vehicles over the period to 2050 – a more conservative result when compared to other stakeholders such as T&E, Bloomberg and the CCC.

154. The assumptions in this analysis result in relatively high EV costs versus petrol/diesel costs for a number of reasons: this analysis does not include costs to cars and vans as a result of potential Euro 7 requirements (as this is not yet a UK regulation – and will be considered in subsequent legislation); it does not assume future improvements to petrol and diesel vehicles which push up their cost (as the ZEV mandate does not specify efficiency improvements); the modelling assumes battery electric vehicles range increases in future (most other modelling assumes range is fixed).

155. As a result, DfT's central case reflects a conservative estimate of the challenges and costs faced by the automotive industry. However, predicting innovative technology prices into the future is inherently uncertain; to reflect this uncertainty several cost sensitivities are considered. This includes a scenario which assumes cost parity between ZEVs and ICEVs in the long-term (see Annex C and 'Section 2.0: Sensitivity Analysis'. for more details reflecting if EV costs converge to ICEVs at faster or slower rates). This more optimistic and low-cost scenario is more closely aligned with the views of some high-profile external commentators.

156. It should also be noted that there is assumed to be no change in the composition of new sales by car/van segment. Larger, heavier vehicles are generally expected to be more costly to decarbonise, because they tend to require larger batteries – a key driver of the current ZEV cost premium. Therefore, this implicitly assumes that the cross-price elasticity of demand for different vehicle types is segments is zero, implying that different vehicle segments (e.g. Sports Utility Vehicles versus Hatchbacks) are in no way substitutable.

157. In reality, it is likely that some consumers are able and willing to substitute between vehicle segments (implying a non-zero cross-price elasticity of demand). In this case, were prices for one segment to rise by significantly more than those of a different segment, it would be expected that rational consumers would substitute towards the lower-priced good.

158. In the context of the ZEV mandate, this suggests that the assumption made regarding the cost and energy consumption of new ZEVs may also be upwardly biased. However, there is some uncertainty once again, as to assume a different mix of vehicle segments on the market would be to pre-suppose individual manufacturers' competitive strategies. Therefore, due to this uncertainty and in the interest of mitigating optimism bias, this conservative assumption is applied.

Table 35 ZEV vs non-ZEV cost across stakeholders

Organisation	Scope	Publication year	Price parity in	
			Car	Van
DfT downside (slow cost convergence)	UK	2022	N/A	N/A
DfT Central	UK	2022	N/A	N/A
DfT upside (fast cost convergence)	UK	2022	2049	2027
DfT most optimistic case	UK	2022	2027	2026
Fleet Europe	EU	02/2022	2030s	2030s
T&E + BNEF[24,25]	EU	05/2021	2026-27	2025-26
CCC[26,27]	UK	12/2020	2030	2030
ICCT	US	10/2022	2024-2034 depending on battery size and cost sensitivities	2025-2039 depending on battery size and cost sensitivities
Exeter University	Germany	06/2022	2023-2026	
Mckinsey	Unclear	2019	2025	
				Total cost of ownership parity in
DfT Central	UK	2022		2025
ICCT	US	01/2022		2020-2035 depending on segment, range, and fuel type
T&E	EU including the UK	03/2022		2021-2024 depending on country, and van size 2021 for UK across all user groups

Cost Results

159. The impact to industry is quantified in each year by estimating the total capital value of the sales mandated to switch to ZEVs versus the baseline. It is assumed there is no change in the make-up of manufacturers' sales by different vehicle segment, though in practice the costs of decarbonising vehicles with different characteristics may vary. This method is ambiguous around the profit margins, impact to industry and their respective profit maximising price strategies.

160. The vehicle sales by powertrains (see the ZEV trajectory above) are multiplied by their respective vehicle costs to provide the total value of the capital assets in the market. The difference is then taken between the proposed central ZEV mandate scenario and the baseline to provide the additional capital cost borne by the industry. Impacts are discounted using the standard (3.5% for the first 30 years of the appraisal period, 3% thereafter) discount rates in line with HMT's Green Book Guidance. As a result, we expect central impacts of ~£27.4 bn (2022 prices, discounted) to industry in the central cost scenario of Policy Option 1.

Table 36 Present value capital costs under the Preferred Option, for cars and vans (present value; 2021 prices; £m)

Vehicle type	Value	Net cost
Car	Capital Cost	26,382
Van	Capital Cost	1,055

161. These costs are significant, however it is important to consider their scale relative to the overall car and van markets. This modelling suggests that from 2024 – 2050, cumulative UK car market turnover may exceed £2tn, or £80bn per year (2021 prices). This is supported by statistics

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[24] https://www.transportenvironment.org/discover/evs-will-be-cheaper-than-petrol-cars-in-all-segments-by-2027-bnef-analysis-finds/

[25] https://www.transportenvironment.org/wp-content/uploads/2021/08/2021_05_05_Electric_vehicle_price_parity_and_adoption_in_Europe_Final.pdf

[26] https://www.theccc.org.uk/wp-content/uploads/2020/12/The-UKs-transition-to-electric-vehicles.pdf

[27] CCC (2020), The Sixth Carbon Budget – the path to Net Zero.

published by industry bodies; for instance, SMMT suggests that in 2019 UK automotive manufacturing turnover was roughly £79bn in 2019 prices.

162. Accounting for the large size of the UK auto sector shows that, while significant, marginal capital costs are small relative to overall manufacturing costs and turnover. Table 37 shows that for cars, the Preferred Option could add 2.7% to overall capital costs from 2024 – 2050, which constitutes 1.9% of expected turnover. For vans, the figures are 0.4% and 1.0%, respectively. This suggests that the overall impact on the automotive manufacturing sector is likely to be substantial, but not disproportionate.

Table 37 Capital costs and turnover for car and van markets in the Preferred Option versus the baseline (£m; 2021 prices; undiscounted)

		Capital cost	Turnover
Car	Baseline	1,743,000	2,086,000
	Policy Option 1	1,790,000	2,126,000
	% change	2.7%	1.9%
Van	Baseline	259,000	310,000
	Policy Option 1	260,000	313,000
	% change	0.4%	1.0%

163. Sensitivities which assume a faster convergence of BEV and ICEV costs (and are more closely aligned with forecasting undertaken by the Climate Change Committee, Transport and Environment, and Bloomberg New Energy Finance), there are net benefits to industry. These are presented in 'Section 2.0: Sensitivity Analysis'.

Infrastructure Costs

164. The proposed ramp-up in ZEV sales will require significant infrastructure investment in order to provide sufficient charging capacity. As these proposals impose a direct increase in demand for chargepoints, estimated associated costs are included in the cost benefit analysis.

165. This analysis focuses on electric chargepoints, which are the dominant form of ZEV infrastructure in 2022, however the Government recognises that infrastructure to support other types of ZEVs such as hydrogen refuelling stations or battery swapping may also be required and developed. Infrastructure modelling will be kept under review in order accurately and proportionately reflect the impact of these proposals on the charging infrastructure network.

166. Chargepoint demand is estimated based on internal government analysis of the expected increase in take-up for electric-power vehicles, and a range of assumptions regarding consumer charging behaviour. It should be noted that chargepoint demand will vary with several variables, such as consumer behaviour and the state of future battery technology. These determinants are inherently uncertain and subject to change over time.

167. The Government will continue to refine its estimates of chargepoint demand and underlying assumptions, meaning that future estimates may differ from those presented here. Nonetheless, the best currently available estimates are presented below in order to allow a more complete cost benefit analysis of these proposals

168. The profile for chargepoint delivery is based on the ZEV mandate trajectory, modelling of the composition of the car and van fleet, and the assumption that current charging behaviour is representative of future behaviour, to estimate demand for fuel and chargepoints of different types. These demand estimates are combined with cost estimates (capital, operational, and reinstallation), chargepoint lifetime estimates, and a learning rate of 10% cost savings for each doubling of chargepoint installations in order to estimate the up-front and ongoing infrastructure costs.

169. A 'baseline' chargepoint cost trajectory is deducted from each policy scenario's trajectory in order to reflect the marginal cost of the ZEV mandate. This baseline trajectory is based on the level of ZEV and PHEV uptake assumed to occur in absence of these proposals.

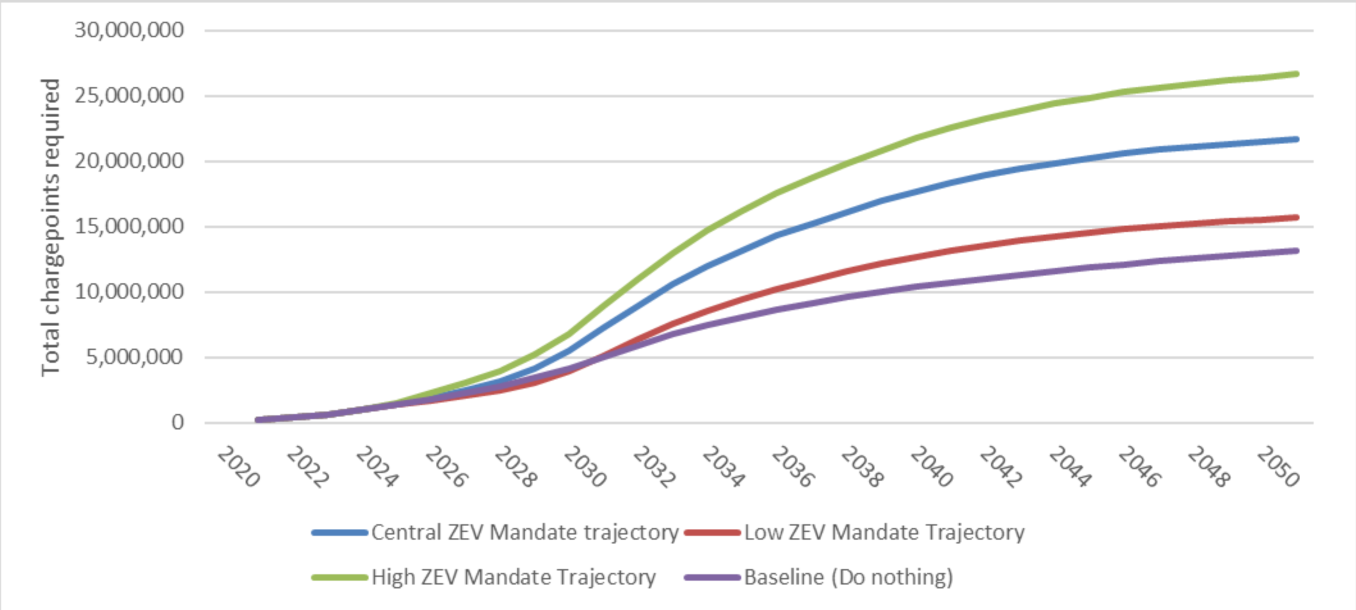
170. Table 38 presents the central costs assumed for each chargepoint type. Hardware and installation/reinstallation are incurred when a chargepoint is installed or replaced (every 15 years for all chargepoint types except rapid chargepoints, which are every 10 years). Maintenance costs are incurred annually.

171. In order to reflect the inherent uncertainty surrounding costs of nascent technologies, infrastructure cost sensitivities are included in the upside and downside sensitivities presented in 'Section 2.0: Sensitivity Analysis'. In absence of rigorous evidence on the level of likely variation, a +/- 25% adjustment is applied to reflect high and low infrastructure cost outcomes, respectively.

Table 38 Chargepoint cost assumptions[28]

Type	Hardware	Installation	Reinstallation	Maintenance
Residential off-street	£650	£375	£375	£0
Workplace	£3,358	£4,680	£400	£500
Residential on-street	£1,288	£3,660	£400	£280
Destination	£3,358	£4,680	£400	£500
Rapids	£23,500	£13,400	£11,500	£1,000
Depot	£3,358	£4,680	£400	£500

Figure 39 Chargepoint demand trajectories



172. Much like the current ICEV infrastructure, ZEV chargepoints will be required indefinitely; as a result, maintenance and reinstallation costs will continue as long as ZEVs are in-use. However, in keeping with HMT Green Book guidance, these proposals are appraised over a fixed time period, ending in 2071.

173. In order to accurately reflect the balance of costs over this period, chargepoint costs are adjusted for the period 2056-2071. This is because their expected functional lifetime extends past the end of the appraisal period, whereas their benefits are incurred annually and therefore are implicitly limited. Therefore, chargepoint costs are pro-rated to align with the proportion of total lifetime benefits which are achieved within the appraisal period.

174. The resulting present value costs associated with infrastructure requirements are presented in Table 40, below. It should be noted that these costs include the private costs borne by those

[28] These cost assumptions are taken from a range of sources, including: 'Understanding the costs and impacts of potential approaches to providing electric vehicle charging for households without private off-street parking', Ricardo Energy & Environment/Climate Change Committee; the 'Improving the consumer experience at public chargepoints' Impact Assessment; 'A portfolio of power-trains for Europe: a fact-based analysis', Environmental and Energy Study Institute.

installing and maintaining the chargepoints, i.e. predominantly households and businesses; these are not costs to Distribution Network Operators (DNOs). There may be additional costs of reinforcing the electricity grid (as set out in Table 25), however this is currently highly uncertain and not included in the cost benefit analysis.

Table 40 Present value infrastructure costs for the Preferred Option (present value; 2021 prices; £m)

Vehicle type	Cost type	Net cost
Car	Capex	8,985
	Opex	1,848
	Total	10,834
Van	Capex	2,155
	Opex	477
	Total	2,632

Tax Impacts

175. There are a number of anticipated changes in tax revenues as a result of these proposals. Some are transfers, which result from switching between fuels with different applied taxes; others arise from expected increases in travel due to differences in fuel costs.

Fuel duty and VAT Transfers

176. In line with the Green Book guidance, transfers of resources between people (e.g. gifts, taxes, grants, subsidies, or social security payments) should be excluded from the overall estimate of Net Present Social Value (NPSV). This is because the cost to one party is exactly offset by and equal benefit to the other, leading to no net change in social welfare.

177. Following a change in the fleet composition due to the proposed ZEV mandate, consumption of petrol and diesel is expected to fall relative to the baseline scenario. In addition to the cost of production, the prices paid by consumers include fuel duty and VAT. The increasing switch from petrol and diesel to electricity, on which fuel duty is not charged, and VAT is charged at a reduced rate for home charging, is therefore likely to lead to a reduction in taxes paid by consumers, for a constant level of fuel demand.

178. In line with the Transport Appraisal Guidance/Green Book guidance this tax revenue change is counted as a transfer. However, this transfer is non-trivial for HM Treasury and is therefore estimated in this assessment. DfT will work with HMRC and HM Treasury to understand the implications of this transfer.

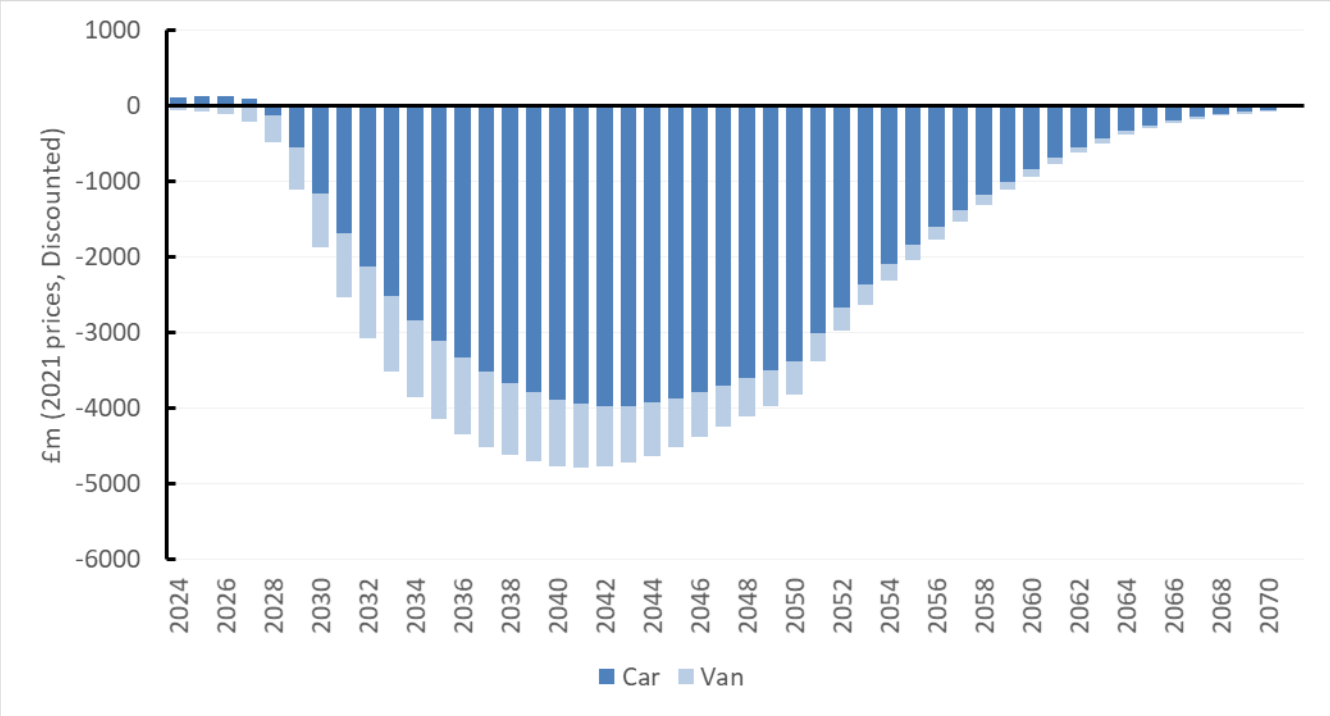
Figure 41 Tax revenue transfers fuel duty and VAT under the Preferred Option (2021 prices; negative values imply a reduction in tax revenue)

Powertrain	Unit	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Car	£m	112	137	138	103	-128	-552	-1155	-1680	-2129	-2505	-2826	-3102
Van	£m	-51	-73	-110	-207	-355	-548	-714	-852	-947	-1005	-1028	-1032

Vehicle Excise Duty (VED) transfers

179. Following the 2022 Autumn statement, VED has been updated to broadly equalise the average amount of tax paid for ZEVs and non-ZEVs. This update will apply to ZEVs registered since 2017, thereby covering the whole ZEV mandate delivery period. For this reason, there is expected to be no net transfer between Government and consumers and/or businesses.

Figure 42 Tax revenue transfers (VED + fuel duty) under the Preferred Option



Additional Tax Impacts

180. The switch to ZEVs is assumed to lead to increased mileage per ZEV driver, because electric fuel is cheaper than petrol and diesel. Electricity currently has a 5% VAT rate (for home-consumption), so this 'rebound effect'[29] is expected to lead to an increase in Government VAT revenues, compared to a world with no ZEV Mandate.

181. Unlike the change in fuel duty and VAT revenues described above, this increase in VAT revenue is not a transfer. The increase in mileage per driver leads to a utility benefit and financial cost for consumers, valued at the retail price of the fuel used. Because this utility value includes the VAT paid, there is an increase in tax revenue *in addition* to the private cost and benefit (which are equal) to the consumer.

182. The increase in VAT revenue resulting from increased electric mileage per driver is therefore included in the monetised appraisal, and shown in Table 43. Unlike tax transfers, this additional impact is included in the monetised appraisal.

Table 43 VAT revenue associated with the rebound effect under the Preferred Option (Present value; 2021 prices; £m)

Vehicle type	Net cost
Car	2,436
Van	1,663

Benefits

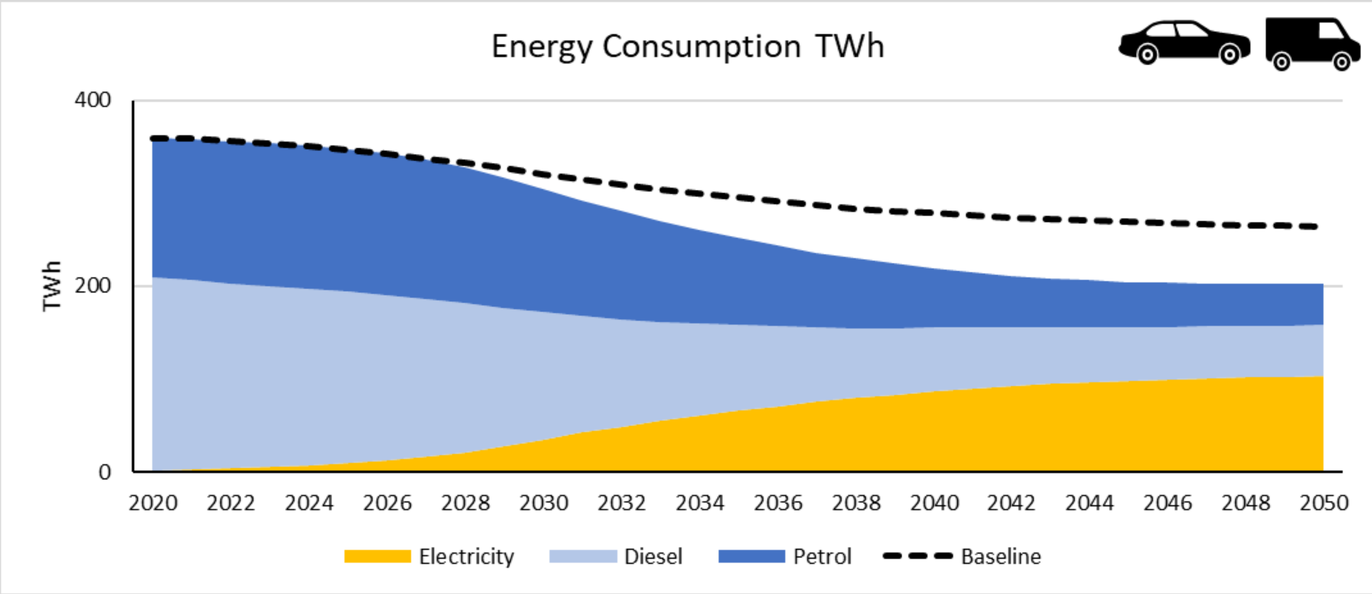
Carbon Impacts

183. These proposals lead to a significant change in the fuel consumption of the UK car and van fleet, as ICEVs are gradually replaced by ZEVs. Petrol/diesel fuel consumption falls as the number of these sales falls relative to the baseline, while there is some increase in electricity consumption due to the greater number of ZEVs and the associated rebound effect. That said, as

[29] The rebound effect, alongside limitations in its estimation, is set out in more detail in the 'Indirect Costs and Benefits', below.

shown in Figure 44, the net impact is a significant reduction in total Terrawatt hours (TWh) energy demand – driven by the greater fuel efficiency of electric vehicles.

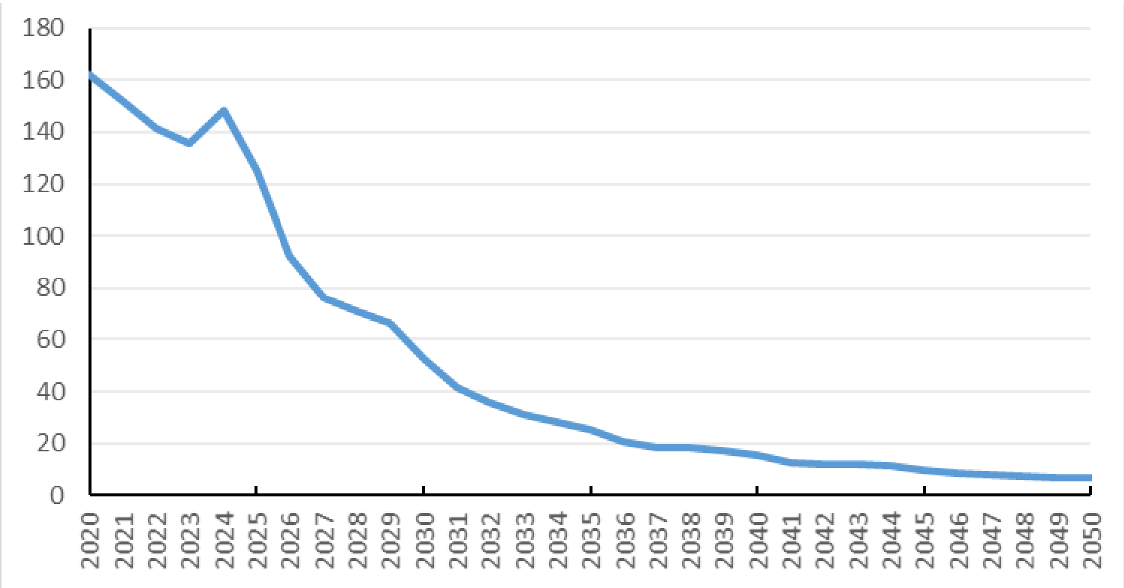
Figure 44 Energy demand changes for cars and vans



184. These changes lead to significant changes in emissions: the reduction in consumption of petrol and diesel reduces non-traded emissions (shown in Figure 46), whereas the small increase in electricity demand will come with an additional, albeit much smaller, cost of increased traded emissions (shown in figures Figure 46 and Figure 47), until electricity generation reaches carbon neutrality.

185. The increase in traded emissions is quantified using DESNZ published electric grid intensity factors (shown in Figure 45) and estimates of increased electricity demand. As shown, the reduction in non-traded emissions significantly outweighs the small increase in traded emissions, leading to overall emissions savings which peak at roughly 25 $MtCO_2e$ around 2045.

Figure 45 Electricity generation emissions intensity[30]



186. For non-traded emissions, the reduction in non-ZEV sales feeds through into a reduction in the proportion of the fleet that is non-ZEV. As shown in Figure 44, at its peak this leads to a reduction

[30] Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal - GOV.UK (www.gov.uk)

in petrol and diesel energy consumption of more than 110 TWh per year, which results in non-traded emissions savings exceeding 20 $MtCO_2e$ per year (shown in Figure 46).

Figure 46 Annual car traded and non-traded emissions savings for Policy Option 1

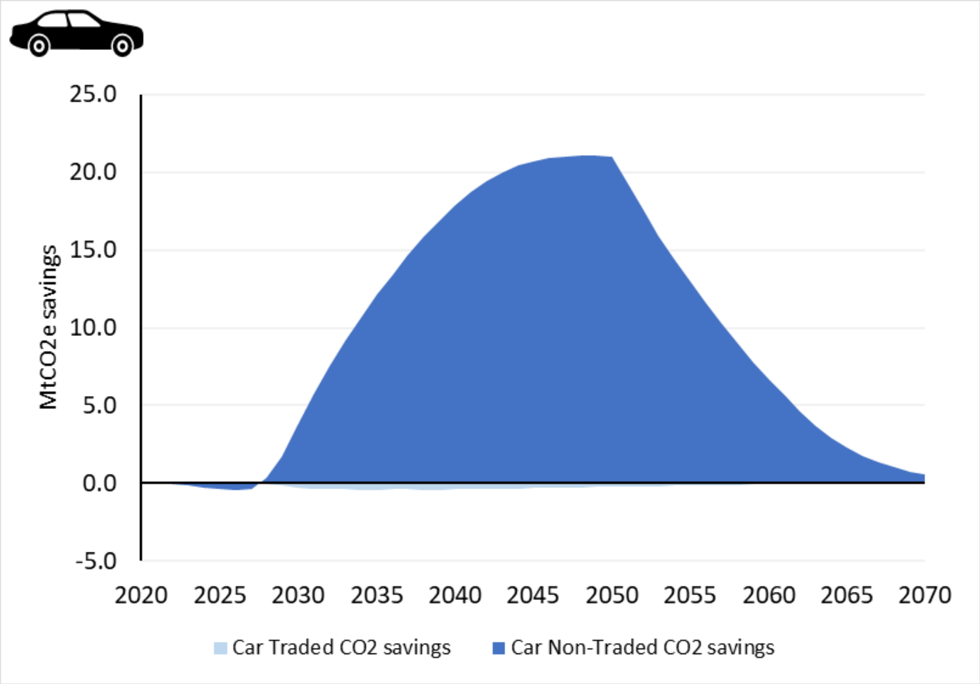
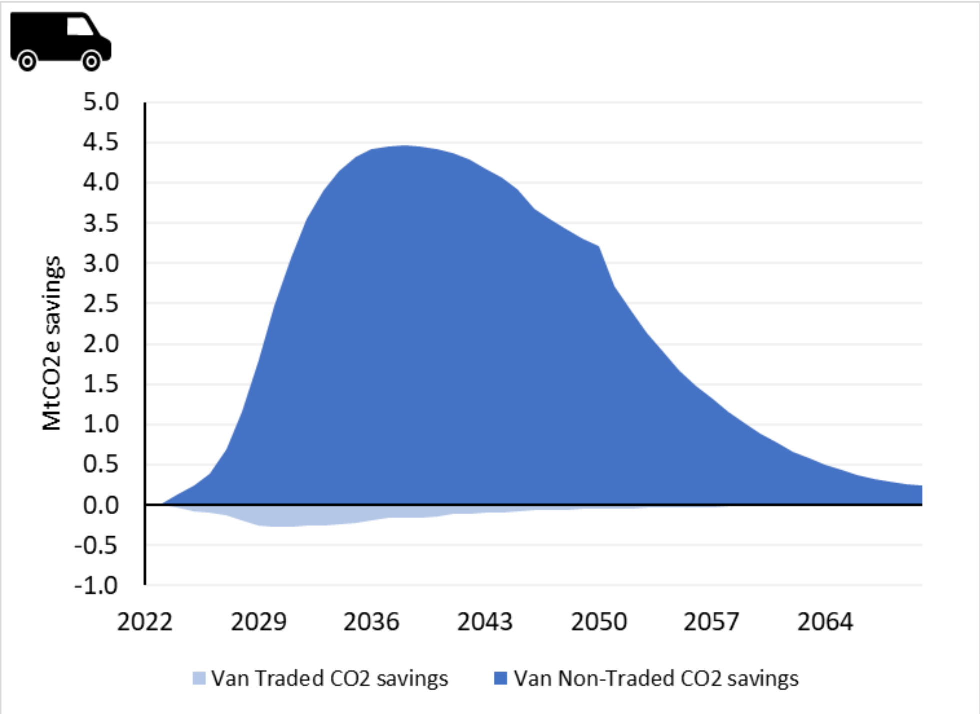


Figure 47 Annual van traded and non-traded emissions savings for Policy Option 1



187. As shown in Figure 46 and Figure 47, non-traded emissions savings benefits far outweigh traded emissions costs. There are several drivers of this: firstly, ZEV fuels are more efficient than ICEVs; for this reason, the increase in electricity demand is of a much smaller magnitude than the decrease in petrol and diesel consumption. Secondly, the carbon intensity of electricity generation is substantially lesser than that of petrol and diesel consumption and is expected to decline significantly over the next few decades. This is the reason that traded emissions peak and begin to decline around 2035, despite that the number of ZEVs in the fleet, and electricity consumption, continues to increase.

Table 48 Traded and non-traded monetised impacts for cars and vans (present value; 2021 prices; £m)

Vehicle type	Emission type	Net benefit (£m)
Car	Traded CO_2e	-1,614
Van	Traded CO_2e	-861
Car	Non-Traded CO_2e	83,319
Van	Non-Traded CO_2e	19,867
Car	Net impact	81,704
Van	Net impact	19,005
Both	Net impact	100,710

188. These impacts are monetised using the published DESNZ carbon values and discounted in line with Green Book Appraisal Guidance. Emissions generated by domestic transport such as cars and vans are classified as non-traded emission sectors. As ZEVs are zero emission at the exhaust, and associated emissions are created at the point of generation, electricity-generation emissions are included in the UK ETS and therefore traded.

The traded and non-traded carbon abatement and monetised impacts are presented in

189. Table 48. As shown, non-traded emissions savings and benefits far outweigh the increase in traded emissions. The net effect is expected to exceed £100bn in social benefits (for cars plus vans), and 31 $MtCO_2e$, 81 $MtCO_2e$, and 415 $MtCO_2e$ in CB5, CB6, and 2020 – 2050, respectively.

Fuel Benefits

190. These proposals will also lead to significant changes in fuel consumption by fuel type (litres or kWh). These fuel types have different associated costs of production, which represent costs to society. These costs are valued using DESNZ long-run variable costs, in line with the Greenbook and Transport Appraisal Guidance.

191. Under the proposed central ZEV mandate scenario, there is a significant decrease in petrol and diesel consumption, which translates into a fuel consumption benefit relative to the baseline. However, there is also a significant increase in electricity consumption, which results in a fuel consumption cost relative to the baseline. As the energy cost of driving electric vehicles is lower than the fuel cost for petrol/diesel vehicles (before tax), these proposals lead to a resource benefit to society.

Figure 49 Fuel cost to society for Policy Option 1 (present value; 2021 prices; £m)

Vehicle type	Value	Net benefit
Car	Fuel Cost	18,898
Van	Fuel Cost	1,101

192. There has been significant variation in the retail prices of electricity, petrol, and diesel, due to a range of global shocks which have affected both supply and demand for each fuel. It is not possible to draw direct conclusions from retail price data, as only a portion of variation in this metric is due to changes in the resource cost of each fuel, however analysis of the proportional changes in fuel costs can provide some useful insight to the potential effect of these shocks on the estimated societal impact of these proposals.

193. The DESNZ Quarterly Energy Prices publication suggests that the recent (Q1 2021 – Q1 2022) increase in petrol and diesel prices exceeds the increase in electricity prices. Although these are retail prices, rather than resource costs, the magnitude of these changes suggest that any persistent price shocks are likely to lead to equal or greater societal benefits than those presented above.

194. However, as these price shocks are driven by geopolitical shocks, they are broadly expected to be transient. Given that the ZEV mandate will begin to drive additional ZEV sales from 2024

onwards (i.e. in the longer-term), it is likely that global supply and demand for these fuels will be more closely aligned with DESNZ' baseline projections, which reflect the long-term supply capacity for these fuels. Note the real price impact onto a driver is discussed later (See 'Section 4.0: Cost of Living').

Operating Benefits

195. Drivers incur several different types of operating costs, such as repairs, servicing, and tyre replacements. These vary between vehicle types and drive trains. ZEVs should have lower maintenance costs as they are simpler in design and have fewer moving parts.

196. Analysis published by EDF Energy suggests that features such as regenerative braking (which reduces wear and tear on wheel brakes) and fewer moving parts lead to lower costs of servicing and replacing worn components. In addition, unpublished regression analysis based on 2020 Fleet Data, undertaken by Element Energy, suggests that overall maintenance costs for ZEVs are lower than ICEVs. The regression models had an average R-squared value of 0.91, suggesting the models explained 91% of the variation in maintenance costs.

197. Because these proposals would lead to greater numbers of ZEVs and fewer ICEVs on the roads, this is expected to lead to a net change in costs faced by drivers. Our modelling monetises the value of maintenance cost savings based on the Element Energy modelling. The present value of maintenance costs benefits for the Preferred Option are shown in Table 50. As shown, the cost savings are significant for both cars and vans. This suggests that, although there may be greater up-front costs associated with ZEVs, particularly in earlier years, ZEV drivers are likely to experience significantly lower running costs. Detailed analysis of the effect on disposable income of the ownership of a ZEV, relative to an ICEV, is presented in 'Section 4: Cost of Living' and 'Annex E – Cost Of Living Depreciation Sensitivities'.

198. Estimated net operating cost savings are presented in Table 50. As shown, these are expected to amount to more than £15bn over the appraisal period, representing a significant cost saving to drivers.

Table 50 Maintenance costs for cars and vans under the Preferred Option (present value; 2021 prices; £m)

Vehicle type	Value	Net benefit
Car	Operating Cost Savings	9,301
Van	Operating Cost Savings	6,116

Air Quality Benefits

199. Greater ZEV uptake is expected to have net co-benefits of cleaner air and associated wider economic benefits. ZEVs almost exclusively have no exhaust emissions of particulate matter (PM) or NOx, which are emitted by petrol and diesel engines and which contribute to poor air quality.[31] Differences in air quality impacts stemming from non-exhaust PM are more complex, uncertain, and mixed. The approach taken with regard to this uncertainty is explained in detail in Annex A.

200. Air quality impacts are discounted using Health discount factors, in line with Transport Appraisal Guidance. The resulting estimated air quality impacts are presented in Table 51; as shown, this results in net benefits to society, despite potential increases in PM (from more mileage from ZEVs and therefore road abrasion and tyre and brake wear) driving some social costs.

201. The detailed methodology which underpins these calculations is presented in Annex A. This annex also presents assumed damage cost by emission type, and net air quality emissions by mass.

[31] Consultation on environmental targets - Defra - Citizen Space

Table 51 Present value air quality impacts under the Preferred Option (present value; 2021 prices; £m)

Vehicle type	Air quality impact type	Net benefit
Car	NOx cost	455
Car	PM cost	-256
Van	NOx cost	843
Van	PM cost	-72

Consumer Surplus

202. The switch to ZEVs is assumed to lead to increased mileage per ZEV driver, due to the combination of reduced mileage costs and 'The Law of Demand'.[32] Electricity is cheaper from a resource cost currently has a 5% VAT rate (for home-consumption) and does not pay fuel duty, so this 'rebound effect' leads to an increase in expected trips and mileage.

203. When thinking of driving a mile as a normal good, these additional trips have an economic social benefit to drivers – the value of the additional trips taken. In line with transport analysis guidance, this is valued through the "rule of a half". Effectively, the change in vkms * the change in the value of vkms (£/km) * ½. As a result, we expect marginal benefits to drivers, as shown in Table 52.

Table 52 Present value consumer surplus benefits under the Preferred Option (present value; 2021 prices; £m)

Vehicle type	Value	Net benefit
Car	Consumer Surplus	906
Van	Consumer Surplus	163

204. It should be noted that this consumer benefit is additional to the operational and fuel cost savings expected to be realised by drivers. Overall, drivers are expected to realise greater disposable income as a result of investing in ZEVs, in addition to expanded driving options, due to the lower cost of transport. The effect of ZEVs on disposable income is discussed in greater detail in 'Section 4.0: Cost of Living'.

Unmonetised impacts

Indirect Downstream Business Costs

205. Additional impacts may exist for car and van garages, traders, and dealerships for additional training required to sell, maintain, repair, and service ZEVs. However, the proposed ZEV mandate scheme does not impose requirements onto these businesses, therefore are deemed indirect impacts.

206. The impact to these firms is expected to be through familiarisation with the technology and the cost of training staff. However, these one-off costs are deemed to be indirect and expected to be of a low magnitude. We welcome views from industry on the variety of business impacts and the scale of financial impacts to these industries following an acceleration in the electrification of the UK car and van fleet.

207. To understand the scale of these potential indirect impacts, the number of firms related to the manufacture of motor vehicles are taken from the ONS UK business activity, size, and location statistics. Figure 53 presents the number of VAT and/or PAYE based enterprises by Standard Industrial Classification (SIC) class. This will provide an overestimate as some of these

[32] This stipulates that there is a negative relationship between price and demand, so reduced mileage costs lead to greater demand for this form of travel.

categories may capture relevant businesses associated with HGVs, buses and coaches, and light category vehicles which are out of scope of the proposed car and van ZEV mandate.

Figure 53 Count of businesses expected to be indirectly affected by the ZEV mandate proposals

	Employment Size Band							
	0-4	5-9	10-19	20-49	50-99	100-249	250+	Total
2910: Manufacture of motor vehicles	785	105	40	20	20	5	20	995
2931: Manufacture of electrical and electronic equipment for motor vehicles	125	15	15	15	10	5	0	185
2932: Manufacture of other parts and accessories for motor vehicles	815	160	100	90	60	65	55	1,345
4511: Sale of cars and light motor vehicles	15,465	2,015	825	445	175	120	125	19,170
4520: Maintenance and repair of motor vehicles	34,990	8,950	2,255	710	145	70	45	47,165
4531: Wholesale trade of motor vehicle parts and accessories	2,620	810	395	210	80	55	30	4,200
4532: Retail trade of motor vehicle parts and accessories	3,565	750	280	110	20	20	5	4,750
7711: Renting and leasing of cars and light motor vehicles	2,910	360	170	95	40	20	15	3,610

Jobs And Growth Impacts

208. Jobs and growth impacts are inherently uncertain, and typically fall outside the scope of UK Government cost benefit appraisals. This is because the HMT Green Book guidance for economic appraisal instructs analysts to assume that the economy is at full employment (meaning that jobs created in one industry displace an equal number of jobs in another), and to assess only the direct impacts of the policy.

209. That said, some direct employment impacts can be assessed using the ‘wage premium’, which relates to the difference in the wage (productivity) of the job created, compared to the job displaced. This in turn leads to a change in the total economic output in a given year, which is equal to the product of the wage premium and associated new jobs.

210. In order to assess the likely employment/output impact, a number of simplifying assumptions are required. For instance, it is assumed that the number of vehicles manufactured in the UK is constant, whereas the ZEV mandate affects the proportion of vehicles manufactured in the UK which are ZEVs versus ICEVs. In addition, ZEV and ICEV manufacturing labour requirements are broadly equal, so differential labour market impacts arise from the supply chains; productivity in each supply chain is constant over time; there are no differences in R&D employment between the two technologies; and that there is no effect on the UK’s trade balance.

211. An additional, significant simplifying assumption is that the ZEV mandate proposals only affect UK manufacturing decisions after other firm and funded policies, such as the Automotive Transformation Fund (ATF). This is compliant with the HMT guidance on economic appraisal; however, it is likely an over-simplification of firms’ investment decision.

212. After accounting for employment in the counterfactual, the Preferred Option is expected to lead to some employment benefits, both in terms of the number of jobs supported and in the wage

premia of these jobs. At its peak, The Preferred Option is anticipated to support several hundred more jobs in the vehicle manufacturing industry than in the counterfactual; initially, a wage premium of around £20,000 is expected, although this is expected to decrease over time, beginning around 2028. This analysis suggests modest vehicle manufacturing employment and wage gains, although there are some important caveats, with variance in applied assumptions potentially affecting the scale of these effects.

213. Several stakeholders have indicated that production investment decisions are made based both on anticipated demand in the economy in which they may invest (driven by the ZEV mandate) as well as the supply-side conditions (which are affected by the ATF). This suggests that, although under the Green Book methodology directly attributes some employment impacts to the ATF, in reality a portion of these are likely to be indirectly supported to some extent by demand-side policies such as the ZEV mandate.

214. Furthermore, increased investment in UK ZEV manufacturing may lead to significant UK export opportunities, particularly as these proposals would put the UK ahead of many of its trading partners in terms of its transport decarbonisation commitments. ZEV production costs are expected to fall over time, in part due to operational learning (i.e. greater cumulative production); as a result, the UK may become more competitive relative to other ZEV-manufacturing economies, even if manufacturing volumes (ICEVs, ZEVs, and PHEVs) themselves do not rise.

215. This increase in relative competitiveness could lead to greater demand for UK output, and subsequently greater UK output and earnings; however, due to the simplifying assumptions set out above, this potential effect is not captured by this analysis. Trade impacts of these proposals are set out in more detail in 'Section 4: Trade Impacts'.

216. Due to the number of significant, simplifying assumptions, and that many of the anticipated effects of the ZEV mandate are not deemed to be 'direct', the monetised impacts are not included in the monetised appraisal. Nonetheless, the Preferred Option appears to be likely to lead to significant social benefits in the form of increased income for supply chain workers.

217. Additionally, there are expected to be significant employment demands from the chargepoint infrastructure industry. In particular, installation, maintenance, and reinstallations (which are modelled in the monetisation of infrastructure costs) are all likely to support a significant number of jobs, first to develop the required infrastructure network and then to maintain it.

218. The ZEV chargepoint industry is nascent and therefore there is little robust data on likely employment impacts, in particular over future decades when demand is expected to increase by several orders of magnitude. However, it is possible to estimate these with some level of confidence using data published by the Office for National Statistics on turnover, employment, and indirect employment effects of the Low Carbon and Renewable Energy Economy (LCREE).

219. Employment and turnover data on the 'Low emission vehicles and infrastructure' sector suggests there are nearly 3 jobs supported per £m turnover for the industry as a whole, or around 2 per £m for manufacture and around 10 per £m for other activities (such as construction and installation). These multipliers can be applied to manufacture, installation, and maintenance costs for infrastructure impacts (net of baseline infrastructure investment) in order to estimate direct, marginal employment supported by the activity driven by these proposals.

Table 54 Estimated infrastructure FTE employment supported by Policy Option 1[33]

	Average annual	2030
Chargepoint hardware	500	1,100
Installation of new chargepoints	2,400	7,200
Reinstallation of replacement chargepoints	900	-
Maintenance	1,200	900

[33] Figures may not sum due to rounding.

Indirect	3,000	3,000
Total	7,900	12,200

220. The ONS also publish indirect employment multipliers, which reflect supply chain employment supported by economic activity in this sector. Combining this multiplier with the top-down estimation of direct employment provides a high-level estimate of total infrastructure employment; these are shown in Table 54.

221. As shown, this analysis suggests that by 2030, employment supported by the infrastructure network alone could total around 12,000 FTE jobs per year. Of these, more than 8,000 are expected to be in the manufacture and installation of chargepoints. As the network matures, installation jobs will decline, however there will be further reinstallation jobs supported by the replacement of existing chargepoints which have reached the end of their functional lifetime.

222. There are also expected to be a significant number of maintenance jobs supported by the infrastructure network. The figures above are calculated using the same turnover multiplier as construction and installation and suggest there will be less than 1 maintenance job per manufacturing and installation job combined.

223. However, it should be noted that this may be an under-estimate. This is primarily because maintenance is likely to be significantly less capital and input intensive than installations, meaning that a greater number of jobs would likely be supported per £m turnover specifically for maintenance activities. This conclusion is supported by related public research, for instance this report published by the European Association of Electrical Contractors suggests there may be more than 2 additional maintenance jobs for each manufacture and installation (combined) job. This estimate was reached using a similar approach to the turnover multiplier applied above, however the underlying data is not published alongside the report. In absence of corresponding UK data, no adjustment is made to the turnover multiplier (of roughly 10 FTE per £m turnover), however it is recognised that this is likely an under-estimate of total jobs.

224. The above report also suggests many more jobs may be supported in related industries and economic activities, including business administration, wholesales, and electricity generation. These may be captured to some degree using the ONS indirect employment multiplier, although there is some uncertainty regarding this. No additional professions or sectors are included in this analysis, though again it is possible that this will lead to a further under-estimate of infrastructure employment.

225. On the other hand, this analysis assumes that all chargepoints are manufactured in the UK and therefore support UK jobs. This assumption may be less likely to hold true, suggesting that fewer manufacturing jobs may be supported. However, this activity is expected to make up only 6-9% of total infrastructure jobs quantified here. Some ‘leakage’ here is therefore unlikely to have a significant effect on overall infrastructure employment impacts.

226. The overall picture is somewhat unclear, with both potential upside and downside uncertainties, however it is clear that increasing infrastructure demands are likely to support a significant number of jobs.[34] These impacts are not monetised, because there is significant uncertainty over the likely wage level and wage premium in this sector, versus comparable counterfactual economic activity. Nonetheless, it does appear that the infrastructure requirements of the ZEV mandate will go some way to support the Government’s objective to ‘Build Back Greener’.

[34] It is possible, however, that other related industries face a contraction if ZEVs have a materially different impact compared to ICEVs. The Government will continue to review the best available evidence with the view to include additional employment analysis in the Government Response.

227. These impacts are presented at the national level, however there may be differences in the regional distributional of certain jobs. Employment associated with the installation and maintenance of the charging network is likely to be distributed, however changes in manufacturing may be more regionally concentrated. In order to proportionately estimate impacts on employment and investment, we will engage with the Green Jobs Delivery Group and the Spatial Data Unit to understand the spatial impacts of the policy over the long term.

Lifecycle Emissions

228. The additional emissions due to vehicle manufacturing, maintenance and servicing, and end-of-life activities (re-using, re-purposing, disposal, etc) have not been monetised within this assessment, as they add significantly to the complexity of analysis.

229. However, DfT have recently published research which quantifies the lifecycle emissions of road transport and this shows that the transition to zero emission vehicles significantly reduces carbon whether appraised from a life cycle or exhaust emission perspective. This research suggests that overall, BEVs are expected to reduce GHG emissions by 65% compared to a petrol car today, and this rises to 76% by 2030.

230. Fuel cell hydrogen vehicles are also estimated to reduce GHG emissions by 56% compared to a petrol car. The analysis accounts for the additional emissions from battery production, which reduce over time as battery production occurs more commonly in Europe. In addition, the same research suggests that ZEVs will lead to lesser emissions associated with maintenance, which is not captured in this assessment.

231. For proportionality for this consultation, this evidence has not been used to quantify lifecycle impacts because: while the evidence supports the case for a transition to zero emission vehicles from a exhaust or a lifecycle basis, DESNZ have confirmed they will consult on carbon border adjustment mechanisms to bring into scope wider carbon leakage; DBT's (the department for Business and Trade) industrial decarbonisation strategy outlines further measures to decarbonise the industrial sector therefore some lifecycle emissions are outside the scope of this assessment; and the differences in production and maintenance emissions are expected to be small and counter-balancing. Nonetheless, further analysis of available evidence will be conducted with the view to improve the breadth and depth of policy appraisal, where proportionate.

Energy Systems Impacts

232. To achieve net zero, the UK will need to decarbonise whole sectors and electrification will play a key role in achieving this. This will require an increase in capacity in the electricity generation, transmission and distribution systems. To some degree these costs are captured in the long-run variable cost (LRVC) of electricity, which is used in this analysis. However, these assumptions are most appropriate for relatively marginal changes in energy consumption, whereas these proposals are expected to lead to a more substantial increase in electricity demand, as shown in Figure 44. As a result, the Greenbook LRVC inputs may under-estimate the system costs arising from these proposals.

233. The extent to which these proposals require greater generation and grid capacity is uncertain and depends on when electric vehicles are charged. Technologies such as "smart charging" allow demand to be shifted across the day to periods which are more beneficial to the electricity system. Furthermore, "vehicle to grid" technology can help balance the system by enabling charge points to discharge electricity to the network during peak times. Our CBA assumes no utilisation of these technologies as a proportionate and conservative assumption. However, both technologies can increase the flexibility of demand and mitigate the need for additional infrastructure.

234. It should be noted, however, that the increase in electricity demand from the transport sector will also coincide, to some extent, with greater electricity demand from other decarbonising sectors, such as domestic heating. As a result, these demands may pose some risk to carbon savings expected to be achieved by the ZEV mandate.

235. That said, because targets will increase incrementally, and it will take time for existing ICEVs to be replaced by new ZEVs, increased demands on generation and the distribution network will rise slowly. The same is true for other sectors, meaning that there are clear, long-term signals for investment.

236. Alongside this, announcements made through the UK Government's Net Zero Strategy, Ten point plan for a green industrial revolution, and Energy Strategy are expected to drive unprecedented levels of private investment in renewable energy sources such as offshore wind and nuclear power. Additionally, commitments to improving business and domestic energy efficiency are expected to reduce existing demand on the electricity and gas networks, freeing up capacity for electrification.

237. There will also be an impact on electricity networks as reinforcement will be required to support additional demand. The joint DESNZ-Ofgem Electricity Networks Strategic Framework recognises the need for transformation, at scale and pace, of the UK electricity network to accommodate both additional demand and new low-carbon generation. It sets out the strategic framework to develop an electricity network which is fit to support the transition to net zero, building on the commitments and key goals set by the British Energy Security Strategy.

238. Taken together, these strategic frameworks set the direction and are expected to leverage significant investment in the UK electricity generation sector. This is expected to substantially raise electricity generation and grid capacity. Nonetheless, as noted in the Electricity Networks Strategic Framework, further, new policies will be required in the future to meet the increasing demands to the electricity network.

239. The magnitude of the costs is uncertain and heavily dependent on a number of factors. Technologies such as smart charging and vehicle to grid increase system flexibility by allowing demand to be shifted across the day or discharged back to the network during peak times. Higher levels of system flexibility reduce cost by mitigating the need for additional energy infrastructure and enhancing energy security. Nonetheless, in the analysis accompanying the 2021 Smart Systems and Flexibility Plan , we estimated that we will need around 30GW of low carbon flexible assets by 2030, which represents a three-fold increase on today's levels.

240. A proportionate, quantitative assessment of the impact of our proposals on the energy system will be produced as part of the Government Response.

Time Savings

241. The increase in ZEV uptake caused by these proposals is likely to lead to differences in households' and businesses' refuelling behaviour. This is expected to lead to differences in time required to refuel vehicles, and subsequent utility impacts for households and cost impacts for businesses. This section sets out high-level analysis of these impacts.

242. Per the rest of the analysis, this section focuses on the impact of increased BEV uptake. Impacts may vary for other ZEV technologies, for instance hydrogen fuel cell vehicles. However, current ZEV deployment has been almost exclusively driven by BEVs. Therefore, in the interests of proportionality, this analysis is based on BEV impacts.

243. There is significant uncertainty regarding the variables which affect the nature and magnitude of this impact, therefore it is not included in the monetised impacts. However, some proportionate analysis is presented to illustrate the likely direction (i.e. whether the net effect is a cost or benefit) and scale of the effect.

244. Increased ZEV uptake will lead to greater use of chargepoints and less use of refuelling stations. There are time costs associated with using refuelling stations for two primary reasons: firstly, these stations are public, and drivers are required to be present while the ICEV is refuelled; secondly, refuelling activities often require detours, or separate journeys to refuel. As ZEV sales increase and replace ICEVs, time costs of refuelling at these stations is expected to fall.

245. However, rising ZEV uptake is expected lead to a commensurate rise in some of time costs associated with electric vehicle charging, although the way in which they affect drivers is likely to differ in several key ways. Firstly, the large majority of charging activity is expected to be achieved by slow-speed, residential on- or off-street chargepoints. Much of this activity is expected to take place over night, or at other times while drivers are at home; they are therefore expected to have a minimal impact on drivers' other activities as no trip detours are required and charging time can be spent on other activities.

246. In addition, other chargepoint types and/or locations such as workplace or destination (e.g. shopping centres) are likewise expected to only minimally affect drivers' behaviour as charging will be possible alongside other activities, and these chargepoint locations are unlikely to require detours or lead to other journey delays. For these reasons, for most chargepoint types, this analysis values the transaction cost associated with charging behaviour (for example, the time taken for a driver to locate and plug-in their vehicle for residential off-street charging), but not the time taken for the vehicle to be charged.

247. The impact may be different for rapid charging. This kind of charging is expected to be less common, but may be required for instance during longer journeys, and/or journeys before which the vehicle has not been sufficiently charged. In these cases, charging may be more disruptive and may lead to greater transaction costs (for instance a detour to use a rapid chargepoint) as well as greater time costs of charging (as these are more specialised locations, it may not be possible for drivers to carry out other activities at the same time).

248. The assumed transaction (or 'hassle') costs of refuelling are presented in Table 55. As shown, although the average plug-in duration for BEV refuelling is considerably longer than for ICEVs, the total time lost recharging or refuelling (the value which is used to calculate the utility or business cost of time spent charging) is considerably lower for all BEV charging activities except rapid charging. This reflects the rationale (set out above) that for the most part, BEV charging is expected to occur passively, while drivers undertake other activities, thereby avoiding additional time costs during charging.

Table 55 Assume transaction (hassle) and refuelling times for refuelling activities

Refuelling type	Transaction time	Average refuelling/recharging time	Total time lost recharging/refuelling
Residential off-street (BEV)	00:01:00	09:13:56	00:01:00
Workplace (BEV)	00:01:00	04:35:13	00:01:00
Residential on-street (BEV)	00:04:00	09:13:56	00:03:00
Destination (BEV)	00:01:00	03:35:13	00:01:00
Depot (BEV)	00:01:00	09:13:56	00:01:00
Rapids (BEV)	00:10:00	00:28:45	00:38:35
ICEV refuelling hassle time	00:10:00	00:01:20 – 00:02:20	00:11:20 – 00:12:20

249. These values are combined with estimates of the number of refuelling events for both BEVs and ICEVs, and for both the policy and baseline scenarios, giving an estimate of the total, marginal amount of time lost per year resulting from these proposals. For BEVs, this is based on estimates of chargepoint utilisation over time; for ICEVs, this is based on estimates of aggregate fuel consumption, average fuel tank sizes, and an assumed 'safety margin' (i.e. it is assumed that the representative driver refuels before their tank is fully empty; the central assumption is that the

median driver refuels when their fuel tank reaches 10%). This adjustment is not required for BEVs as it is implicitly included in the calculation.

250. These costs are monetised using the central values of time taken from the TAG databook. For cars, the average of all non-work time (including commuting) is taken; for vans, the average for working time is taken, as vans are predominantly used for business purposes. These values are adjusted to the correct price year using HMT Green Book's GDP deflators.

251. Using central assumptions, this suggests there could be net monetised time savings of around £508m (2022 prices; present value). If non-rapid ZEV transaction costs were to double, this could fall to around £461m. By contrast, if ICEV drivers' safety margin were to rise to 20%, with other assumptions held at the central value, the value of time savings could exceed £530m.

252. This suggests that these proposals may lead to significant social benefits, in the form of time savings for households and businesses. Due to the number of simplifying assumptions, and the relatively small magnitude of this impact compared to the overall benefits of the Preferred Option (with expected benefits of £145bn, this impact constitutes less than 0.5% of present value benefits), these impacts are not included in the monetised appraisal. However, as the evidence base develops, these impacts may be included in future analyses, including the Government Response Cost Benefit Analysis.

Indirect Costs and Benefits

Rebound Effect Costs (Congestion/Accidents)

253. The rebound effect – induced demand of a good due to a change in the price of the good – is a common effect in environmental economics and should be considered in economic appraisal of environmental policies. In this instance, the ZEV mandate is expected to increase the number of more cost-efficient vehicles on the road; the relative cost-effectiveness of driving (£/km) is shown in Figure 56. As the cost of driving for ZEV owners falls, we expect additional driving demand, and therefore additional road traffic and associated costs.

254. Retail prices (after VAT and fuel duty) are used to estimate the consumer cost per kilometre (£/km), for vehicles of each fuel type. Transport price elasticities of demand are taken from the NTM and multiplied by the relative change in £/km to produce an estimate of induced demand resulting from change in driving cost caused by the replacement of an ICEV by a ZEV.

Figure 56 Market price of driving in terms of Pounds per kilometre for cars

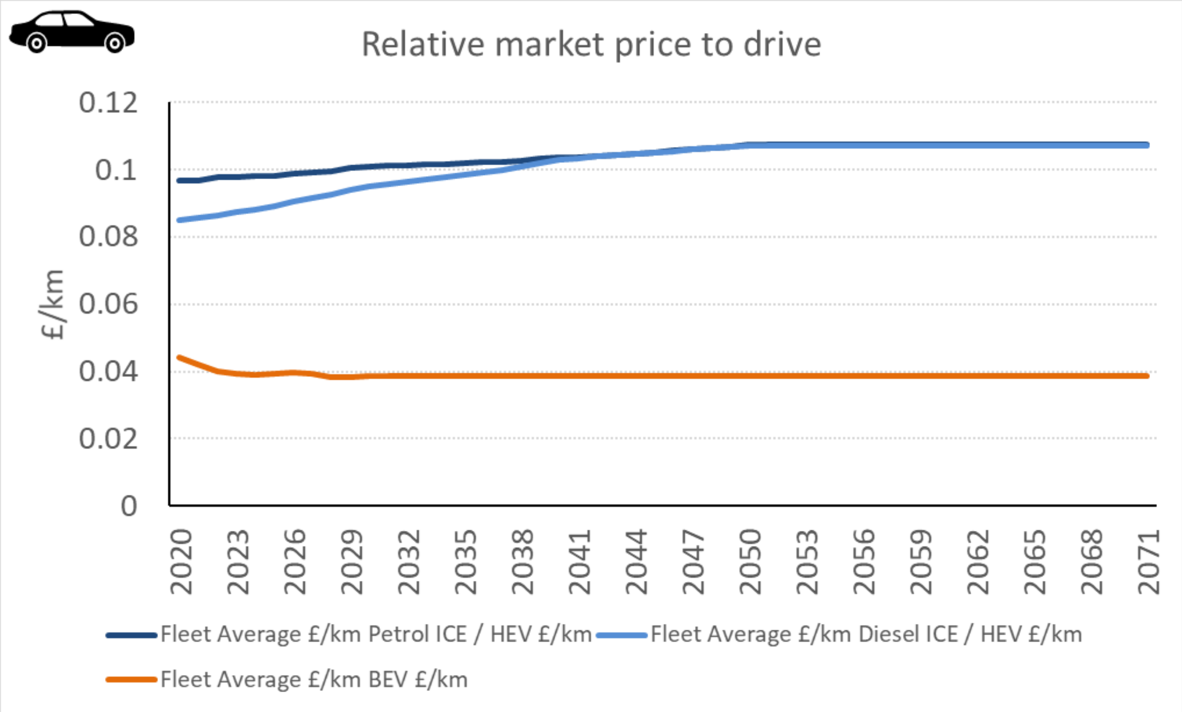


Figure 57 Market price of driving in terms of Pounds per kilometre for vans

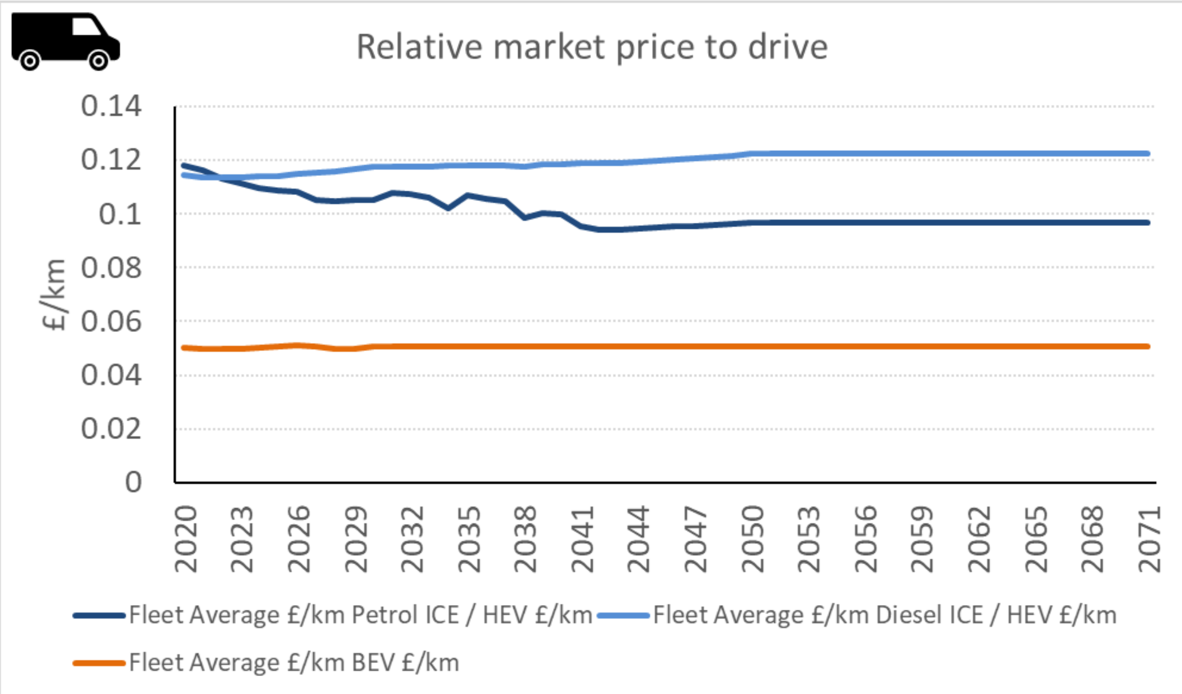
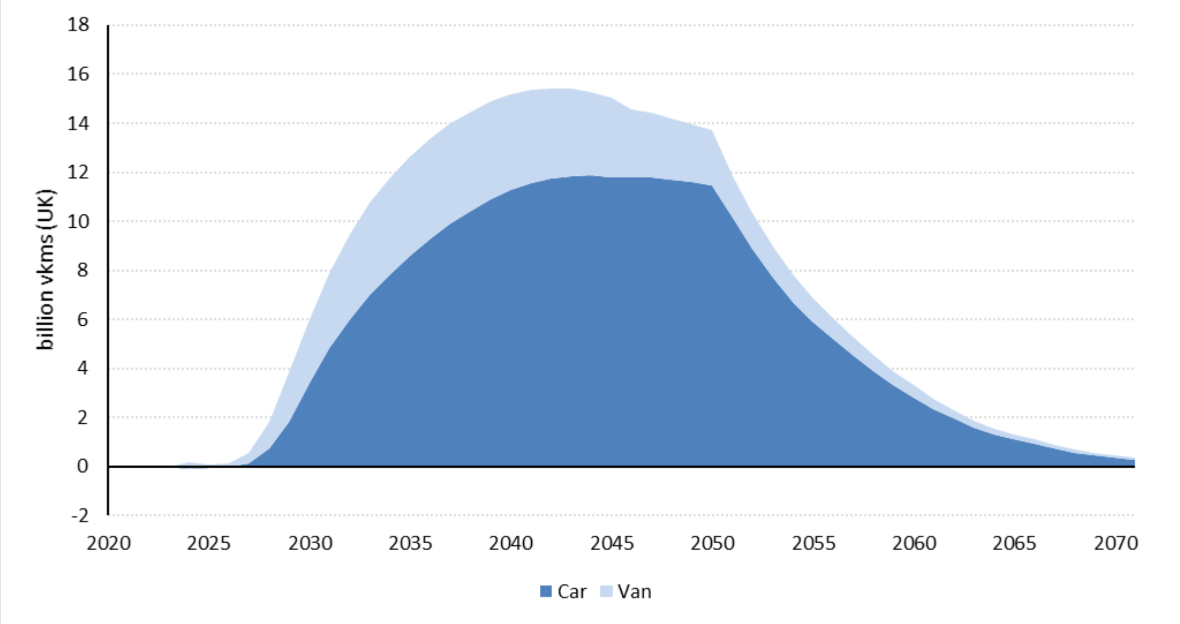


Figure 58 Additional road traffic demand (rebound effect) for cars and vans under the Preferred Option



255. The additional mileage (vkms) is multiplied by the TAG Marginal External Costs for Congestion and Accidents to provide an estimate of this external cost to other drivers in line with TAG MEC guidance. These reflect the additional time spent in congestion due to cars and vans achieving greater mileage. This also represents the greater number of expected accidents as a result of more mileage, and therefore the social damage cost to other drivers as a result.

256. As shown in Table 59, the Congestion and Accident externalities are significantly large and non-trivial. There are, however, several caveats to these estimates.

Table 59 Marginal external costs of Policy Option 1, due to the rebound effect (present value; 2021 prices; £m)

Vehicle type	Value	Net cost
Car	Accident Cost	-3,749
Car	Congestion Cost	-39,879
Van	Accident Cost	-1,218
Van	Congestion Cost	-12,347

257. There are several sources of uncertainty which may affect the magnitude of this effect. Firstly, there are several determinants of the retail price of fuels, including supply- and demand-side drivers and tax policies. Changes in one or more of these determinants could lead to differences in the relative prices of fuels, compared to those used in this analysis.[35]

258. Secondly, this analysis is limited to the direct and isolated effect of these regulations. However, there are several other changes in the transport sector which may affect induced demand for driving. For instance, road building, active transport,[36] and the proliferation of connected and autonomous vehicles would be expected to increase the available capacity on the UK's road network, and improve the efficiency and safety of road transport.[37] All these developments would therefore be expected to reduce the negative externalities associated with induced demand, compared to the direct impacts described here.

259. Thirdly, there is inherent uncertainty in the estimates of price elasticity of demand. These parameters relate to the *marginal* effect of an infinitesimal change in relative prices; for larger changes it is likely that the effect of changes in price diminishes. The relative price per kilometre driven by a BEV, relative to an ICEV, is roughly 50% lower (though this varies over time and by fuel type). It is therefore likely that the magnitude of the rebound effect is lesser than that presented above.

[35] See Fuel Benefits.

[36] For instance, promoted by Active Travel England.

[37] Connected Places Catapult market forecast for connected and autonomous vehicles (publishing.service.gov.uk)

260. Furthermore, as external costs of congestion and accidents rise, so too may private non-financial costs of driving, which could further limit the magnitude of the rebound effect. Documentation of the National Transport Model indicates that the elasticity of driving demand with respect to expected journey time (including traffic) exceeds the price elasticity of demand for driving. This suggests that second-order effects of induced demand may go some way to curtail the increase in driving activity. These second-order effects are outside the immediate scope of this analysis, however they will be captured to some extent through NTM simulations in the Government Response analysis.

261. For these three reasons, it is likely that the rebound effect and associated social costs are likely to be an over-estimate. Nonetheless, they are included in order to reduce the risk of optimism bias. However, a sensitivity which excludes the rebound effect is presented, to capture the broad uncertainty in this range of policy and sectoral developments over a long time horizon. In reality, it is likely that the true outcome and social impacts falls somewhere between these two scenarios.

262. For this piece of analysis, the ‘High’ marginal external costs are used as these better reflect a world with higher numbers of ZEVs. The values in table ‘A5.4.2. High’ provide the external costs for vehicles under scenario 7 (shift to ZEVs) of the RTF18 document, the key assumptions are that 97% of car and LGV mileage powered by zero emission technologies by 2050 (assumes all car and LGVs sold are zero emission by 2040).

263. This is because, as previously stated, the impact of elasticities on induced demand are more precise for *marginal* changes. Marginal external costs are computed in the NTM from marginal demand changes for a variety of scenarios and the magnitude impact of an externality of an additional km on the roads is non-linear. This means, when a link on the roads is relatively free of congestion, an additional vehicle will not have a large impact on speed. As the link becomes more congested, an additional vehicle will have a much larger impact upon average speed, time lost, and flow conditions on the roads. If mileage and congestion is already relatively high (in the NTM ‘high’ case with more induced electric mileage), an additional vehicle on the roads will have a larger average impact on speeds, flow, and time lost.

264. The ‘high’ congestion and accident marginal external costs are computed averages from an NTM scenario in a world with higher electric mileage in comparison to the NTM central case. However, this ‘high’ is closer (in terms of fleet electrification) to the proposed central ZEV mandate case whereby higher electric miles exist, and the marginal externality impacts of induced demand are higher.

Sensitivity Analysis

Cost Benefit Sensitivities; Upside And Downside

265. Several assumptions are made with regard to the costs of the ZEV mandate proposals. This sensitivity varies these input assumptions to ascertain the social cost-effectiveness of these proposals, were these assumptions to vary. The assumptions varied in these scenarios include vehicle capital costs; administration costs; and fuel, energy, and air quality costs. Table 60 sets out the input scenarios for each over-arching cost sensitivity; Table 61 sets out the monetised impacts *including* the rebound effect; Table 62 sets out the same impacts *excluding* the rebound effect. As stated above, due to uncertainty and potential upward bias in the estimation of the magnitude of the rebound effect, it is likely that the true policy outcome lies somewhere in between these scenarios.

266. In addition to the low, central, and high NPV sensitivities, a ‘highest’ NPV scenario is presented. This applies the same assumptions as the high sensitivity, except that ZEV capital costs are assumed to decline more quickly than in DfT’s internal upside ‘fast convergence’ capital cost

scenario. This sensitivity applies assumptions made by several industry stakeholders regarding the future trend in ZEV battery sizes and ranges, which leads to lower future ZEV costs and subsequently reduced social costs. The analysis underpinning this assumption is set out in greater detail in Annex C.

Table 60 Input assumptions for cost sensitivities of Policy Option 1

Outcome (NPV)	Capital	Administration	LRVC	Fuel prices
Downside (Low NPV)	High	High	Low	Low
Central	Central	Central	Central	Central
Upside (High NPV)	Low	Low	High	High
Highest NPV	Very low	Low	High	High

Table 61 Monetised impacts for cost sensitivities of Policy Option 1, including rebound effect (present value; 2021 prices; £m)

Vehicle type	Impact	Low NPV	Central	High NPV	Highest NPV
Car	PVB	63,305	115,315	197,126	203,281
Car	PVC	-91,031	-82,744	-55,328	-55,328
Car	NPV	-27,726	32,571	141,797	147,952
Car	Abatement Cost (£/tCO_2e)	144	105	-4	-17
Van	PVB	17,879	29,752	52,907	53,567
Van	PVC	-21,104	-18,191	-17,165	-17,165
Van	NPV	-3,225	11,561	35,743	36,402
Van	Abatement Cost (£/tCO_2e)	122	77	- 28	-34
Both	PVB	81,185	145,068	250,033	256,848
Both	PVC	-112,135	-100,935	-72,493	-72,493
Both	NPV	-30,950	44,133	177,540	184,355
Both	Abatement Cost (£/tCO2e)	140	100	-8	-20

Table 62 Monetised impacts for cost sensitivities of Policy Option 1, excluding rebound effect (present value, 2021 prices; £m)

Vehicle type	Impact	Low NPV	Central	High NPV	Highest NPV
Car	PVB	63,305	115,315	197,126	203,281
Car	PVC	-50,618	-42,429	-15,120	-15,120
Car	NPV	12,665	72,857	181,968	188,123
Car	Abatement Cost (£/tCO_2e)	60	22	-87	-100
Van	PVB	17,879	29,752	52,907	53,567
Van	PVC	-9,290	-6,447	-5,503	-5,503
Van	NPV	8,586	23,301	47,399	48,059
Van	Abatement Cost (£/tCO_2e)	13	-32	-136	-143
Both	PVB	81,185	145,068	250,033	256,848
Both	PVC	-59,908	-48,875	-20,623	-20,623
Both	NPV	21,251	96,158	229,367	236,182
Both	Abatement Cost (£/tCO_2e)	51	12	-96	-108

267. As shown in Table 61 and Table 62, it is possible that the policy NPV falls below £0, in the most pessimistic scenario. In this case, the NPV is expected to fall within the range of -£31bn - £21bn in the downside sensitivity. This suggests that it is possible that in the worst-case scenario, the policy does not improve social welfare (based on these monetised impacts), however ultimately this will depend on the true magnitude of the rebound effect.

268. However, there are several important caveats to this result. Firstly, it should be noted that the central (the scenario deemed most likely to occur) is significantly positive, and the upside scenario (optimistic, but roughly as likely as the downside scenario) is extremely positive with an estimated NPV exceeding £184bn *including the rebound effect*. When the rebound effect is excluded, this rises to more than £236bn. Furthermore, the downside scenario should be considered as a worst-case scenario where the downside in each cost element occurs simultaneously, which is a relatively unlikely scenario. On the balance of probability, then, it is

deemed very likely that the outcome NPV exceeds £0 and therefore significantly adds to social welfare.

269. Secondly, as discussed above, there are limitations to the methodology for estimating the monetised impacts of the rebound effect, which are very likely to lead to upward bias in the associated marginal external costs. As shown in Table 62, when the rebound effect is excluded, the downside NPV remains significantly positive. This outcome is not presented as the central scenario as there is likely to be some level of induced demand, however it is much more likely that the true outcome falls somewhere between these two values.

270. Thirdly, the capital cost estimates applied in the central scenario are significantly less optimistic than those published by stakeholders with a range of backgrounds, including the Climate Change Committee, Bloomberg New Energy Finance, and the International Council on Clean Transportation. The downside cost sensitivity is significantly less optimistic than the central scenario, which itself may be viewed by many experts as pessimistic. This may suggest that this outcome is less likely to occur, again reducing the probably of a negative social NPV.

271. Another indicator of cost-effectiveness of emissions reduction policies is whether the proposals abate carbon at a cost below the Non-traded Cost Comparator (NTCC[38]), which determines whether the policy is likely to be more cost-effective than average in abating non-traded carbon. The benchmarks for each combination of NPV sensitivity and carbon price scenario are presented in Table 63 Proposed ZEV mandate Option 1 carbon abatement cost-effectiveness versus the non-traded sector under different cost sensitivities (abatement costs excluding rebound effect shown in parentheses), alongside an indication of whether the proposals are expected to be more cost-effective in each case. These are presented both including and excluding the full rebound effect described above, with those excluding it presented in parentheses where the values or outcomes differ.

272. For all scenarios in which carbon prices are central or high, and including the rebound effect, the policy is expected to be more cost-effective than average non-traded carbon abatement. When carbon prices are assumed to be low, both car and van emissions savings may be less cost-effective than average. Car and overall abatement may also be less cost-effective than average in the central set of policy assumptions, coupled with low carbon prices, however van abatement is expected to remain cost-effective in this scenario.

273. When the rebound effect is excluded, the policy is expected to beat the NTCC benchmark in all combinations of sensitivities and carbon prices. In several scenarios, the policy is expected to deliver net social benefits *excluding* non-traded carbon savings. As stated above, it is very likely that the rebound effect presented here is an over-estimate, and it is likely that the true effect falls somewhere between the two scenarios. This increases the likelihood that the true outcome of these proposals would abate carbon in cost-effective way. Overall, this suggests that these proposals provide the opportunity for cost-effective carbon abatement.

274. Furthermore, carbon prices are determined by the cost of abating carbon; therefore, in scenarios which assume high costs, implicitly it is more likely that carbon prices will be higher (especially as links between decarbonising sectors lead to cost increases across the board), rather than lower. Only when several pessimistic assumptions are assumed to occur simultaneously, which is very unlikely, does the expected cost of abatement exceed the NTCC benchmark.

[38] See Annex F for more detail.

Table 63 Proposed ZEV mandate Option 1 carbon abatement cost-effectiveness versus the non-traded sector under different cost sensitivities (abatement costs excluding rebound effect shown in parentheses)

				NTCC under different carbon value sensitivities		
Carbon price				Low	Central	High
Car	Cost to offset a tonne of carbon (£/tCO_2e)			86	172	259
	Abatement Cost under difference cost/benefit sensitivities	Downside	*144 (60)*	No (Yes)	Yes	Yes
		Central	*105 (22)*	No (Yes)	Yes	Yes
		Upside	*-4 (-87)*	Yes	Yes	Yes
Van	Cost to offset a tonne of carbon (£/tCO_2e)			92	185	277
	Abatement Cost under difference cost/benefit sensitivities	Downside	*122 (13)*	No (Yes)	Yes	Yes
		Central	*77 (-32)*	Yes	Yes	Yes
		Upside	*-28 (-136)*	Yes	Yes	Yes
Combined	Cost to offset a tonne of carbon (£/tCO_2e)			87	175	262
	Abatement Cost under difference cost/benefit sensitivities	Downside	*140 (51)*	No (Yes)	Yes	Yes
		Central	*100 (12)*	No (Yes)	Yes	Yes
		Upside	*-8 (-96)*	Yes	Yes	Yes

275. Taken together, this suggests that the Preferred Option is likely to achieve value for money and cost-effective carbon abatement. There are combinations of assumptions which yield a negative estimate for social NPV and greater-than-average abatement costs, though this is only expected to occur with a combination of multiple extreme downside outcomes occurring in several areas simultaneously.

Real-World Emissions

276. Historically real-world emissions exceed test cycles such as the New European Driving Cycle (NEDC) and Worldwide Harmonised Light Vehicle Test Procedure (WLTP), with NEDC test cycles estimated to be downwardly biased by 33%-45%. This gap has also grown over time from an estimated ~8% in 2000 to 39% in 2018 (to the NEDC test cycle) which has reduced the carbon savings from historic policies based around delivering carbon savings based on a test cycle. ICCT research suggests that test cycles have recently moved over to WLTP to mitigate this measurement error, although some downward bias remains, and there is still the potential for the gap between measured and real-world performance to grow.

277. More recently, research has shifted into measuring PHEV real-world performance against emissions test cycles. Evidence from 2019-2022 suggests that there are very significant performance gaps for PHEVs in the range of 160-500%. This research was undertaken by the ICCT and covers a wide range of models, in several countries, and both privately-owned and company cars – although there are some potential limitations of this research, which are discussed in Annex G.

278. These estimates of real-world performance gaps are used to adjust the central assumption for non-ZEV emissions, as well as calculate low and high sensitivities. This is intended to reflect the inherent uncertainty surrounding these assumptions, given the many factors affecting real-world emissions, such as driving patterns; driving modes; weather; charging behaviour. The outcomes of these sensitivities are presented in Figure 31 for the average car/van non-ZEV.

Figure 64 Real-world emissions sensitivities (gCO_2/km) for the average car

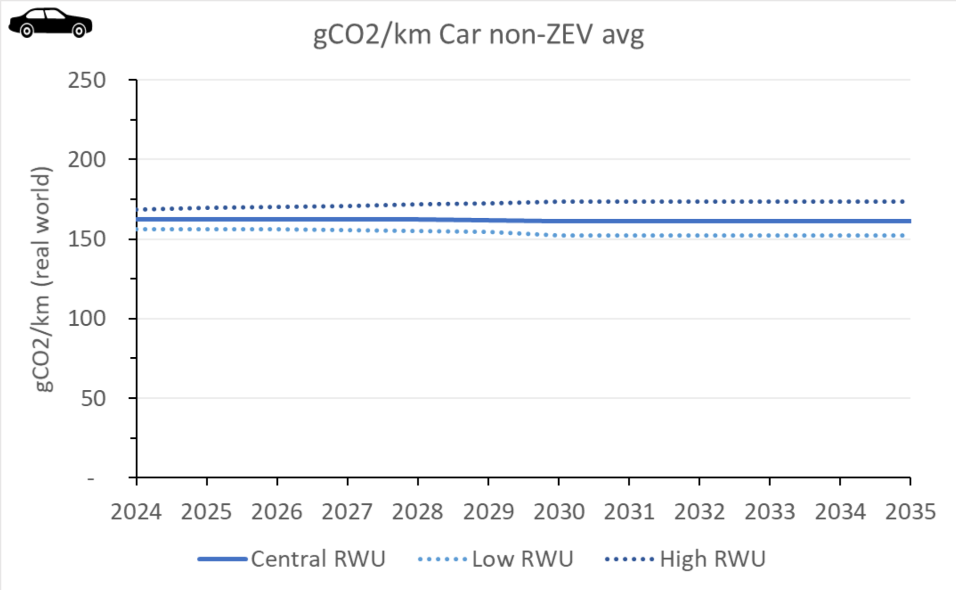


Figure 65 Real-world emissions sensitivities (gCO_2/km) for the average van

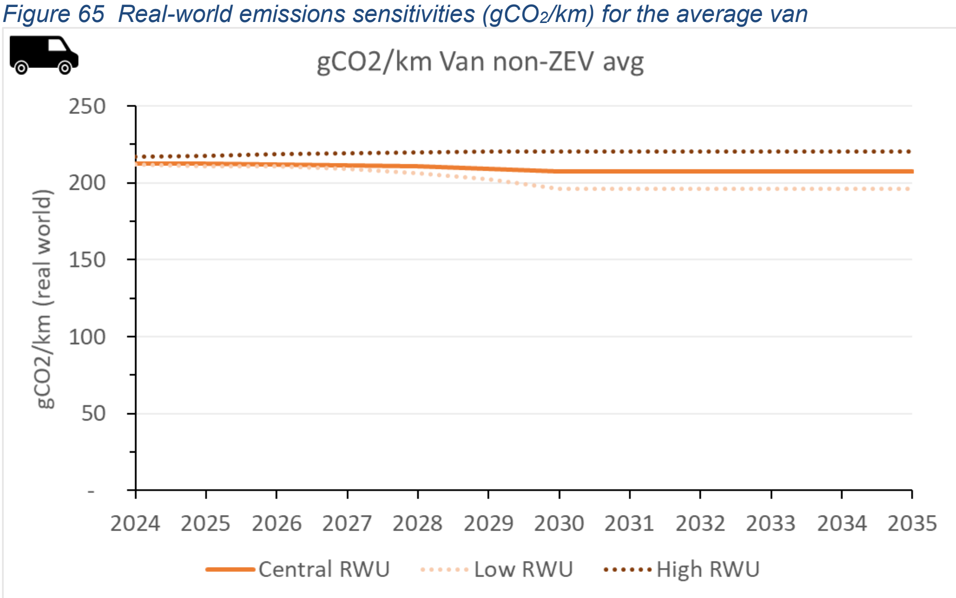


Table 66 Carbon Savings ($MtCO_2e$) for the Preferred Option under low, central, and high real-world emissions sensitivities

	Emissions	CB4	CB5	CB6	2020-2050
Low	Car	1	24	65	352
	Van	2	12	22	88
Central	Car	-2	19	60	330
	Van	1	12	21	85
High	Car	-4	14	54	302
	Van	1	11	20	78

279. Table 66 shows that carbon savings are sensitive to changes in the real-world uplift assumptions for non-ZEVs, although in all cases, the differences between sensitivities in aggregate emissions are very large. The difference is greater, in proportional terms, in the later years of the appraisal period. This is unsurprising: as time passes and ZEVs replace ICEVs (typically older ones, which are less likely to be PHEVs), fleet emissions will fall. For a given number of PHEVs in the fleet, the size of the emissions gap uncertainty *relative to overall emissions* will rise. However, eventually PHEVs will be increasingly replaced by ZEVs, reducing the level of uncertainty on overall fleet emissions.

280. Nonetheless, differences in all periods are very large and indicate that there may be market failures associated with the non-ZEV portion of the UK fleet. As vehicles can remain in the fleet for up to 21+ years, this may pose an opportunity to achieve significant carbon savings through additional policies which seek to close this real-world emissions gap.

Real-World Uplift Assumptions

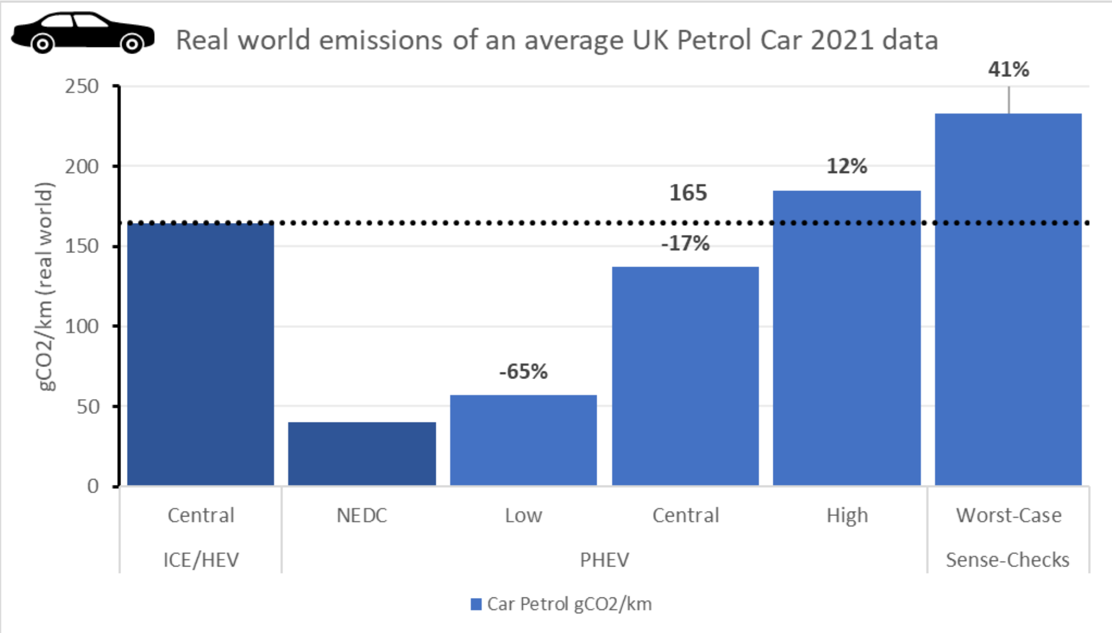
281. The government has already announced intentions to end the future sale of new non-zero emission vehicles. A fundamental contribution towards this are these ZEV mandate framework proposals within this cost benefit analysis intending to increase the regulatory certainty of ZEV infrastructure investment and sales from 2024-2030. By 2035 we will require all new cars and vans to be fully zero emission at the exhaust from 2035.

282. Between 2030 and 2035, new cars and vans will be permitted to be sold if they have the capability to drive a significant distance with zero emissions. The precise parameters of the SZEC definition have not yet been defined.

283. Following the recent ICCT 2022 report on PHEV real-world usage, a risk exists whereby PHEVs may emit 3-5 times the gCO_2/km as stated on emissions test cycles. This is thought to be primarily driven by drivers not charging PHEVs often enough through different reasons: behaviour of drivers; chargepoint availability for company cars; limited PHEV battery sizes; fuel cards for company car incentivising refuelling with petrol and diesel, etc. As a result of this recent and pivotal evidence, more time is needed to understand how significant zero emission capability (SZEC) should be defined.

284. Given the latest emerging evidence we present an illustration below of a range of uncertainty to illustrate the risk of erroneous SZEC decisions without the best available evidence. In Figure 64, our central estimate reflects the UK sample evidence for PHEVs which shows that average UK Petrol PHEVs consume enough fuel to emit ~137 gCO_2/km compared to ~40 gCO_2/km on the NEDC test cycle (3.43 times the fuel than suggested on the test cycle).

Figure 67 Real-world emissions for PHEVs real-world emissions scenarios versus NEDC and average ICE/HEV



285. This has been adjusted for private and company car shares of registrations and mileage using DVLA statistics, reflecting the fact that company cars are often sold into the private vehicle fleet and are more likely to exhibit this driving pattern thereafter.

286. Weighting average emissions by the private/company car share of vehicle mileage results in a UK real-world uplift factor of 343% (fuel consumption is 3.43 times the consumption observed on the test cycle). If this trend were to persist, an average PHEV would only emit 17% less CO_2 than the average petrol ICE/HEV (137 gCO_2 /km) – a stark contrast to the stated 40 gCO_2/km in NEDC type approval statistics. This is shown in Figure 67.

287. For vans, few PHEV models are in circulation in the UK and few are in the production pipeline, according to DfT's engagement with the industry during the April 2022 ZEV mandate

consultation. As a result, little evidence exists around the PHEV real-world emissions risk for vans. This differs significantly to the car market whereby investments and PHEVs are already in production.

288. Additionally, it is likely that this risk may be lower for vans than for cars. For instance, it is expected that future demand for BEV vans will be higher than PHEV equivalents because with higher mileage, vans incur greater fuel and maintenance costs than cars and therefore accrue significant running cost savings compared to ICEV/PHEV vans. Research commissioned by the Department for Transport suggests the total cost of ownership of battery electric vans is already quite favourable compared to ICEVs, which is supported by analysis conducted by other industry stakeholders. As PHEVs tend to be higher-cost than their ICEV counterparts, this suggests that the economic case for battery electric vans, relative to PHEVs, may be even stronger.

289. Furthermore, the strength of the economic case may be expected to have a greater effect on purchasing decisions for vans than for cars. Vans are predominantly used for business use, and there is a strong profit motive for businesses to make investment decisions based on cost-effectiveness; therefore, they may be more likely to purchase BEVs than PHEVs. This may also have a bearing on vehicle manufacturers' product development decisions, and lead to lesser investment in the development of PHEV van technology.

Market Constraints

290. As a central assumption, the fleet is assumed to grow over time (by c. 1% per annum over the appraisal period), reflecting the relationship between economic and population growth and vehicle ownership and travel. This is based on outputs of the National Car Ownership Model However, uncertainty exists around the size of the vehicle sales market, with variation in supply- and demand- side drivers likely to affect the size of the car and van markets.

Supply Side

291. In particular, Vehicles Statistics suggest that since Covid-19, the car/van sales market has been supressed in 2020-2022 relative to the previous 5 years, attributed to global semi-conductor shortages and Covid-19 affecting manufacturing. A risk exists whereby supply chains are unable to scale-up in order to meet the increased demand caused by the ZEV mandate for ZEVs and ZEV inputs, for instance semiconductors and battery materials. This could result in businesses delaying the replacement of older vehicles.

292. However, analysis of the supply-side risks of key input materials for EV manufacturing suggests that there are several mitigating actions, such as the diversification of resource extraction and battery technology; increased productive capacity of semiconductor factories; and increased battery recycling capacity, all of which should go some way to reduce supply-side risks. This risk is discussed in more detail in 'Section 3.0: Supply Constraints'.

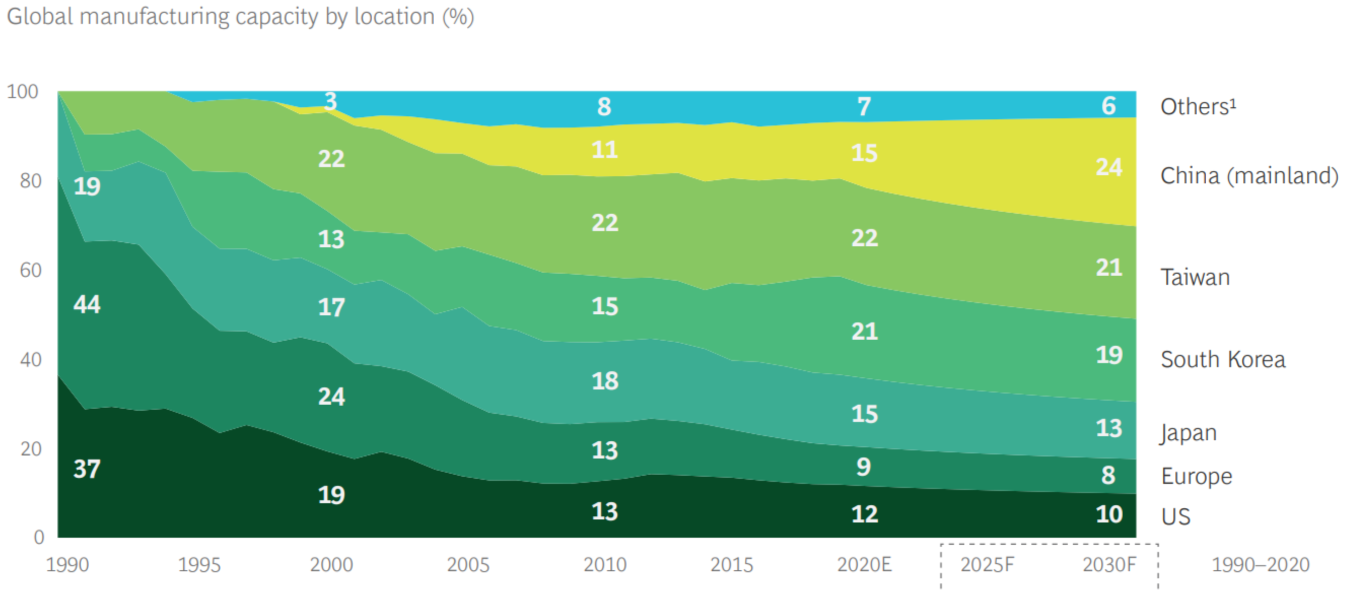
293. In addition, these proposals include a recognition the Government may exercise discretion in the operation of an enforcement regime in the case of extraordinary circumstances beyond the control of manufacturers. This is intended to ensure that these regulations are reflective of- and consistent with- the industry-specific context.

Demand Side

294. It is possible that some consumers elect to delay the replacement of their existing ICEV, instead of replacing it with a ZEV. However, the likelihood of this latter demand side risk is deemed low based on social research surveys whereby 82% of respondents said they would buy a new vehicle within the next 5 years when surveyed in December 2021 indicating a low probability of supressed demand.

295. While market research suggests that the semiconductor shortage is alleviating, geopolitical risks still exist around semiconductor shortage as most supply comes from few countries currently and is forecast to still be dominated by a few major players out to 2030.

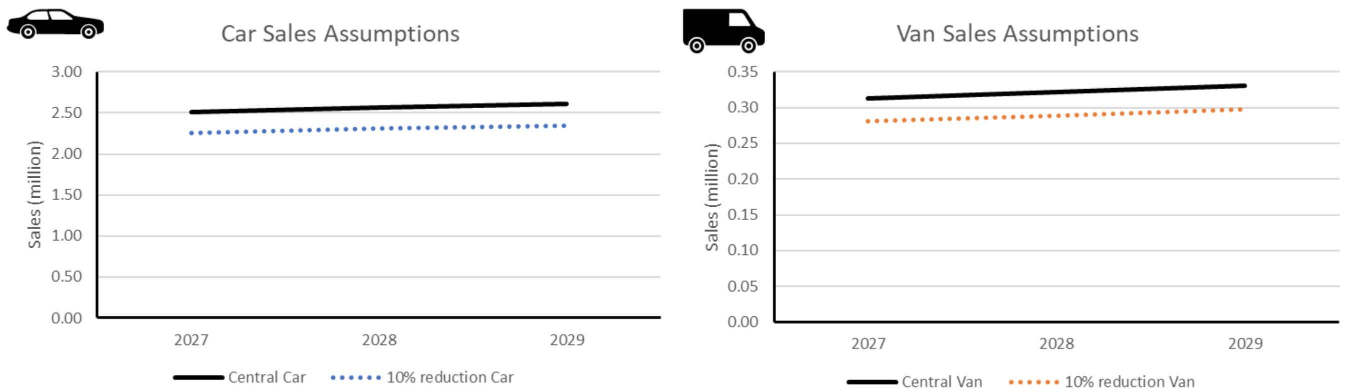
Figure 68 BCG and Semiconductor Industry Association forecast of semiconductor manufacturing capacity[39]



296. Despite that the expected low probability of these risks, a downside risk scenario is modelled in order to reflect a worst credible case outcome. If vehicle sales were to fall, either due to constrained supply, demand, or a combination of both, two potential outcomes are possible. Either vehicle scrappage rates remain constant, in which case the car and van fleets would shrink over time, or scrappage rates would fall, in the most extreme case maintaining the size of the fleet despite lower sales volumes.

297. For prudence and to illustrate the risks, we model a world where the market is 10% smaller in terms of sales volume relative to expectations in 2027-2029 inclusive (3 years).

Figure 69 Assumed central sales for cars and vans



298. This time horizon is selected because, for supply-side issues, long-term signalling coupled with excess demand would be expected to catalyse increased investment in increased supply of input materials and/or innovation in battery and other technology, thereby alleviating the constrained output in the later years of the scheme.

299. However, in the short-term, we recognise the stickiness in capital investment, supply, and manufacturing needs lead time to adjust production and investment plans (5-7 years for manufacturing product cycles based on our technical consultation responses and 5 years to get battery factories to reach operational capacity).[40]

[39] https://www.semiconductors.org/wp-content/uploads/2020/09/Government-Incentives-and-US-Competitiveness-in-Semiconductor-Manufacturing-Sep-2020.pdf

[40] https://www.faraday.ac.uk/wp-content/uploads/2022/06/2040-Gigafactory-Report_2022_Final_spreads.pdf

300. Demand-side issues are also assumed to be temporary, for several reasons. Firstly, there is some social research evidence which suggests that as ZEV take-up increases, social perceptions of ZEV performance improves, and separately the Transport and transport technology: public attitudes tracker suggests that consumers increasingly intend to purchase electric vehicles while purchase intentions for petrol vehicles are falling.

301. Additionally, increasing investment in the chargepoint network will improve access to charging, while technological developments driven by global investment in ZEVs is expected to drive down costs and improve ZEV performance. Finally, this scenario assumes vehicle mileage remains unchanged; in this case vehicle scrappage cannot be delayed indefinitely as performance will degrade over time.

302. Given constraints, ZEV sales are suppressed by 10%, but the same mileage is delivered by the fleet. This assumes individuals must and feasibly can hold onto their older vehicles for longer. As a result, the fleet contains a greater number of older ICEVs.

Table 70 Reduction in carbon savings ($MtCO_2e$) under market shrinkage scenarios

Scenario	Vehicle	CB4	CB5	CB6
Central	Car	- 0.3	19.6	59.6
10% reduction in sales	Car	- 0.4	17.9	59.6
Net lost savings	Car	- 0.1	- 1.7	0.0
Central	Van	1.3	11.1	20.6
10% reduction in sales	Van	1.2	10.7	20.6
Net lost savings	Van	- 0.0	- 0.4	- 0.0
Proportional change overall	Both	-18%	-7%	0%

303. The significant assumption is that the oldest vehicles are not written off and instead able to be maintained for another few years. As a result of older vehicles in the fleet persisting for longer, additional CO_2 is emitted into the atmosphere with the largest impacts landing in Carbon Budget 5 between 2028-2032.

304. Table 70 shows that the reduction in carbon savings in CB4, CB5, and CB6 is non-trivial, although the effect declines following the end of the reduction in sales. This suggests that, even in this pessimistic scenario in which sales are temporarily depressed, the fleet remains the same size, and vehicle mileage is constant (which, together, is relatively unlikely), this policy will still deliver significant carbon savings. The flexibilities designed into the policy (e.g. trading and banking and borrowing) aim to minimise the likelihood of an impact on overall demand.

Under-/Late-Delivery Due To Borrowing

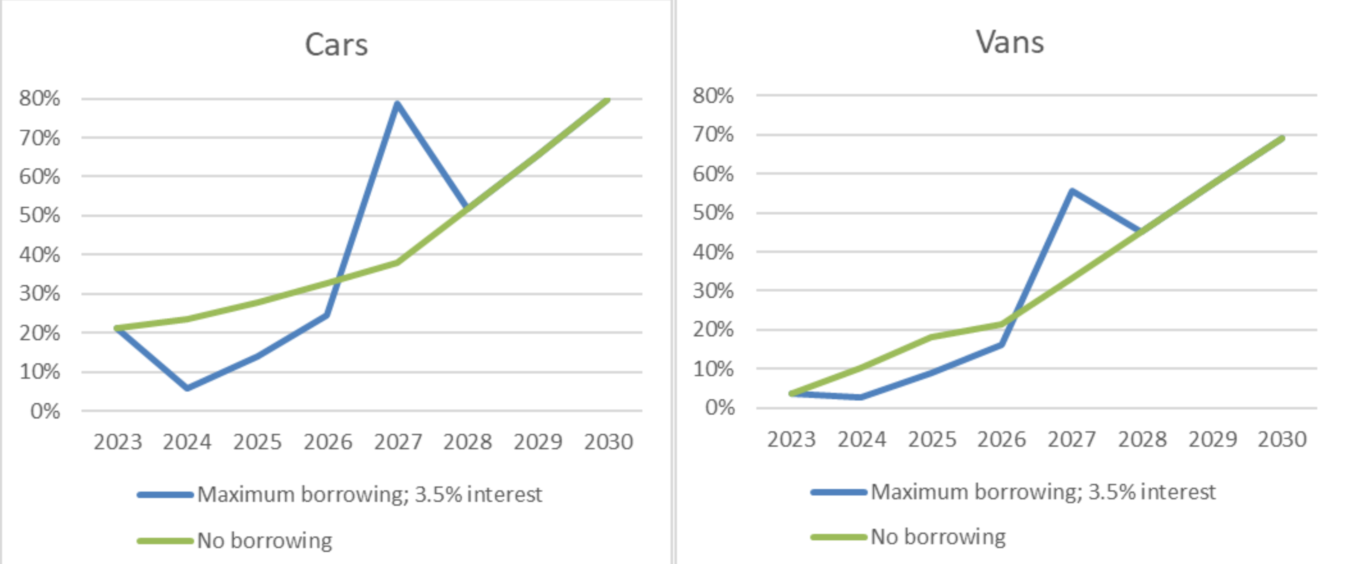
305. In line with HMT Green Book guidance, the analysis of central scenarios assumes that manufacturers achieve their target in each year of the scheme. Manufacturers are expected to comply with the scheme, as the proposed penalty framework has been designed in order to ensure that the costs of non-compliance exceed compliance costs, meaning that rational firms have a greater incentive to meet their targets.

306. However, this policy proposal includes several flexibilities in response to concerns raised by stakeholders through the technical consultation. The ‘borrowing’ framework would allow manufacturers to effectively delay the delivery of their individual annual targets by borrowing allowances from future years. Although these allowances would be required to be ‘paid back’ in future years, leading to the same number of ZEVs being delivered overall, borrowing could undermine progress against shorter term targets such as Carbon Budget 5.

307. In order to reflect the worst-case, short-term effects of the proposed flexibilities, a ‘late delivery’ sensitivity is presented. In this scenario, each manufacturer is assumed to maximise their borrowing from subsequent years. The parameters regarding borrowing, such as limits and

interest, match those set out in 'Section 1.0: Additional policy details'. The maximal effect of these flexibilities on the overall market trajectories are shown in Figure 71. Corresponding figures which present the maximal borrowing trajectory *without interest* are presented in Annex I.

Figure 71 ZEV annual sales shares for the maximum borrowing/late delivery scenario, versus the central scenario



308. Despite these mitigating actions, this flexibility poses some risk to the policy's expected contribution to interim carbon budget targets. Table 72 shows the expected carbon savings under the central and late delivery scenarios; as shown, the flexibilities are expected to lead to significant lost carbon savings in Carbon Budget 4, however the increase in required ZEV sales in 2027 offsets this and leads to marginally higher carbon savings over the rest of the appraisal period. This is required in order to offset the lost social (present) value from the delayed delivery of carbon savings.

Table 72 Net carbon impacts of central versus late-delivery scenario[41]

Scenario	Value	CB4	CB5	CB6	2020-2050
Central	Net total	-0	31	81	415
Late delivery	Net total	-4	35	84	426
Net	Net lost carbon savings	-4	4	4	10
%	% change	<-100%	13%	4%	2%

309. However, it should be noted that this sensitivity presents a 'worst-case' where all manufacturers maximise their borrowing and ZEV sales as a whole are therefore significantly depressed. In reality, although some manufacturers may choose to do so, others already plan to produce and sell a greater number of ZEVs than their targets require. In addition, under-performing manufacturers may find that trading offers a lower-cost approach to meeting annual targets, which may also reduce the level of aggregate borrowing and raise the overall proportion of new vehicle sales made up of ZEVs. Therefore, it is likely the true level of borrowing falls below that presented here.

Under-Delivery Of ZEVs Due To Allowance Transfers

310. The flexibilities proposed to mitigate the risk of excessive compliance costs and under-delivery also include the option for manufacturers to transfer allowances between the ZEV mandate and non-ZEV CO_2 scheme component targets. Transfers from the non-ZEV to ZEV schemes would allow manufacturers to use their more efficient non-ZEVs already baked into current production plans to go some way to delivering their ZEV targets.

[41] Figures may not sum due to rounding.

311. This is proposed that this transfer route be capped at 25% of the annual ZEV target (5.5% of ZEV sales in 2024, 7% in 2025, 8.25% in 2026 for cars), to safeguard a sufficient level of ZEV delivery. These flexibilities pose risks to carbon savings due to uncertainty in non-ZEV real-world emissions and how these convert to ZEV allowances.

312. In this instance, the best available evidence suggests that a ZEV saves approximately 168 gCO_2/km relative to the average non-ZEV (ZEVs have zero exhaust emissions, so their emissions savings equal the emissions of the non-ZEV they replace). A PHEV is estimated to emit 40 gCO_2/km through the WLTP test cycle, however to account for the average non-ZEV real-world emissions, this figure would be adjusted by +20% (the average car non-ZEV real-world uplift from WLTP to real-world), giving a carbon efficiency of 48 gCO_2/km.

313. Carbon leakage could occur if this credit value misaligns with PHEV real-world efficiency. There is emerging evidence that the real-world performance gap for PHEVs may be greater than for the average non-ZEV, driven to a significant extent by differences in consumer charging behaviour; this is set out in more detail in 'Section 2.0: Real-world uplift assumptions', above. As a result of uncertainty in real-world emissions, non-ZEVs and especially PHEVs could be transferred imperfectly in carbon terms with ZEVs.

314. In order to fully illustrate the potential scale of carbon savings risked by this flexibility, this scenario analysis assumes manufacturers use excess PHEV deployment to accrue excess non-ZEV allowances to trade into ZEVs allowances (in reality, it may be a combination of efficient ICEVs and PHEVs). As a result, fewer ZEVs are sold into the UK fleet and carbon savings are reduced. Table 73 shows the expected carbon savings lost under different PHEV deployment scenarios based on SMMT's car outlook forecasts on feasible PHEV deployments that could be used in this transfer to provide an uncertainty range. An unlikely worst case is also presented to illustrate potential effects if all manufacturers were to maximise their non-ZEV to ZEV transfer allowance.

315. The carbon analysis of this transfer for the van market differs. This is because the key risk stems from potential under-estimation of the real-world emissions of certain non-ZEVs, in particular PHEVs. However, for vans the scale of this impact is likely lower because there are far fewer van PHEVs (0.3% sold in 2021 compared to 6.6% for cars in 2021).

316. This is expected to persist, with future deployment of PHEV vans likely to be much lower than for cars. There are several reasons for this: vans typically have greater annual mileage. therefore there are stronger incentives to invest in ZEV vans over PHEVs, which are likely to carry greater up-front costs than ICEVs and cost more to run than BEVs. As vans are primarily used for business purposes, cost-minimising businesses are more likely to invest in ZEV over PHEV vans, and as a result, PHEV vans may receive low uptake into the future relative to car PHEVs.

317. Furthermore, the carbon impact is driven by the real-world emissions of PHEVs. Currently, little is known on the real-world emissions for van PHEVs because so few exist in circulation. However, businesses which do own PHEV vans could reduce their costs by better-utilising the battery-electric drivetrain, as this is less costly per mile than the petrol/diesel element. Therefore, the carbon risk itself for PHEV vans is also likely to be reduced.

318. With all of these things taken together, it is likely that the scale of impact of the allowance transfers are an order of magnitude lower for vans compared to cars. Therefore, to be proportionate, sophisticated carbon modelling has not been conducted for the vans transfer.

Table 73 Carbon impacts of central versus transfers scenario for cars

	ZEV mandate carbon savings risked $MtCO_2e$ (% of central ZEV mandate savings)			
	CB4	CB5	CB6	2020-2050
Low	-0.2	-0.3 (-1%)	-0.2 (0%)	-0.8 (0%)
Central	-0.7	-1.1 (-3%)	-0.8 (-1%)	-3.2 (-1%)
High	-1.1	-1.7 (-6%)	-1.4 (-2%)	-5.2 (-1%)
Maximum (worst case)	-2.2	-3.2 (-10%)	-2.6 (-3%)	-9.8 (-2%)

Mass-Adjusted Non-ZEV CO_2 Requirement In Addition To Central Zev Sales Targets

Policy Design

319. The final policy option under consideration is similar to Policy Option 4, however the non-ZEV car CO_2 requirements are adjusted to incentivise the sale of lighter non-ZEVs, which on average are more carbon-efficient. This is based on recommendations set out in the CCC's 2022 Progress Report to Parliament, addressing the fact that car mass has steadily risen over the last two decades.

320. In this scenario, as a benchmark of what manufacturers can feasibly implement, manufacturers are assumed to replace their heaviest vehicles with ZEVs first to achieve the ZEV mandate leading to a lower fleet sales average gCO_2/km due to mass changes only. However, this does not assume further efficiency improvements through other technologies research and development for each powertrain which could also contribute to these levels of efficiency improvements.

321. The real-world new sales efficiencies associated with this option are presented in Table 74. As shown, this leads to a gradual decline in emissions per kilometre travelled by cars; for vans there is no change.

Table 74 Estimated new sales real-world gCO_2/km efficiencies for Policy Option 5

Vehicle type	Drive train	2024	2025	2026	2027	2028	2029	2030
Car	Petrol ICE / HEV	156	154	153	152	150	148	143
Car	Diesel ICE / HEV	179	177	175	174	173	170	165
Car	Petrol PHEV	129	127	126	124	123	120	115
Car	Diesel PHEV	126	124	123	122	120	118	113
Van	Petrol ICE / HEV	148	148	148	148	148	148	148
Van	Diesel ICE / HEV	213	213	213	213	213	213	213
Van	Petrol PHEV	172	172	172	172	172	172	172
Van	Diesel PHEV	162	162	162	162	162	162	162

Figure 75 Comparison of efficiency requirements for cars under options 4 and 5

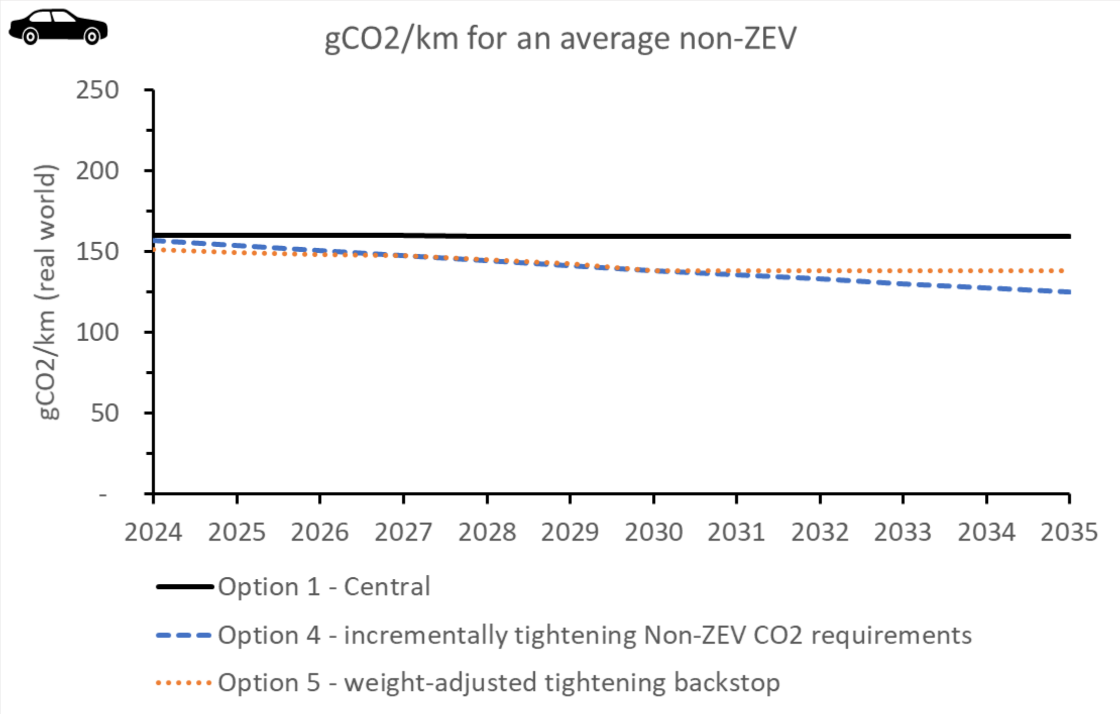
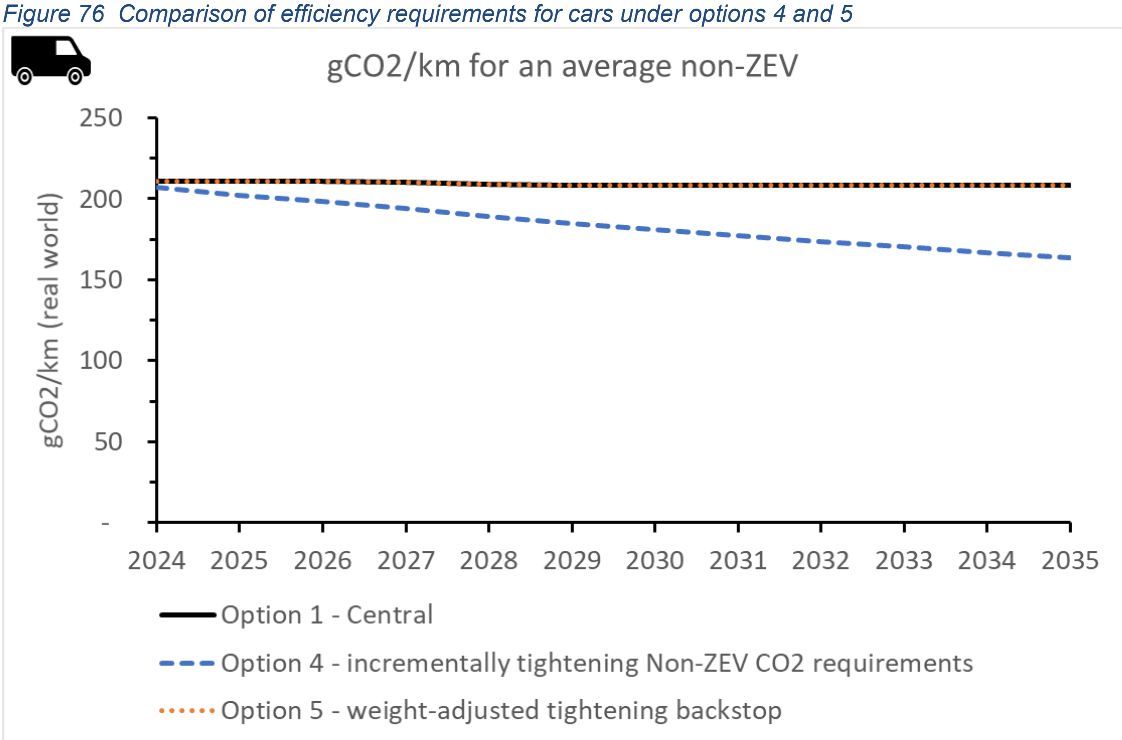


Figure 76 Comparison of efficiency requirements for cars under options 4 and 5



Impacts

322. The impacts of this policy, relative to the Preferred Option, are shown in the tables below. It should, however, be noted that the analysis of both options assumes full delivery of the requirements, in line with HMT's Green Book guidance. The proposed details of this sensitivity would place a significant additional burden on manufacturers as it would lead to a net increase in the WLTP-assessed average new sales carbon emissions intensity.

323. At the same time as meeting the stretching central ZEV trajectory targets, manufacturers would be required to meet these requirements or face penalties. They could do so by improving their non-ZEV new sales' efficiencies, through investing in more efficient engine technology, shifting their product mix to favour lighter, more efficient vehicles, or selling a greater number of vehicles which are judged by WLTP assessments to be more efficient, such as PHEVs.

324. However, there are several risks associated with this. Firstly, this option is significantly more stretching than the Preferred Option and therefore carries greater delivery risk; if there were under-delivery, manufacturers would face higher cumulative payments and the social impacts (including carbon savings) would be lower than set out below. Furthermore, there are risks relating to the gap between PHEV real-world versus WLTP emissions, associated with proportional increases in PHEV sales caused by these requirements (which also apply to Policy Option 4 and are laid out in 'Section 2.0: Quantified Impacts'). Again, if these risks materialise then quantified impacts of Policy Option 5 would be lesser than those presented here. Therefore, these estimates should be considered an upper-bound of this options NPV, cost-effectiveness, and potential emissions savings.

Table 77 Comparison of net carbon savings of this sensitivity versus the Preferred Option

	Policy Option 1 (Preferred option)	Policy Option 5	Net impact
CB4	0	3	3
CB5	31	37	6
CB6	81	88	7
2020 - 2050	415	455	40

Table 78 Comparison of monetised impacts of this sensitivity versus the Preferred Option, excluding the rebound effect

		Policy Option 1 (Preferred option)	Policy Option 5	Net impact
Car	PVB (Discounted)	115,315	133,053	17,738
Car	PVC (Discounted) (excl. rebound)	-42,429	-47,517	-5,088
Car	NPV (Discounted)	72,857	85,506	12,649
Car	Abatement Cost	22	17	-5
Van	PVB (Discounted)	29,752	30,395	643
Van	PVC (Discounted)	-6,447	-6,830	-383
Van	NPV (Discounted)	23,301	23,560	259
Van	Abatement Cost	-32	-30	2
Both	PVB (Discounted)	145,068	163,448	18,380
Both	PVC (Discounted) (excl. rebound)	-48,875	-54,347	-5,472
Both	NPV (Discounted) (excl. rebound)	96,158	109,066	12,908
Both	Abatement Cost (excl. rebound)	12	9	-3

Table 79 Comparison of monetised impacts of this sensitivity versus the Preferred Option, including the rebound effect

		Policy Option 1 (Preferred Option)	Policy Option 5	Net impact
Car	PVB (Discounted)	115,315	133,053	17,738
Car	PVC (Discounted)	-82,744	-95,841	-13,097
Car	NPV (Discounted)	32,571	37,212	4,641
Car	Abatement Cost	105	106	1
Van	PVB (Discounted)	29,752	30,395	643
Van	PVC (Discounted)	-18,191	-18,922	-731
Van	NPV (Discounted)	11,561	11,472	-89

		Policy Option 1 (Preferred Option)	Policy Option 5	Net impact
Van	Abatement Cost	77	81	4
Both	PVB (Discounted)	145,068	163,448	18,380
Both	PVC (Discounted)	-100,935	-114,764	-13,829
Both	NPV (Discounted)	44,133	48,684	4,551
Both	Abatement Cost	100	101	1

3.0 Risks and unintended consequences

Supply Constraints

325. The ZEV mandate is expected to lead to an increase in the UK's share of the global EV market. At the same time, global demand for EVs and several other low-carbon industries is expected to rise, raising demand for similar input materials. The UK makes up a small proportion of demand for these inputs, and its share of production is much lower (the UK does not produce many of them). For this reason, it is exposed to global shifts in supply and demand.

326. Demand for several key minerals such as lithium, nickel, cobalt, as well as other inputs like microchips/semiconductors is broadly projected to increase significantly over the next decade. Supply for these inputs is also projected to increase, in response to long-term, widespread signalling of an increasing push towards electrification of industries which are currently largely dependent on fossil fuels.

327. For certain input resources (such as cobalt and lithium), the projected increase in supply and demand is expected to be broadly equal, although some small mismatches may occur. In addition, current shortages of other inputs, such as semiconductors, are expected to alleviate by the beginning of the ZEV mandate trajectory, as investments in increased capacity expands productive capacity. In these cases, the likelihood of shortages and supply chain issues is likely to be fairly limited.

328. There are, however, some input markets which may be unable to increase supply at the same rate that demand is expected to increase (based on current technologies). There are also certain markets where production is very concentrated and geopolitical issues may pose a further risk to the supply of these resources. In these cases, it is possible that demand exceeds supply and there are difficulties meeting the requirements of the numerous sectors and nations competing for these resources.

329. That said, battery technology continues to develop, which is expected to lead to a diversification of the input materials required. For instance, the development of sodium-ion batteries is likely to mitigate strains on global lithium supplies; similarly, several car manufacturers have already begun producing ZEVs with cobalt-free batteries, and batteries free from both cobalt and nickel are also in widespread use.

330. Furthermore, widespread investment in battery recycling technology is expected in the medium- to long-term. This is expected to increase supply of certain battery inputs – for instance, The Faraday Institute expects recycling of Cobalt to produce a significant amount of supply after 2030, and anecdotal evidence from Li-Cycle Corp suggesting that recycled cobalt, nickel and lithium could make up 10%-20% of global demand by the end of 2030. Such developments are expected both to alleviate supply issues in the ZEV supply chain as well as in other low-carbon technology supply chains, reducing competition for virgin, high-grade resources.

331. With regard to timing, it should be noted that these proposals would gradually raise the proportion of sales to be made up of ZEVs from 22% in 2024 to 80% in 2030 for cars. This increase will be incremental and has been clearly signalled in advance, meaning that supply chains have notice that demand will be increasing, and that the increase in demand will be gradual.

332. These technological developments offer several benefits: not only do they diversify the battery supply chain, reducing reliance on individual resources and nations, but they also, in cases, are expected to deliver performance benefits through increased energy density and reduced costs. This suggests that although the ramp-up in ZEV delivery may lead to some risks and costs, these effects are also likely to catalyse developments which will deliver social value in the long-run.

333. Finally, these proposals include a recognition the Government may exercise discretion in the operation of an enforcement regime, should certain criteria be met. This is intended to ensure that these regulations are reflective of- and consistent with- the geopolitical and industry-specific context.

Risk to Carbon Savings

334. The primary objective of these proposals is to deliver carbon savings and contribute to progress towards the UK Government's legally binding emissions reductions commitments. However, it is important that the requirements of these regulations are deliverable and do not place undue burdens on businesses and consumers.

335. Several 'flexibilities' are proposed in order to allow manufacturers to meet their obligations at the lowest possible risk and cost, however some of these flexibilities carry risk to the delivery of carbon savings. There is also inherent uncertainty in a number of the assumptions underpinning this analysis. This section will first discuss uncertainty and risks associated with the policy design, before considering the uncertainty inherent in key assumptions.

Potential Impact of Trading and Manufacturers Strategies

336. The allowance trading scheme could lead to differences in carbon savings, compared to those presented in the central scenario. The value of allowances allocated in a given year are equal, regardless of the manufacturer to which it was allocated or the ICEV that the ZEV 'displaces'; however, each manufacturer has a different starting point and the emissions intensity of their new sales varies. Although ZEVs are, by definition, zero exhaust emissions, the vehicles they replace have different emissions, so the *marginal* effect of ZEVs is not constant.

337. For example, if a manufacturer with an initially low-carbon fleet (for instance, because they produce predominantly smaller, lighter vehicles) were to sell an allowance to a manufacturer with more carbon-intensive new sales, the second manufacturer could count this allowance against their obligation and produce one fewer ZEV. Although the number of ZEVs sold and credits earnt is unchanged at the market level, this is achieved by decarbonising less emissions-intensive vehicles first, meaning more emissions-intensive vehicles will remain on the road for longer, and leading to greater overall emissions.

338. Related to this, individual manufacturers will have different decarbonisation strategies. It is possible that some manufacturers will prioritise the decarbonisation of lighter or plug-in hybrid vehicles because it may be cheaper or more profitable to do so. This would be expected to lead to greater average emissions of new non-ZEV sales, which would in turn lead to greater fleet emissions compared to the central assumption, where ZEVs displace sales of new non-ZEVs of average carbon intensity.

339. In order to mitigate this risk, it is proposed that manufacturers are set a constant gCO_2/km target for non-ZEVs. This is intended to balance the competing priorities of: i) preventing regression in the carbon intensity of new non-ZEV sales, and ii) minimising the regulatory burden on car manufacturers, by requiring no further improvements to be made on non-ZEVs. This is expected to allow manufacturers to focus their R&D and investment on the production of ZEVs.

Banking and Borrowing

340. The flexibilities afforded to manufacturers through banking and borrowing in the first three years of the scheme would allow manufacturers to delay a portion of their delivery. Although it would be possible for manufacturers to over-deliver in the earlier years and then under-deliver in the latter years of this period, this outcome is deemed unlikely, on aggregate, as BEV costs are expected to decline and manufacturers require time to develop and operationalise new assembly lines and models. Therefore, it is possible that the market as a whole may back-load compliance over this period, which could affect carbon savings; although, as set out in the 'Under-/late-delivery' section, the expected effect of this is mixed and may vary over different time periods.

341. Several limitations to banking and borrowing are proposed, which intend to mitigate the risk posed to carbon savings. Caps on the amount of borrowing permitted limits the amount of a year's delivery which can be delayed, while interest charged on borrowing aims to offset or limit the savings foregone by delaying delivery. Finally, limiting banking and borrowing to the first three years of the delivery period (with all borrowed allowances to be repaid in year four at the latest) will also limit the potential for ZEV delivery to be delayed.

Bonus Credits

342. Bonus credits which aim to incentivise sales of ZEVs for particular purposes, for instance use by car clubs, could also undermine carbon savings. These bonus credits are proposed because there are strategic benefits to increasing the uptake of shared mobility services such as car clubs, for instance reduced production emissions. However, as each ZEV sold to a car club is proposed to receive 0.5 credits, in addition to not using an allowance, the overall number of ZEVs required to be delivered will be reduced, assuming that there are non-zero ZEV car club sales. Therefore, if the carbon savings accruing to increased car club uptake are lesser than the foregone savings of greater private ZEV sales and usage, aggregate carbon savings may fall.

343. In addition, there is some uncertainty as to whether greater ZEV sales to car clubs will precipitate greater car club usage. There is some evidence that ZEV take-up is already greater in the car club fleet than in the broader UK private car fleet, implying that car clubs already face greater incentives to purchase ZEVs. This suggests that some car club ZEV sales supported by the bonus credit could be 'deadweight' – whereby the supported activity would have occurred in absence of the incentive. In this case the car club bonus credits may undermine carbon savings without achieving significant additional benefits. The Government welcomes stakeholders' views on policy details such as this through this consultation.

Payments For Non-Compliance

344. The final feature of the policy which may present a risk to carbon savings are the payments for non-compliance in a given year. This payment functions as a 'price cap' for allowances traded between manufacturers, meaning that manufacturers may choose to pay the payment to under-deliver should their own cost of producing a ZEV (relative to producing an ICEV) *and* the open-market price of a traded ZEV allowance exceed the payment value. Unlike allowances purchased from other manufacturers, this payment does not achieve the sale of a ZEV and therefore achieves no direct carbon savings. Per HMT Green Book guidance, manufacturers are assumed

to comply with regulations and therefore no payments are modelled in these scenarios; any payments made in the real world would accrue to the Exchequer, and would represent a transfer.

345. Nonetheless, payments for under-delivery are deemed to be required for two key reasons. Firstly, if no payment is specified, it is implicitly set to £0; that is, there would be no financial incentive against non-compliance. Secondly, as set out in the previous section, there are many determinants of supply and demand for ZEVs which may affect sales and prices in any particular year. Payments function as a measure to protect consumers from excessive costs, by limiting the price paid by manufacturers if they are unable to deliver their obligation, and mitigate risks to competition by preventing over-delivering manufacturers from setting disproportionately high prices for their surplus allowances.

346. However, it is important that payments are set such that they sufficiently incentivise compliance with the scheme and compensates society for the welfare cost of non-compliance. This requires that the payment exceeds the expected difference in production costs between ZEVs and non-ZEVs, otherwise firms may minimise costs by producing non-ZEVs and making payments.

347. With regard to the open economy, the risk of non-compliance can be further mitigated by ensuring that the payment is no less than that imposed in connected markets where there are similar requirements, such as the EU car market and CO_2 regulations.

348. Finally, the payment should be set no less than the marginal social costs (carbon savings, resource benefits, air quality benefits, etc.) of the sale of a non-ZEV instead of a ZEV. The analysis under-pinning this issue is set out in greater detail in 'Annex I – Banking and Borrowing'.

Consumer Behaviour

349. Separate from policy details, carbon savings will vary if the way in which consumers use vehicles varies from the central assumptions. As set out in paragraph 261, the rebound effect assumed in the central scenario is likely to be an over-estimate, therefore carbon savings are likely greater than the 'rebound effect' scenario and lesser than the 'no rebound effect' scenario; these scenarios can effectively be considered lower and upper bounds (respectively) of expected policy impacts.

350. However, it is possible that consumer behaviour changes in a way not predicted in this analysis. For instance, as ZEVs become cheaper to own and run over shorter time horizons, car ownership may rise by more than expected. This could lead to greater mileage and subsequently greater external costs in the form of increased emissions from electricity production, air quality impacts, and congestion/accident costs.

351. That said, there are several reasons for which this risk is expected to be fairly low. Firstly, some level of fleet growth is assumed in all scenarios, meaning that some of this effect is already captured. Secondly, proposed policy features such as the incentivisation of car club ZEV sales are intended to stimulate growth in the car club fleet and demand for car clubs. This in turn could lead to opposite changes in consumer behaviour which reduce the total number of kilometres driven and reduce social costs.

352. By contrast, as set out in paragraph 291, it is possible that potential supply and demand side constraints could lead to fewer sales. If there were no change in vehicle scrappage, this would lead to a smaller fleet and likely reduced carbon emissions as those who do not replace their scrapped vehicles use alternative modes of transport. On the other hand, if consumers attempted to extend the life of their vehicles, this could raise the average age of non-ZEVs in the fleet and increase average emissions compared to the central scenario. A 'worst-case' scenario, in which this latter case occurs, alongside unchanged vehicle kilometres, is presented in 'Section 2.0: Market constraints'.

353. However, as discussed above, recent public attitudes research suggests that consumers increasingly intend to purchase electric vehicles, while intentions to purchase non-ZEVs are

falling. This change in public attitudes indicates that the chance of this ‘worst-case’ scenario occurring is low.

The Market and Competition

354. These regulations will have a significant effect on the automotive industry. This section briefly sets out the potential risks, unintended consequences, and mitigating actions, however more detailed discussion is provided in the next section.

355. Due to differences in manufacturers’ product cycles and decarbonisation strategies, the proposals may affect different manufacturers in different ways. In particular, some manufacturers have already committed to phase-out dates for non-ZEVs and many have begun (or plan to begin) producing ZEVs, whereas some other firms may have intended to decarbonise their sales using non-zero emission technologies, during the transitional period, or to do so over a longer time horizon. In the simplest form of the ZEV mandate, with annual targets and no sources of flexibility, there could be undue differential impacts for these two groups of firms.

356. In addition, in absence of any exemptions and/or derogations, the regulations could cause barriers to entry and thereby limiting competition. This is because manufacturers would only be able to enter the market if they had already developed ZEV models which they would sell alongside any non-ZEV models.

357. Several policy features are proposed in order to mitigate these risks: flexibility achieved through the provision of banking, borrowing, trading, and non-compliance payments allow manufacturers to meet their obligations through delivering ZEVs in different time periods and/or purchasing allowances from Government or other manufacturers. This is expected to mitigate the potential differential impacts caused by the regulations.

358. In order to address barriers to entry, ZEV mandate allowances are offered to small volume manufacturers (SVMs). SVMs are not set binding targets, although they may sell ZEVs and trade the allowances they are allocated. This avoids creating barriers to entry, although taken in isolation there may be barriers to growth, as SVMs producing no ZEVs would be required to significantly alter their product mix once they cross the SVM registrations threshold.

359. Taken together, these measures are expected to preserve healthy competition by mitigating differential impacts based on manufacturers’ pre-determined strategies and their sizes, and support competition by avoiding barriers to entry and growth. More detailed discussions of the impacts of the regulations on competition, and small and micro businesses, can be found in ‘Section 4.0: Competition Assessment’ and ‘Section 4.0: Small and Micro Business Assessment’.

4.0 Wider impacts

Competition Assessment

360. These regulations will affect incumbent manufacturers as well as potential market entrants. It is therefore prudent to consider the potential effect on competition in the car and van markets.

361. The regulations will have some differential impact on firms of different sizes, as small volume manufacturers (SVMs) are proposed to be exempt from annual ZEV targets. Small volume manufacturers are those with fewer than 2,500 car or van registrations per year and may be unable to fund investment in ZEV production, and/or incur disproportionate costs in administering the scheme. No derogations are proposed for manufacturers with annual registrations exceeding 2,499.

362. For non-exempt manufacturers (around 99.5% and 97.5% of sales, for cars and vans, respectively), these proposals are expected to apply similarly. This is because each manufacturer's target is based on a proportion of their sales in a given year, so it inherently scales with their size relative to the rest of the market. In terms of their UK presence, then, the requirements of the scheme relative to the manufacturer's size is likely to be broadly equal.

363. However, there are some costs associated with the scheme which are likely to be relatively fixed, most prominently the costs of setting up new business functions to monitor and ensure compliance. As these are not expected to vary closely with manufacturers' sales, larger manufacturers may be at some advantage to smaller ones, as their costs could be spread over a greater number of sales.

364. Current analysis suggests that the costs of setting up this function, relative to current regulatory requirements, are likely to be less than £200k per manufacturer, on average. Should these estimates be broadly accurate, the effect on competition of these fixed costs is likely to be negligible. Industry stakeholders are encouraged to provide evidence on the costs of administering the scheme through this consultation.

365. As SVMs are not set binding targets, they may choose not to incur the fixed costs associated with monitoring and evidencing compliance. For this reason, these proposals have a differential impact on SVMs versus non-SVMs. However, SVMs hold very small shares of the car and van markets; therefore, the effect of this differential impact on competition and market structure is expected to be minimal. In addition, some SVMs may choose to sell ZEVs and the allowances that they are allocated, though doing so would lead to administrative costs. This would reduce the average differential impact between SVMs and other manufacturers.

366. Smaller manufacturers above the SVM threshold could be perceived to be placed at a disadvantage compared to SVMs based on the proposed thresholds, however these proposals are broadly aligned with the thresholds in the regulations which they replace. The current retained EU CO_2 regulations provide derogations in the form of bespoke targets for SVMs which have between 1,000 – 10,000 and 1,000 – 22,000 registrations, for cars and vans respectively, *across the whole EU market*.

367. If these thresholds were to be applied proportionally to manufacturers' UK sales, the corresponding upper bounds would be circa 1,600 registrations for cars and circa 3,500 registrations for vans. The proposed threshold of 2,500 for both cars and vans is relatively closely aligned with these thresholds and is therefore not expected to have a significantly different impact on competition compared to the existing, baseline regulations.

368. In addition, a number of policy details are proposed, which intend to limit differential impacts which could affect competition in the automotive markets (as set out in Section 1). The rationale and methodologies under-pinning each of these policy details are explained in greater detail in the annexes.

369. Firstly, manufacturers will be permitted to trade allowances. This will help address uncertainty over sales volumes and proportions in individual years, and allow firms facing relatively high costs of decarbonisation to minimise costs by purchasing ZEVM and CO_2 allowances from firms with lower decarbonisation costs.

370. Secondly, banking and borrowing permits some level of under-/over-delivery in individual years; this is intended to allow individual manufacturers to align their longer-term production plans with annual targets and mitigate adverse impacts for manufacturers whose ZEV production is planned to ramp up later in the delivery period. Borrowing may also allow under-delivering manufacturers

to reduce compliance costs if they expect to face lower decarbonisation costs in the future than the price of ZEVM and CO_2 allowances determined on the open market.

371. Thirdly, the payment for non-compliance is also expected to mitigate any anti-competitive effects. The payment will be charged on a per-allowance of under-delivery basis, effectively functioning as a ‘price cap’ for ZEV allowances. This will prevent excessive costs of compliance for under-delivering firms by limiting the price which can be charged by over-performing firms.

372. Similarly, these proposals include a recognition that the Government may exercise discretion in the operation of an enforcement regime, should certain exigent criteria be met. This is intended to ensure that these regulations are reflective of - and consistent with - the geopolitical and industry-specific context. This could, for instance, be used to suspend payments for under-delivery should there be compelling evidence of supply chain issues which are outside the control of regulated vehicle manufacturers.

373. Taken together, then, the derogations offered to SVMs suggest that these regulations will impose no additional barriers to entry for car and van manufacturers. Manufacturers with annual sales exceeding 2,500 vehicles are proposed to receive no derogations, and those at the bottom of the distribution may face some disadvantage relative to larger manufacturers, who may be able to spread fixed costs over a greater number of sales. However, the marginal effect of these proposals on administrative costs is expected to be very small, therefore these costs are not expected to be disproportionate.

Innovation Test

374. These proposals are expected to drive innovation in the car/van and battery sectors for several reasons. The mandate for increasing proportions of *zero emission* vehicles marks a departure from regulations requiring incremental efficiency gains. This sends a clear signal to the market that investments supporting the development of zero emission technologies – which have historically received less investment than efficiency-improving technologies – will have a greater long-term return on investment.

375. These long-term signals are also expected to be beneficial for the chargepoint market, where uncertainty over the level of demand has hampered investment to date. Improved certainty over the level of ZEV uptake from 2024 will improve private business cases for chargepoint investment, which is expected to lead to greater roll-out of EV infrastructure. As this occurs, some research suggests that it is likely that innovation, economies of scale, and learning-by-doing will lead to cost reductions.

376. With regard to ZEVs themselves, increasing uptake may lead to increased competition which often leads to innovation. As with the current ICEV market, ZEV manufacturers are likely to differentiate products based on efficiency, range, and/or cost (among other features), which will increasingly require investment in research and development as the market develops. The regulation remains technology neutral and manufacturers will be encouraged to invest in other ZEV technologies, such as Fuel Cell Electric Vehicles, which will be equally supported by the regulation and may have advantages for specific use cases.

377. The ZEV mandate will lead to an increase in the demand for batteries for battery electric vehicles, which in turn will support economies of scale and investment in battery production helping reduce costs and improve energy density. Greater production will also bolster investment in future battery technologies, for instance ‘solid-state’ batteries, with greater energy density as manufacturers seek to improve ZEV performance.

378. Finally, as noted in Section 3, the ZEV mandate will lead to an increase in demand for several input materials in battery production. Although there are not expected to be binding resource constraints which prevent the delivery of the ZEV mandate, competition for these materials may (and in some cases, already has) lead to innovation in areas such as battery technology. This innovation has led to an expansion of the range of suitable battery technology inputs (such as the introduction of nickel and cobalt-free batteries) as well as achieving increased energy density, in some cases.

379. This suggests that there is significant scope for innovation in ZEVs and battery technology, and that incentives are likely to strengthen as demand for ZEVs rises. To the extent that these proposals drive additional demand for ZEVs, they are expected to support greater investment in innovation.

Cost of Living

380. Given the current global economic context, it is important to consider the potential effect of policies such as the ZEV mandate on households' disposable income and business costs. This section draws together published research on the cost of ownership of battery electric vehicles versus conventional ICE vehicles and presents some internal analysis. The broad conclusion is that ZEVs will be a cost-effective alternative to ICE vehicles and their cost-effectiveness is expected to improve as costs (such as battery) fall as deployment rises. Total Cost of Ownership (TCO) captures the up-front cost of the vehicles, depreciation of the asset over time, costs to maintain, fuel benefits of running the vehicle, insurance, and taxes.

381. Internal DfT analysis has considered the TCO of battery electric and petrol cars leased today. The analysis considered the cost over a three year lease, for a car with average mileage and a basket of different car types with basic trim. This analysis found that on average, over a three year lease a BEV would cost £1,500 more than a petrol ICE, for an average mileage motorist. Although fuel and maintenance costs are lower for the BEV, these are currently more than offset by higher lease costs. This TCO calculation will move in BEVs' favour for higher mileage drivers, drivers who benefit from avoided congestion charge and drivers who benefit from the company car tax exemption.

382. However, over time it is widely expected that battery costs will continue to fall, reducing BEV purchase prices and improving the TCO picture. Further internal analysis predicts that the average car driver will break-even over a five-year ownership period if driving a BEV instead of the average ICEV by 2025. BEVs replacing petrol ICE cars are expected to break-even over a five-year ownership period for those bought in 2026 onwards, whereas BEVs may already be cheaper to own over 5 years than diesel cars bought today. However, this TCO picture is highly dependent on mileage/depreciation assumptions, and prices in the energy markets which are particularly uncertain; under other defensible assumptions BEV TCO may be higher than for ICEVs, for longer.

383. These findings are supported by international evidence. Several sources suggest that ZEVs are likely to increasingly offer cost savings compared to ICEVs. For instance, research commissioned by The European Consumer Organisation suggests that for second and third owners, zero emission cars already have a lower total cost of ownership than ICE cars.

384. Furthermore, it forecasts that ZEVs may become more cost-effective than ICEVs for the first owner in 2023 – 2024 (depending on vehicle type/size). Similar conclusions are reached by other organisations such as the Nickel Institute, Liu *et al.* (2021), and AutoTrader's Road to 2030 report which suggests that battery-electric cars saved owners £115 per 1,000 miles in 2021, on average (the figure rises to nearly £145 in 2022, though this is affected by oil supply shocks which are expected to be transient). All these analyses find that although zero emission cars typically carry

a greater 'sticker price' (the initial price paid to purchase the vehicle), running costs such as fuel, maintenance, and excise duty costs are significantly lower. Vans are typically driven significantly more than cars, therefore it is likely that the findings of this research would apply equally, if not more strongly, for van drivers.

385. Analyses which consider secondary (and further) ownership find that ZEV cost-effectiveness is even greater as depreciation narrows the gap between the upfront price of ZEVs and non-ZEVs (the upfront value of the vehicle falls over time). These sources also find that the cost-effectiveness of ZEVs relative to ICEVs is expected to increase and ZEV investment will pay back quicker over time, as ZEVs approach cost-parity with ICEVs.

386. The figures below present the forecast cumulative cash flow of the ownership of BEVs versus petrol and diesel ICEVs, as well as the weighted average, in order to illustrate impacts for the representative consumer. The weighted average is based on petrol and diesel ICEV sales shares as a proportion of overall ICEV sales, taken from the baseline scenario.

387. The analysis includes estimates of the up-front costs of BEVs versus ICEVs in 2025, 2030, and 2035, including updates to Vehicle Excise Duty policy announced in the 2022 Autumn Statement. Updated fuel prices, reflecting recent trends in the global markets for petrol, diesel, and gas, plus their effects on the domestic electricity market, are applied. It also includes several ongoing costs, in particular: fuel costs, Vehicle Excise Duty, and maintenance costs. All cost inputs match those used in the calculation of the social net present value, presented in Annex A.

388. In each comparison, BEVs are assumed to achieve the same annual mileage as their ICEV counterpart, in order to compare the cost of achieving the same level of output.[42] Finally, cash flows are adjusted for resale and depreciation using depreciation data by drivetrain type provided by AutoTrader.

389. In the central estimates presented here, BEVs are assumed to depreciate at the same rate as the petrol/diesel ICEV that they replace. This is for two key reasons: primarily, backward-looking depreciation statistics are likely biased by the state of technology when the resold vehicles were initially purchased. For example, the Nissan Leaf is quoted given their battery degradation which is likely to affect resale value.[43]

390. By contrast, this analysis covers BEVs purchased in 2025, 2030, and 2035, at which times battery and BEV technology is expected to have greater longevity and less at risk of range degradation. Due to the expected advancements in BEV technology, specifically relating to the way in which performance holds up over time, it is therefore deemed reasonable to expect that BEVs sold in these future years will depreciate at a lesser rate than those sold in 2017, for example.

391. Secondly, this analysis investigates the cost of achieving the ICEV level of usage with a BEV, which means the ICEV mileage is used in estimating BEV running costs. Depreciation is closely related to mileage, and there is growing evidence that BEVs typically achieve greater annual mileage due to their lower running costs. Therefore, depreciation rates based on actual BEV usage may over-estimate the hypothetical depreciation of a BEV which is used to achieve the mileage of the petrol/diesel ICEV that it replaces.

392. For these two reasons, it is deemed more suitable to apply the depreciation rates associated with the counterfactual ICEV that the BEV is assumed to replace. However, in order to mitigate

42 In practice, BEVs may be expected to achieve greater mileage, due to their reduced mileage costs. However, this increased mileage can be considered a utility benefit as well as a running cost (the two are equal as both are valued using the retail price of fuel), therefore the cost and benefit sum to zero.

43 https://www.geotab.com/uk/blog/ev-battery-health/

any optimism bias, several steps are taken. Firstly, the 'high' depreciation rate reported by AutoTrader is used. Secondly, additional sensitivities are presented in 'Annex E – Cost Of Living Depreciation Sensitivities' in order to illustrate how private cost-effectiveness might change under different depreciation scenarios.

393. As shown in Figure 80, BEVs are expected to break even, on average, with petrol cars in a little over 5 years (with net savings rising from roughly -£140 at the end of year 5 to + £430 at the end of year 6); for diesel cars, BEVs would break even considerably faster, largely because diesel cars typically achieve much greater mileage, so the reduced mileage cost of BEVs leads to greater savings. The 'representative' (weighted average) ICE car driver may be up to roughly £800 better off, after 5 years, achieving their driving activity with a BEV instead of their ICEV.

394. Figure 81 shows that BEVs are significantly more cost-effective for second-hand owners over 5 years, with the average petrol and diesel driver being between at least around £4,200 - £7,600 better off. The two key drivers of this are reduced running costs, as per first-hand ownership, and depreciation leading to much lower up-front costs. As a result of this latter effect, the reduced running costs offset the BEV premium significantly faster.

Figure 80 Cars: Cumulative cash flow for 1st owners of BEVs versus petrol/diesel ICEVs after 5 years

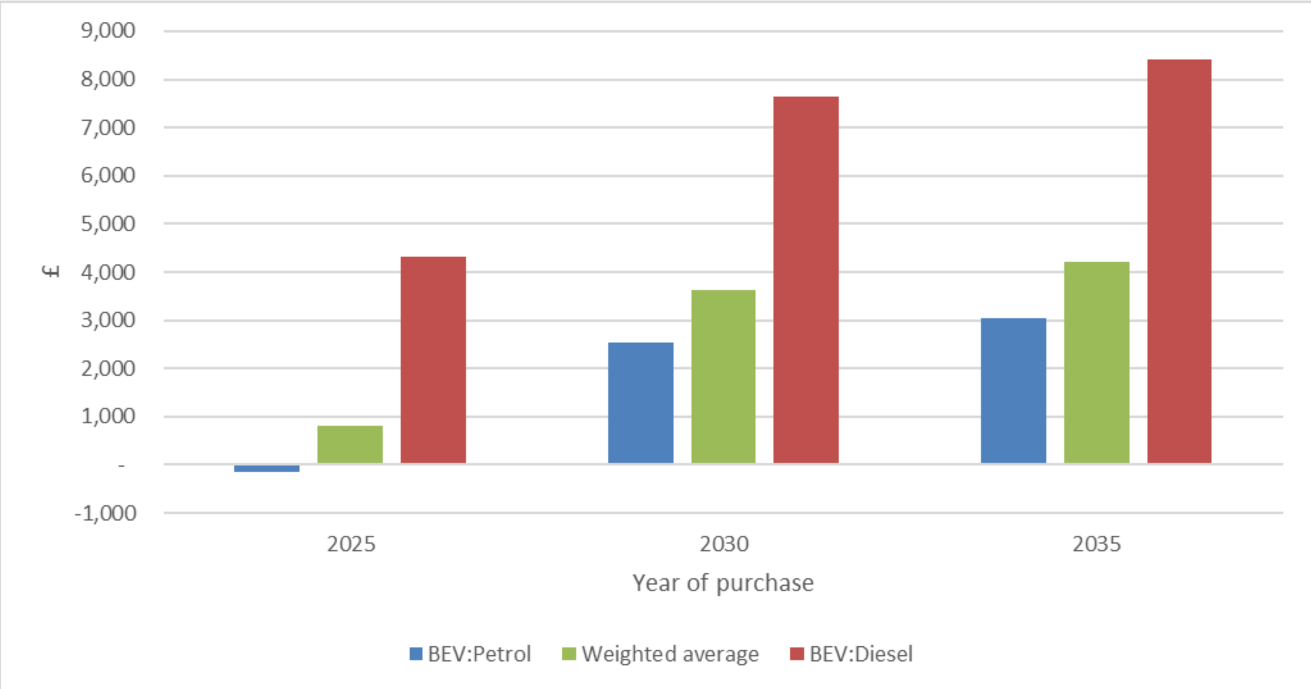
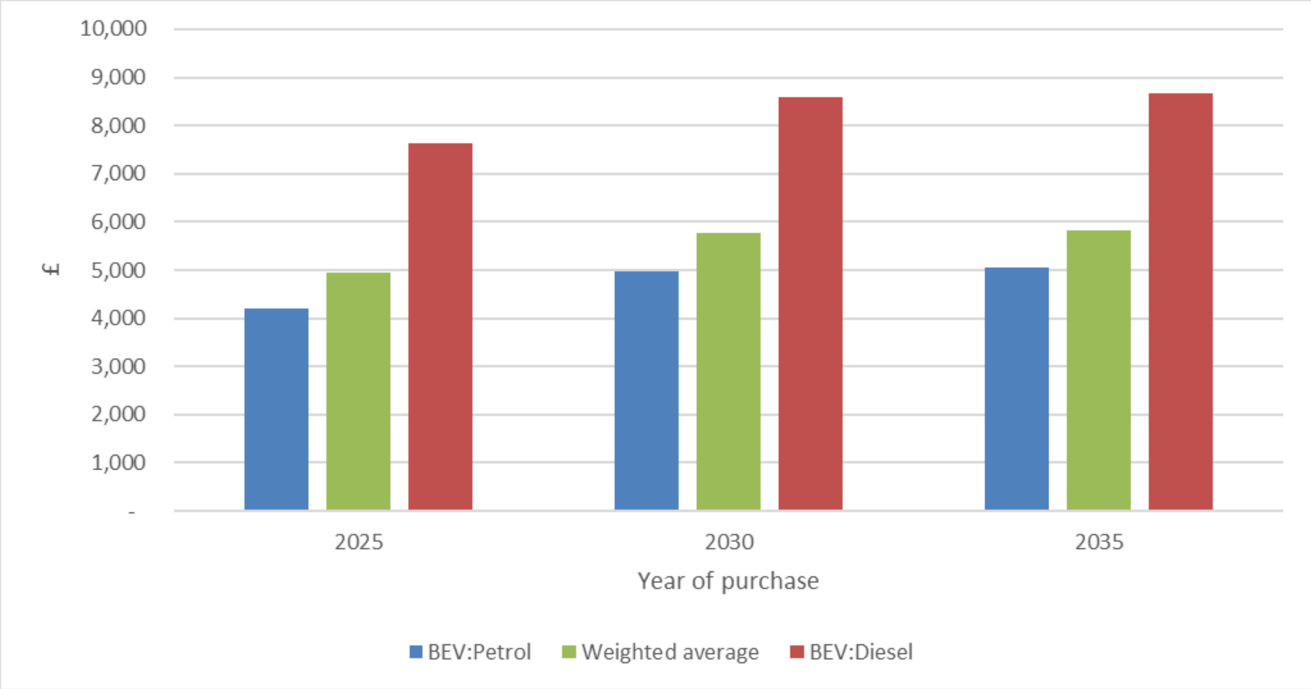


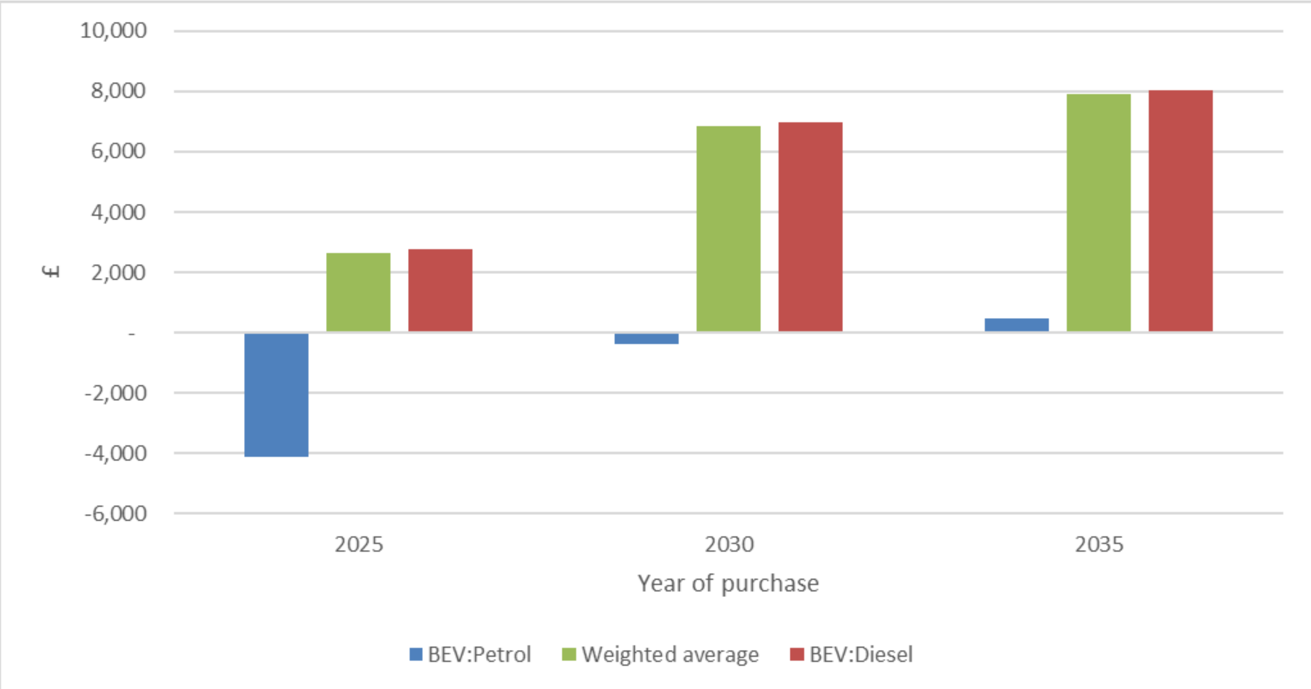
Figure 81 Cars: Cumulative cash flow for 2nd owners of BEVs versus petrol/diesel ICEVs after 5 years



395. A similar trend is seen in the van market: the cost-effectiveness of BEV vans is expected to improve, relative to ICEVs, over time. Figure 82 shows that for first-hand ownership, BEVs are likely to achieve significant cost savings, compared to diesel ICEVs (which currently make up almost all of new van sales) and the average van user.

396. Overall cost-effectiveness for petrol vans is less positive, especially in 2025, which is largely due to a greater expected BEV premium towards the beginning of the ZEV mandate, slightly greater diesel fuel costs (relative to petrol, leading to greater savings for BEVs), and that recent data suggests that petrol vans depreciate in value at a lesser rate than diesel vans. Nonetheless, drivers purchasing a BEV instead of a petrol van from 2030 onwards would be expected to achieve net cost savings over 6 years or less.

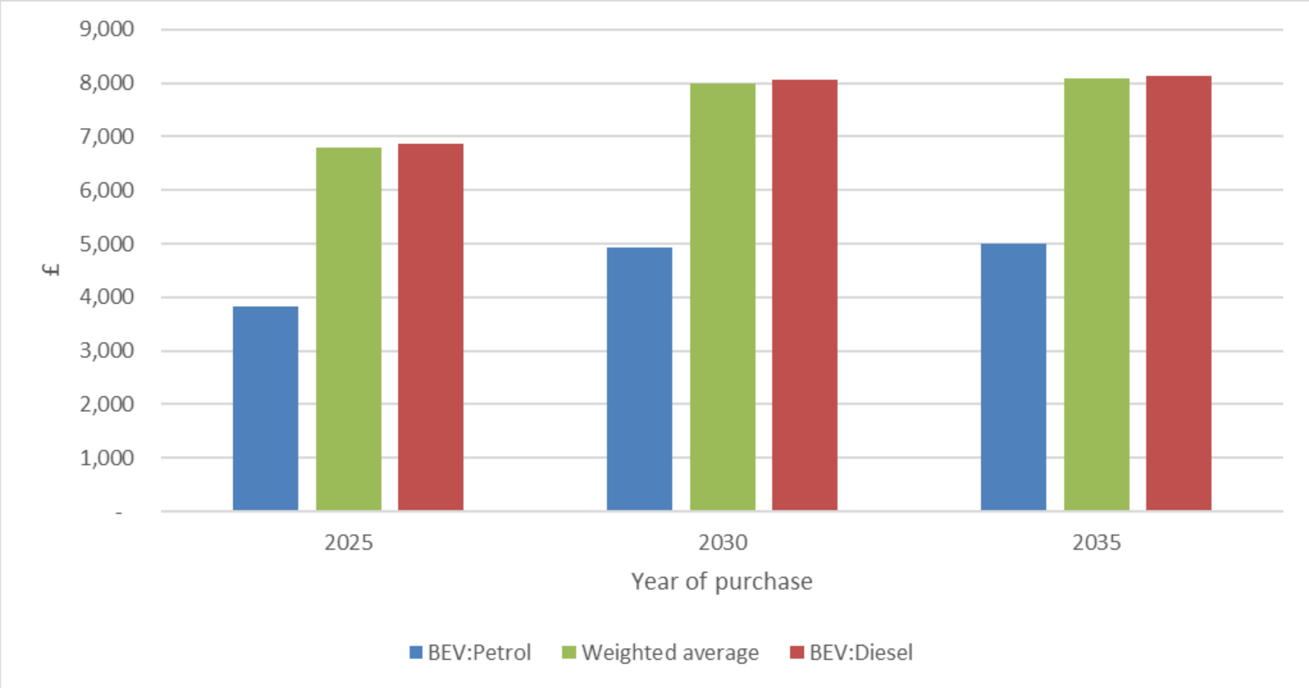
Figure 82 Vans: Cumulative cash flow for 1st owners of BEVs versus petrol/diesel ICEVs after 5 years



397. When considering the second-hand van market, overall cost-effectiveness is significantly greater for both petrol and diesel vans. As above, this is because depreciation reduces the value

of the BEV premium, meaning that it takes less time for the reduced ongoing costs of BEV ownership to offset the remaining difference in up-front costs for the second-hand purchaser. Because petrol vans retain their value more than diesel vans, this effect is particularly significant when comparing the cost-effectiveness of a BEV versus ICEV petrol van.

Figure 83 Vans: Cumulative cash flow for 2nd owners of BEVs versus petrol/diesel ICEVs after 5 years



398. This high-level analysis suggests that even relatively early adopters of ZEVs are unlikely to be materially worse-off, on average, despite the expectation that ZEVs in these years are expected to have greater up-front costs. In addition, greater savings are expected to be realised in the secondary market, particularly as the greater depreciation rate for BEVs narrows the gap between second-hand BEVs and ICEVs substantially. For first-hand owners, ownership models which spread costs over time, such as vehicle leases, may allow consumers to better align the increased costs of purchasing a BEV with the reduced costs of ownership, leading to neutral or positive effects on disposable income.

399. It should be noted, however, that this analysis is sensitive to the assumed depreciation rates for petrol, diesel, and electric vehicles. In order to reflect this uncertainty, additional scenarios are presented in 'Annex E – Cost Of Living Depreciation Sensitivities'. Relative changes in energy costs will also impact upon the relative costs.

Small and Micro Business Assessment

400. The UK Government's current definition of small and micro businesses is based on companies' employee headcount and annual turnover. Micro businesses are defined as those with fewer than 10 employees or annual turnover below €2m (c. £1.69m); for small businesses the thresholds are 50 employees and annual turnover of €10m (c.£8.4m).[44]

401. Typically, small and micro businesses are exempt from UK regulations, in order to avoid disproportionate regulatory burdens which may raise barriers to entry and limit competition. For this reason, exemptions and derogations are included in these regulatory proposals.

402. The small and micro volume manufacturer exemption thresholds included in these proposals match those applied through the existing regulatory framework, which applies to all registrations

[44] Conversions will vary continuously with currency valuations.

made in the EU area. This threshold was set in order to prevent any disproportionate effect for small and micro businesses. The UK car and van markets are significantly smaller than their EU counterparts, therefore the proposed regulations provide exemptions for a much larger number of small manufacturers.

403. In the interests of proportionality, the headcount and turnover data for each manufacturer in the UK market is not collected. However, desk-based research of company headcount data suggests that each of the three largest manufacturers qualifying for an exemption based on their three-year average annual registrations from 2017 - 2019 employed significantly more than 500 people (the threshold for large-sized businesses) and each achieved annual turnover exceeding £1.1bn. This suggests that it is very unlikely that any small or micro businesses would be set mandatory targets through the ZEV mandate.

404. They would, however, be permitted to sell ZEVs, and earn and trade allowances with participating manufacturers. This provides SVMs an opportunity to develop and sell zero emission vehicles and be rewarded for doing so, stimulating competition in the ZEV market.

405. Taken as a whole, these proposals are unlikely to have any adverse impact on small or micro businesses, for three key reasons. Firstly, this exemption framework is broadly aligned with the existing regulations, meaning that the marginal effect of these proposals is likely to be small; secondly, the largest exempt manufacturers have headcounts and turnovers significantly exceeding the threshold for small enterprises, therefore it is unlikely that any non-exempt manufacturers would classify as small or micro businesses; finally, exempt manufacturers are not excluded from any opportunities offered by the proposals, as they may take part and sell earnt allowances if they choose to do so.

Equality Impact Assessment

406. There is a statutory duty to consider the effects of policies on those with protected characteristics under the Public Sector Equality Duty set out in the Equality Act 2010. This covers 9 protected characteristics as follows: age, disability, gender reassignment, pregnancy and maternity, race, religion or belief, sex, and sexual orientation.

407. This quantitative analysis focuses on the economic implications for discrimination – if the policy and its impacts could put groups of protected characteristics at an unfair (economic and financial) disadvantage. This analysis also considers equality of opportunity – if individuals have the same financial and economic opportunities given their protected characteristics as compared to the status quo.

EU analysis of CO_2 regulations

408. The EU CO_2 regulation impact assessment assessed the affordability of different ZEV powertrains in 2030, 2035, and 2040 against alternatives. They find that affordability[45] restrictions are observed for the largest vehicles, PHEVs, and FCEV powertrains. However, in all of their scenarios BEVs are affordable except for the larger segments and that these become affordable over time – largely due to expected declines in battery costs coupled with the greater availability of smaller, lower-cost models. Similarly, due to purchase intentions, this does not affect the lowest income groups as they are assumed to be 3rd or 2nd users.

UK analysis of ZEV mandate and CO_2 framework

409. These regulations do not directly affect these groups, as they place requirements on car manufacturers, as opposed to households. However, households will be affected indirectly, as

[45] Affordability in this context is based on whether household groups have the financial capacity (either through savings or income) to be able to repay the loan for vehicle ownership over 5 years.

the regulations are expected to increase the average upfront cost of purchasing new vehicles while also reduce the running and maintenance costs of those vehicles. As noted earlier, our cost of living analysis indicates that over the lifetime of vehicles there are likely to be large savings to vehicle owners from the move to electric vehicles. Furthermore, it shows that average first owners are likely to receive savings over a 5-year ownership period from 2025 onwards, and these savings are likely to be even larger for second owners.

410. Net cost savings are expected to increase over time, as the cost of ZEVs and non-ZEVs converge with increased uptake and technological advancement. Therefore, although groups which are currently identified as having below average income and savings may face barriers to purchasing ZEVs on the first-hand market *in the short-term*, in the longer-term and on the resale market these barriers will be significantly lower.

411. In addition, results of wave 8 of the Transport and transport technology: public attitudes tracker shows: that lower-income households are less likely to have a driving license; that ZEV ownership to-date is far higher amongst higher-income households; that lower-income households are more likely to purchase second-hand; and that higher-income households are more likely to purchase BEV as their next vehicle.[46] This suggests that, even for low-income households who need to drive, the ZEV mandate is unlikely to have material adverse effects, partly because they are far more likely to purchase second- or third-hand vehicles, which have significantly declined in cost due to depreciation.

412. Early adopter, higher income groups may therefore bear the higher upfront costs in the short-term, while the lower income groups are proportionately more likely to experience higher net cost savings in the longer-term from the second-hand market. Despite this, the upfront costs may impose some specific barriers to households with lower savings or less access to credit.

413. Taken together, this suggests that lower-income households are less likely to be affected directly or indirectly as they are less likely to drive, and that their reduced propensity to purchase a ZEV as their next vehicle will delay the effect on this group. Furthermore, the delayed effect is likely to lead to reduced costs and greater net savings for lower-income households, as upfront ZEV costs are expected to fall over time. Finally, these households are more likely to experience greater cost savings because they are more likely to purchase vehicles on the second-hand market, which is likely to be significantly more cost-effective.

414. As a result, it is not clear that barriers faced by lower-income groups in the short-term materialise in overall adverse impacts. Rather, early adoption by relatively higher-income households, with stronger preferences and/or greater purchasing power, is likely to develop the market for ZEVs and increase their supply on the resale market, subsequently bringing down longer-term costs for more constrained households. This may lead to greater net savings for lower-income households in the long-term. This effect is an important qualification when considering the potential barriers and differential effect identified in the discussion below. Table 84 summarises the expected impacts and sets out mitigating actions; these impacts are discussed in greater detail in Annex J.

[46] UK wide surveys show more than three-quarters (79%) of those from lower income households (earning less than £25,999) intended their next vehicle to be second-hand. By comparison, higher income groups are twice as likely to say they would likely purchase or lease a new vehicle

Table 84 Summary of expected impacts for groups with protected characteristics

Protected Characteristics	Impacts	Summary	Mitigations?
Age	No negative impact.	Driving ZEVs should deliver a similar experience to the status quo – not disproportionately impacting individuals by older ages Older groups have more savings, and intend to buy new vehicles demonstrating the capability to absorb the upfront cost. Younger groups are likely to have lower savings, and be second-hand users, proportionately fronting less of the up-front cost of ZEVs but also accruing the benefits.	
Disability	Potential impact to accessibility in the short-term. Positive impact in the long-term. Potential impact on supply of wheelchair-accessible vehicles.	Individuals with a disability tend to have lower savings and may be disproportionately impacted by the upfront cost of ZEVs. Some disabled individuals may also be less likely to be able to purchase a suitable second-hand vehicle, for instance if they require a wheelchair-accessible vehicle.	As a mitigation, we have proposed additional credits for WAVs, incentivising wheelchair assessable vehicles to be produced and sold to ensure they are readily available and cheaper for individuals in society with a disability.
Sex	No negative impact.	Due to similarities in income distributions of these groups, it's unlikely the proposals will affect the large majority of households in materially different ways – however, some impacts may occur on a case-by-case basis.	
Pregnancy and maternity	Potential impact to accessibility in the short-term. Positive impact in the long-term.	Greater barriers to BEV uptake may exist for single-adult and single-child households. However, there are still total benefits in the secondary market in the longer-term.	
Race and ethnicity	Potential impact to accessibility in the short-term. Positive impact in the long-term.	Some barriers may exist for BEV uptake for first-hand users for some races. However, there are still total benefits in the secondary market in the longer-term.	
Religion or belief	Potential impact to accessibility in the short-term. Positive impact in the long-term.	There is some, but little, information indicating income and savings levels may differ by different religious groups. It is possible some groups are impacted differently by these proposals.	
Sex and sexual orientation and gender reassignment	No negative impact.	LBG&T groups are not likely to face specific barriers to engagement with these proposals based on their financial status.	

415. This analysis investigates households' access to BEVs, as judged by their income and savings. This is because the primary way in which drivers will be affected is by the difference in up-front and running costs, relative to the counterfactual – in which BEVs make up sales only insofar that the market has demand for them.

416. The data that underpins this analysis is taken from the Department for Work and Pensions' Family Resources Survey. Unfortunately, data is not collected on all protected characteristics; in

addition, savings evidence only covers a portion of those characteristics covered by income evidence. Income and savings data is presented where available; where it is not, broad assumptions around household savings can be made based on the relationship between household income and savings, which is shown in Figure 85.

417. As shown, there is a generally positive relationship between household income and household savings. This is intuitive: as income rises, households have greater resources and may be able to save more of their income. Even in the case that the proportion of income saved is constant, the absolute value of savings rises, all other things being equal. Therefore, in absence of data on household savings, there is assumed to be an at least partial overlap between households' income and savings groups.

Figure 85 Household savings, by gross weekly income

418. Detailed analysis of the effect of these proposals on each protected characteristic is set out in Annex J.

Trade Impact

419. The ZEV mandate could be thought of as a non-tariff measure in that it will affect trade through a kind of product regulation – elements of this could be thought of as a technical barrier to trade, although there are similarities to quantity restrictions in that it will apply differentially based on the number of ZEVs and non-ZEVs already traded. That said, the mechanism is atypical as instead of imposing more stringent requirements on all vehicles traded, or greater costs on vehicles traded above a certain quota, the regulations will require the sale of a non-ZEV to be compensated by a given number of ZEV sales. This will cause some degree of trade friction for non-ZEVs.

420. The regulations will apply equally to imports, exports, and domestic trade as they apply to UK registrations regardless of product origin. The regulations impose no explicit barrier or cost on production and exports; manufacturers would be free to produce ICEVs for international trade. It may, in fact, facilitate exports of non-ZEVs to economies without ZEV mandates and/or with less stringent regulations, because the domestic non-tariff measure (NTM) imposed through the ZEVM would likely lead to greater implicit costs associated with domestically-produced (and sold) ICEVs, relative to the costs they incur when exported to these other nations.

421. That said, these regulations would be very unlikely to be viewed as trade-promoting or protectionist measures, for several key reasons. Firstly, there is no distinction between domestic and foreign producers; secondly, the majority of both domestic and foreign vehicle manufacturers produce a mix of ZEV and non-ZEVs. For these reasons it's not likely to have a differential effect on domestic versus foreign producers or trading partners in a way which may lead to trade issues.

422. The overall effect on the UK trade balance is not clear. Trade modelling is generally based on large amounts of historic data; given the nascent nature on the BEV market; challenges modelling NTMs in general; and broader challenges regarding modelling the effect of quantity-based NTMs (as which the ZEVM could be conceived), it is unlikely that bespoke trade modelling (e.g. structural gravity) would deliver proportionate value. However, the effect on domestic/foreign manufacturers and the trade balance should be considered in the development of the monitoring and evaluation plan.

423. For the years following 2035, where the ZEV mandate will require 100% of standard cars and vans to be zero emission, the regulations should be thought of as a technical barrier to trade. This period is, however, outside the scope of this cost benefit analysis. Further analysis will be conducted to assess the trade impacts of subsequent regulations at the appropriate time.

424. The regulations may require WTO notification, given that they will affect UK trading partners. They are, however, very unlikely to lead to any dispute, unless specific provisions are made which favour domestic over foreign producers.

5.0 Monitoring/Evaluation (Post Implementation Review)

425. Monitoring and evaluation activities will be conducted in order to meet a) the requirement for a statutory Post Implementation Review (PIR), first due in 2029, and b) to evaluate elements of scheme design with the view to improving it for the second phase of the policy, which will run from 2031 – 2035.

426. To support the development of a robust monitoring and evaluation plan a theory of change has been developed. This theory of change sets out the mechanisms by which the policy is expected to achieve its aims. It will confirm the impacts of interest, key actors involved, and a number of the assumptions underpinning the policy. It will also be used to finalise the policy's Key Performance Indicators (KPIs). This assessment will be kept under review and may be subject to change as policy details continue to develop.

1. **Review status:** Please classify with an 'x' and provide any explanations below.

	Sunset clause		Other review clause		Political commitment		Other reason		No plan to review

Regulations to be reviewed every five years to ensure continued suitability.

2. **Expected review date** (month and year, xx/xx):

0	1	/	2	9	Five years from when the Regulations come into force

3. Rationale for PIR approach:

As these proposals are currently at consultation stage, this section sets out a potential PIR approach. This will be refined as policy is developed, and in response to consultation feedback.

Potential evaluation approaches

Given the complex nature of these proposals, the potential for unintended consequences, and potential interactions between policy features, a hybrid evaluation approach may be suitable. This may cover impact, process, and economic evaluation methods.

Impact

To understand if the policy has had the intended impacts and progress on objectives, to what extent, and by how much. This will be used to estimate the impact of the proposals on ZEV and non-ZEV sales, new non-ZEV sales' efficiency, fleet make-up and emissions, etc. In addition, impact evaluation could help illustrate the proposals effect on vehicle prices, access to wheelchair-accessible vehicles, and infrastructure investment.

Process

Process evaluations aim to understand whether proposals function in the intended way. This could provide insight into the efficacy of certain policy design features, such as credit-trading and its interaction with other flexibilities, such as banking, borrowing, and non-compliance payments.

Economic

This approach would seek to assess the real-world social cost-effectiveness of these proposals. For instance, it could ascertain whether the proposals achieved social value for money, actual abatement costs.

Data collection

Much of the data required for the PIR is already collected by the DVLA. This includes data on new vehicle registrations, existing licensed vehicles in each subsequent year, and GHG emissions by make and model. Additional primary data on scheme delivery (including trading, non-compliance payments, and credit transfers) will need to be collected by the scheme administrator, and other evidence such as consumer perceptions of electric vehicles are already collected through the National Travel Attitudes Survey. Therefore, a large amount of the data required for the PIR is likely to carry little resource burden, although the scheme administrator will be required to have processes in place to collect data in the appropriate format.

Other evidence will need to be collected specifically for this PIR. This includes information on whether these proposals impact on access to wheelchair-accessible vehicles and competition in the automotive sector. A number of approaches may be required to collect this additional information, such as surveys and stakeholder feedback sessions[47]. However, this data collection is deemed to be proportionate due to the importance of monitoring in detecting unintended outcomes.

Key Objectives, Research Questions and Evidence collection plans

Key objectives of the regulation(s)	Key research questions to measure success of objective	Existing evidence/data	Any plans to collect primary data to answer questions?
Increased sales of ZEVs relative to counterfactual	Have ZEV sales exceeded the expected baseline, and have they matched targets?	DVLA statistics on new vehicle registrations by drivetrain type	Primary data will be provided by car and van

[47] The methods applied in the PIR are subject to change as the scheme proposals develop.

			manufacturers to the Government's administration body
No regression in emissions intensity of non-ZEV new sales	Do manufacturers maintain their baseline average gCO_2/km?	Test cycle emissions: DVLA statistics on new vehicle registrations' emissions Real-world emissions: International evidence and research on real-world emissions gaps from the ICCT, CCC, Ricardo.	Primary data will be provided by car and van manufacturers to the Government's administration body. In the longer-term, DfT are looking into the possibility of data collection on real-world fuel consumption.
Reduction in CO_2 emissions of non-ZEV car and van fleet	Do non-ZEV sales (at flat baseline gCO_2/km) lead to reduced non-ZEV fleet emissions as older, less efficient vehicles are decommissioned?	DVLA data on licensed vehicles and emissions by make and model.	This data is already collected by the DVLA.
Reduction in CO_2 emissions of UK car and van fleet	Does increased uptake of ZEVs lead to a reduction of the required scale in total transport and UK emissions?	National statistics on emissions by sector.	This data is already collected for purpose of national statistics.
Achieve progress against UK Carbon Budgets and set course for net zero 2050	Do carbon savings sufficiently contribute to progress against the UK's legally-binding Carbon Budgets?	DVLA data and DfT modelling feed into the Energy Emissions Projections to monitor progress towards the UK's carbon budgets and to inform energy policy and associated analytical work across government departments	DVLA statistics on new vehicle registrations and emissions along with DfT and DESNZ modelling
Expand infrastructure network to meet increasing demand of ZEVs	Has the number of ZEV chargepoints risen in step with increased charging demand? Do investors have the signals and certainty required for business cases to be positive?	Primary data on publicly available chargepoints is collected and published by the Department for Transport.	Primary data on private chargepoint installations is collected and will be used to assess the charging network's capacity.
Maintain access to special purpose vehicles	Do consumers of special purpose (e.g. wheelchair accessible) vehicles continue to have access to suitable vehicles? Is access maintained through exemption of these vehicles, or are decarbonised alternatives increasingly available?		Engagement with consumer and advocate groups, and such at Motability.
Facilitate competition and avoid excessive business impacts	Do the UK car and van markets remain competitive, without prohibitive barriers to entry? Do flexibilities/routes to compliance allow manufacturers to meet scheme requirements without disproportionate costs? Are scheme impacts proportionate and not prohibitive for industry stakeholders?		Primary data from the trading scheme will be monitored to measure if trading occurs. DVLA statistics will be provided to understand the sales in the market to understand the scale of burdens is having on sales. Engagement with manufacturers will also inform this issue.
Maintain affordability for consumers	How do ZEV up-front costs change over this period?	ONS manufacturer producer price inflation for the automotive industry	Primary data collection on the outturn of vehicle purchase prices, fuel prices, and maintenance costs can

	Are ZEV costs of ownership affordable for consumers? How do costs of ownership change over this period?	will give early indication of vehicle cost changes. ONS First- and second-hand car price index will give an early indication of up-front price changes.	be used to re-estimate the TCO.
Improved consumer perceptions of ZEVs' feasibility and cost-effectiveness	What is public sentiment to ZEVs and how does this change over this period? What are consumers' key concerns/barriers to purchasing ZEVs and do these change over this period?	National Travel Attitudes Survey already asks questions on perceptions and purchase intentions of ZEVs.	National Travel Attitudes Survey already asks questions on perceptions and purchase intentions of ZEVs.
Trading	What number of allowances are traded each year? What is the value of traded allowances? What were the carbon impacts of trading? Are there opportunities to improve the effectiveness of trading?	DVLA data DfT modelling of carbon impacts Manufacturer surveys	Primary data will be provided by car and van manufacturers to the Government's administration body to measure if trading occurs.
Pooling	How many companies pooled together? How did companies perform against targets on an individual versus pooled basis? What were the carbon impacts of pooling? Are there opportunities to improve the effectiveness of pooling?	DVLA data DfT modelling of carbon impacts Manufacturer surveys	Primary data will be provided by car and van manufacturers to the Government's administration body
Banking and borrowing	What number of sales are banked or borrowed each year? Do manufacturers pay-off all borrowed allowances? What are the carbon impacts of banking and borrowing? Are there opportunities to improve the effectiveness of banking and borrowing?	DVLA data DfT modelling of carbon savings	Primary data will be provided by car and van manufacturers to the Government's administration body
2-way allowance transfer	Do manufacturers access the allowance transfer to meet ZEV mandate? How many credits are purchased by year? What are the CO_2 implications of 2-way credit transfers?	DVLA data DfT modelling of carbon savings	Primary data will be provided by car and van manufacturers to the Government's administration body
Payment activity	Do manufacturers make non-compliance payments for ZEVM and CO_2 allowances? How many payments are made by year? What are the carbon impacts? What was the driver of these decisions? Are there opportunities to improve the payment process?	DVLA data Manufacturer surveys	Primary data will be provided by car and van manufacturers to the Government's administration body
Car clubs	What was the level of demand for ZEVs from car clubs (versus the market as a whole)? Did this impact on car club uptake? What are the carbon impacts of car club? How did manufacturers find the process? How did car club providers find the process?	DVLA data Car club surveys	Engagement with participating Car Clubs and industry bodies, such as CoMoUK.

427. A broader set of evaluation questions will also be included in the PIR. These are likely to include questions such as:

- To what extent have the policy aims been achieved?
- How is the policy being implemented in practice?
- What (intended and unintended) impact has the policy had on relevant stakeholders and markets? Including additional burdens and benefits to manufacturers and consumers
- Are the impacts evenly distributed across society? Including consideration of impacts on lower income households.

428. At the Government Response stage, the budget for monitoring and evaluation activities will be reviewed and included into the government administrative budget.

6. Annexes

Annex A – Modelling Methodologies

429. This annex sets out several elements of the methodology which underpins this analysis.

The Baseline

430. The baseline analysis takes a similar approach to The European Consumer Organisation in its estimation of the total cost of ownership in 2021. The approaches to calculating capital costs, maintenance costs, and vehicle uptake, which ultimately determines how the fleet changes over time, are set out in Table A1.

Table 86 Baseline calculations

Steps	Details
Capital Cost	
1	Measure fuel consumption (kWh/km)
2	Measure stated battery range (km)
3	Estimate battery capacity (kWh = kWh/km*km) to meet stated battery range
4	Estimated battery cost (£) = battery price (£/kWh) * estimated battery capacity (kWh)
5	Measure vehicle prices (P11D prices) are estimated by Element Energy based on a range of data, of which sources include: Cars: FleetNews[48] Vans: WhatVan[49] Caveat on ZEV prices ▪ 2020 P11D sale prices for ZEVs in the UK. Values are either taken as sales weighted average values from Fleet News data (2020), or when vehicles aren't on sale, taken as ratios to other vehicle types from ICE sale prices.
6	Estimate gate cost for ICEs Observed P11D sales price * (100% - X% ICE margin assumption)
7	Back calculate the chassis cost (and assume chassis cost is the same for all powertrains) Bottom-up non-chassis costs are estimated from EE and Ricardo 2016 published information.
8	Add battery cost on top (and cabling/wiring harness/etc) to give the EV gate cost Calculate non-chassis cost for EVs using bottom up estimates from Ricardo 2016 published information [step 7] but also the battery cost estimates in step 4 [see above].
10	Calculate new margins for HEVs/PHEVs/BEVs based on the observed price/estimated gate cost.
11	Ad hoc cost sensitivity Construct a Low/High sensitivity for given relative capital cost assumptions [summary in 'Annex B: Assumptions Log']
Maintenance Cost	2020 Fleet News data is used to understand the simple relationship between vehicle maintenance costs and purchase prices and mileage. These coefficients are then used to project the expected maintenance costs for differing purchase price sensitivities and mileage. Element Energy produce a regression to understand the relationship between maintenance costs and prices constructed from data covering 10,000 – 100,000 km mileage (over the lifetime of the lease, ca.3 years). Average r-squared values are 0.91 suggests a good fit.

48 FleetNews, 21st July 2020
49 WhatVan, October 2020

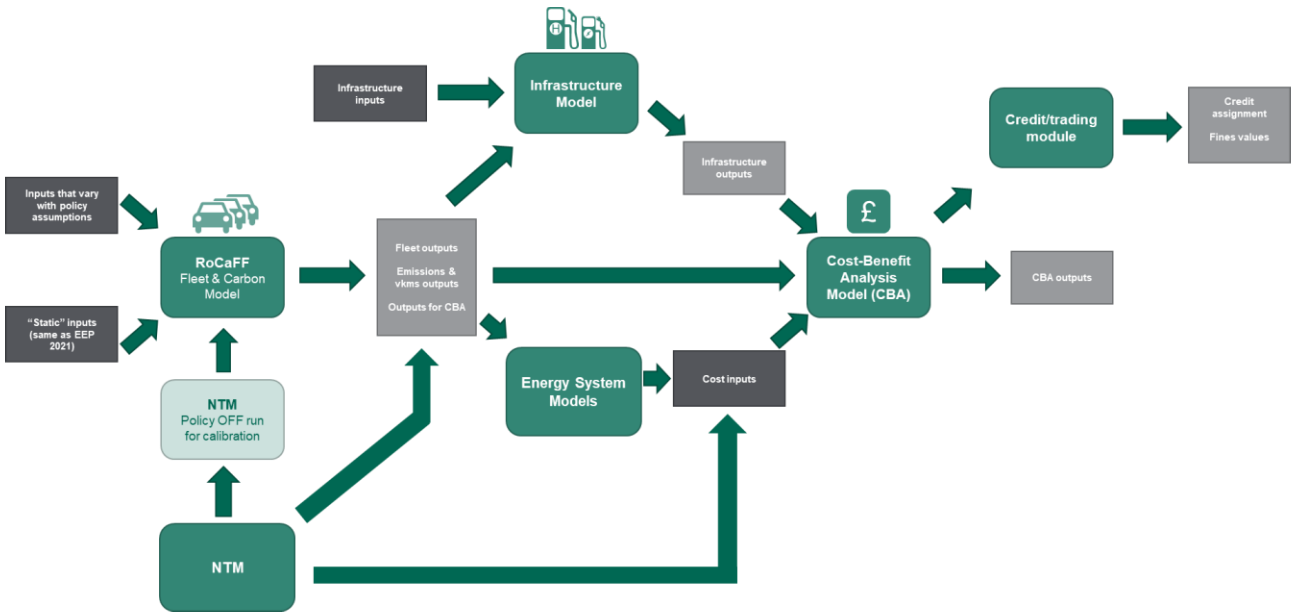
Baseline forecast	We used our in-house Electric Car Consumer Model (ECCo) which models the response of consumer demand to differing price assumptions given differing battery prices and surveys on consumer's willingness to pay stated preferences by segments. This takes a range of factors such as upfront cost, running cost, electric driving range, chargepoint availability, chargepoint performance, brand supply to understand preferences. Probabilities are then assigned to the likelihood of purchasing each vehicle given these changing input assumptions. This forms assumptions on vehicle sales % uptakes over time.

Fleet Modelling

Model system overview

431. The below schematic outlines the full model pipeline for the ZEV mandate analysis. It can be broken down into several 'modules' which include the fleet model (RoCaFF) and the cost benefit analysis model.

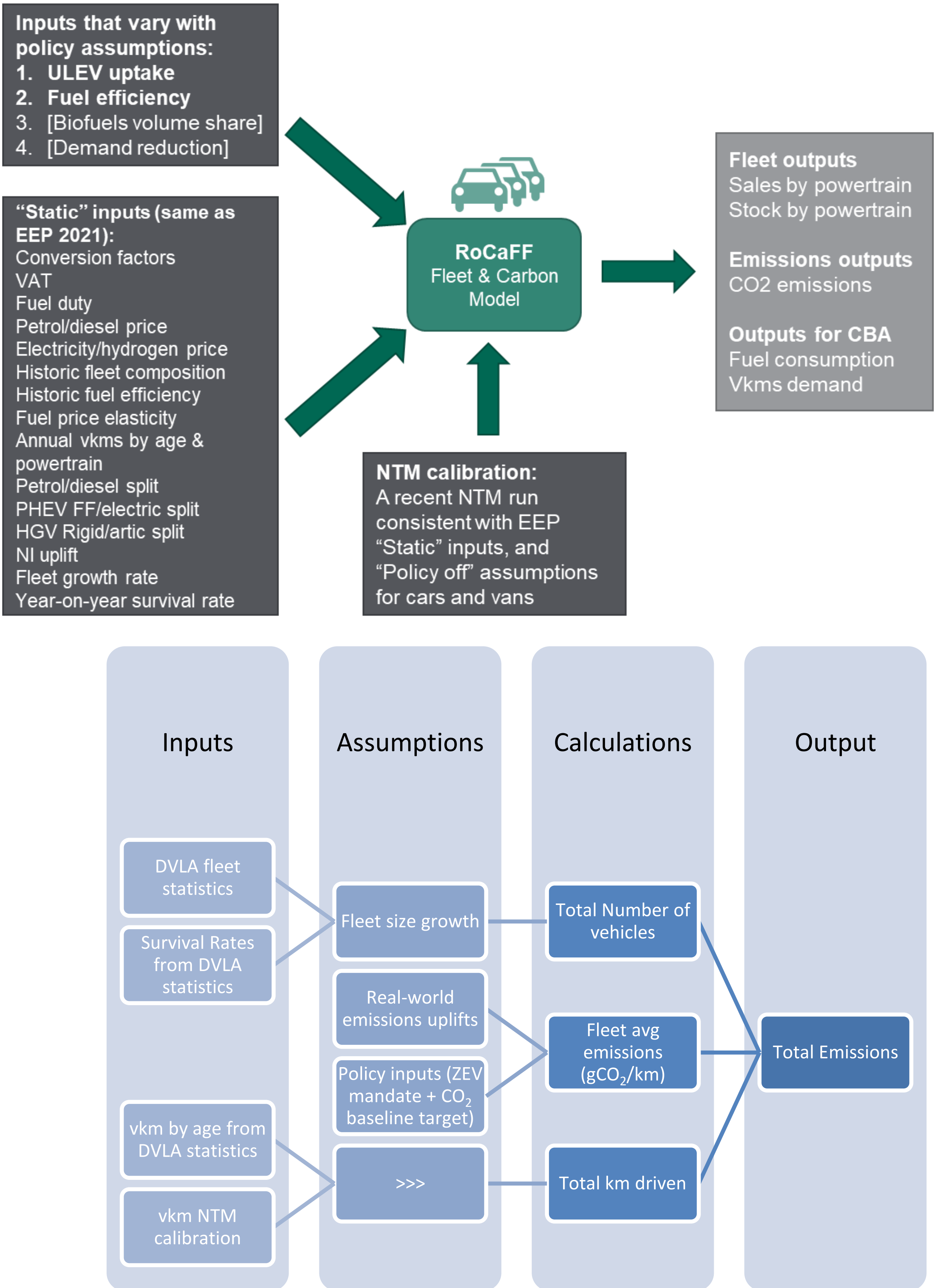
Figure 87 ZEV Mandate Model Pipeline



Fleet model schematic

432. Figure 88 sets out the fleet modelling process. A number of static inputs and policy variables form inputs to the analysis. These are combined with a calibration against the Department for Transport's National Transport Model (NTM). Together these inputs are used to estimate the turnover, composition, use of, and emissions of the car and van fleets. The outputs of this process are fed into the cost benefit analysis model in order to appraise policy scenarios and estimate carbon impacts of each option.

Figure 88 Fleet Model overview



433. Table 87 below sets out the detail underpinning the above schematic.

Table 89 Detailed fleet modelling methodology steps

Group variable	Index range	
Vehicle ∈	{Car, Van}	
Powertrain ∈	{Petrol ICE/HEV, Diesel ICE/HEV, Petrol PHEV, Diesel PHEV, BEV}	
Year ∈	{2024, 2025, …, 2071}	
Age ∈	{0, 1, …, 21+} Where 21+ is the average for all vehicles above 21 years old.	
Step	**Method**	**Output**
Historic vehicle uptake and emissions statistics		
1	gCO_2 /km by powertrain and year is observed in DVLA statistics by age of vehicle	gCO_2 /km (NEDC or WLTP) by vehicle, powertrain, age, year
2	Real-world uplifts are added on top	gCO_2 /km (real-world) by vehicle, powertrain, age, year
3	Historic DVLA licences statistics are used to estimate survival rates of vehicles	Survival rate by vehicle, age
Future Uptake and emissions policy assumptions		
4	Assumptions are input for sales and gCO2/km by vehicles, powertrain, and year. This reflects our policy scenarios.	% sales gCO_2 /km l/km kWh/km
Stock/Flow mechanism		
1	Stock data based historic license statistics from DVLA	Sales and stock of vehicles by powertrain for years < 2022
2	Future stock forecast based on NATCOP growth forecasts (~1% growth per year)	Number of vehicles in fleet stock over time for years > 2021
3	Survival rates of vehicles in the fleet are calculated using DVLA licence statistics. These represent natural turnover of vehicles in the fleet over time.	Survival rate by vehicle, age
4	Assume a new vehicle sale occurs to meet stock requirements given the stock depreciates each year by the % survival rate	Number of new vehicles in fleet over time for years > 2021
5	Total sales in a given year is multiplied by assumptions on % uptake by vehicle, powertrain, year. These sales, disaggregated by powertrain, is assigned a gCO_2 /km based on the requirement in that year (due to regulation assumptions)	Sales by vehicle, powertrain Sales by vehicle, powertrain, gCO_2 /km
Fuel consumption		
1	Stock * mileage * gCO_2 /km by vehicle, age, year, powertrain to give total CO_2	Total gCO_2
2	Stock * mileage * l/km by vehicle, age, year, powertrain to give total liquid fuel consumption	Total litres petrol/diesel
3	Stock * mileage * kWh/km by vehicle, age, year, powertrain to give total electric fuel consumption	Total kWh electricity
4	The NTM is used to provide a vkm and CO_2 forecast of GB.	Total km (calibrated)

	All figures are calibrated to the NTM (National Transport Model) the "Gold-Standard" in road transport fleet models to reflect the actual mileage and emissions on the roads using a more complex trip-end model to account for driving behaviour on the road network.	Total litres petrol/diesel (calibrated) Total kWh electricity (calibrated) For GB
Mileage and Calibration to NTM		
2	This is uplifted to UK wide to account for Northern Ireland transport based on NAEI published emissions of GB and NI.	Total km (calibrated) Total litres petrol/diesel (calibrated) Total kWh electricity (calibrated) For UK
Biofuels adjustment		
1	Input biofuels energy penalty to reflect biofuels use consistent with the EEP 2021	
2	Recalculate new fuel consumption with biofuel blend to reflect slightly higher fuel consumption	Total km (calibrated after biofuels) Total litres petrol/diesel (calibrated after biofuels) Total kWh electricity (calibrated after biofuels) For UK
Rebound Effect		
1	Driving demand elasticities are taken from the NTM	% change in mileage given a % change in fuel cost
2	As a result of biofuels making driving more expensive per km, and electric vehicle policy making driving cheaper per km, the cost to drive each km changes. % fuel consumption change * fuel price = % change in cost of driving	% change mileage given a % change in the cost of driving (due to EV policy and biofuels energy penalties)
3	% change in cost of driving * driving demand elasticities	Change in mileage (kms)
4	Add this mileage change onto mileage, fuel emissions, liquid, and electric fuel consumption.	Final vkms Final CO_2 Final fuel consumption (litres, kWh)

Cost Benefit Analysis Model Method

434. For the CBA model, all estimates are calculated for the Baseline scenario and a given Policy scenario. Differences are then taken to estimate the CBA impacts of each proposal, relative to the baseline. The high-level calculations of the CBA model are set out in Table 90 below.

Table 90 High-level CBA calculations

Static inputs	Variable	Notes
1	GDP deflators and discount rates	See Annex B.
2	Marginal External Costs	See Annex B.
3	Capital Costs	See Annex B.
4	Operating Costs	See Annex B.
5	Scenario fleet outputs	See Table 85

6	Fuel average long-run variable costs	See Annex B.
7	Grid intensity factors	See Annex B.
8	Air quality damage costs	See Annex B.
	etc	
Calculate Capital Costs		
2	Multiply costs of vehicles * sales of vehicles by vehicle, powertrain, year.	Total Capital Cost
Calculate Operating/Maintenance Costs		
1	A linear regression of 2020 Fleet data is used to understand the relationship of maintenance costs (from wear-and-tear repairs) with purchase prices and mileage with an average R-squared of 0.91. $$Maintenance = (m1 * mileage + c1) * vehicle\ cost + (m2 * mileage + c2)$$	Data is constructed covering 10,000 – 100,000 km mileage (over the lifetime of the lease, ca.3 years) for a range of powertrains.
2	Maintenance costs are estimated for each vehicle powertrains cost sensitivities and DfT mileage statistics per year for an average vehicle	
3	Multiply costs of vehicles * stock of vehicles by vehicle, powertrain, year.	Total Maintenance Cost
Infrastructure chargepoints costs		
1	Chargepoint demand volumes (baseline and scenario) estimated through joint internal analysis by DESNZ and DfT.	
2	Hardware, installation, and maintenance costs estimated based on new installations, reinstallations, and total number of chargepoints.	
3	Adjust future costs for productivity benefits (learning rates, economies of scale, etc.)	
4	Net scenario from baseline for marginal impact.	
Air Quality		
1	Calculate average speed on England roads 2021	Table CGN0503d Table CGN0404a Table TRA0102 ~56 kph
2	Gather non-exhaust AQ emissions (PM10)	TAG
3	Gather exhaust AQ emissions (using average speed) (PM2.5/NOx)	DEFRA NAEI 2020 October
4	Multiply total vkms by emissions factors by vehicle, powertrains, year.	Total PM2.5, PM10, NOx
5	Multiply AQ damage costs from TAG by the total emissions	TAG
Non-traded emissions & Fuel		

1	Change in fuel consumption (petrol, diesel) * CO_2 factors * DESNZ CO_2 values (low/central/high sensitivities)	l/km * km * gCO_2e/km* £/tCO_2e
2	Change in fuel consumption (petrol/diesel/electric) * LRVC Fuel prices (low/central/high for sensitivities) Note: LRVC are used to represent factor costs rather than market prices, in line with Greenbook and Transport Appraisal Guidance.	l/km * £/l = £ cost of fuel kWh/km * £/kWh = £ cost of fuel
Congestion / Accidents		
1	TAG Marginal external costs (High) * change in vkms	
Traded emissions		
1	kgCO2e/kWh factors are used from DESNZ * the change in electricity kWh demand to estimate traded CO_2 emissions [future modelling will use bespoke scenario runs from DESNZ energy systems modelling]	
2	Traded CO_2 * DESNZ traded carbon values	
Discounting		
1	Social time preference discount rates are applied to all cost and benefits. Health discount rates are applied for Air quality impacts.	

Air Quality Impacts Methodology

435. This section contains supplementary information on the methodology for estimating the air quality impacts of ZEVs, relative to ICEVs. For more information, please see Transport Analytical Guidance (TAG) and the TAG databook on gov.uk.

Exhaust emissions

436. As noted in 'Section 2.0: Air Quality Benefits', it is expected that ZEVs will lead to lower exhaust emissions as fully electric vehicles have no exhaust emissions. Exhaust emissions of existing vehicles vary according to the speed at which the vehicle is driven.

437. To quantify the emissions of ICEVs, the average vehicle speed on English roads in 2021[50] is weighted by traffic statistics of travel on different types of roads[51] to produce a weighted average of 56.34 kph. This is used alongside DEFRA's NAEI 2020 October exhaust speed emissions curves to estimate the average emissions of different powertrains presented (see Annex B).

438. The exhaust and non-exhaust emissions factors are multiplied by the new sales fleet driving distance by powertrains in both the baseline and proposed central ZEV mandate scenario to provide an estimate of the total air quality emissions in both scenarios. As a result of more electric miles being driven and a fall in combustion engine miles, we expect a fall in air pollutant exhaust emissions (NOx and PM2.5 and PM10).

Non-exhaust emissions

439. In contrast because ZEVs still emit non-exhaust emissions ZEVs could still contribute to air quality emissions. For this assessment, as aligned with TAG, we categorise non-exhaust emissions as larger particulate matter PM10 from road abrasion and tyre and brake wear and

50 Table CGN0503d & Table CGN0404a
51 Table TRA0102

consider these equal per km for both a combustion engine vehicle and an electric vehicle. Note that PM2.5 is a subset of PM10 however there is significant uncertainty around by how much.[52]

Table 91 Non-Exhaust emissions of vehicles

Table A 3.5d of TAG:	Non-exhaust emissions (g/km)		
Emission type	Road abrasion	Tyre wear	Brake wear
Cars	0.00750	0.00730	0.00700
LGVs (Vans)	0.00750	0.01140	0.01050

440. Non-exhaust emissions can increase if ZEVs drive more miles than conventional vehicles. Non-exhaust emissions of ZEVs could decrease due to technologies such as regenerative braking, but this is not quantified within this assessment due to uncertainty in future technology adoption and efficacy to reduce these emissions specifically for EVs over alternatives.

Monetisation

441. The quality of the air can have an impact on human health, productivity, wellbeing, and the environment.[53] To quantify this impact, air quality damage costs are taken from Defra's air quality appraisal guidance, adjusted to our 2021 price year using HMT Green Book guidance for economic appraisal. In line with air quality appraisal guidance, we apply a 2% annual uplift from 2017, reflecting the assumption that willingness to pay for health outcomes will rise in line with real GDP growth.

442. Because exhaust PMs are almost entirely made up of PM2.5 we apply the PM2.5 damage cost directly for these emissions. In contrast, non-exhaust PM emissions are made up of a combination of PM2.5 and PMs between the sizes of 2.5 microns and 10 microns. For these, we apply the PM10 damage costs (PM2.5 damage costs are converted using DEFRA's road transport PM2.5/PM10 conversion factor of 0.635).

Table 92 Air quality damage costs from Defra's appraisal guidance

Pollutant	Central Damage Cost (£/t): central	Damage cost sensitivity range (£/t): low	Damage cost sensitivity range (£/t): high	Annual uplift from 2017
PM2.5 Road Transport	81,518	17,567	252,695	2%
NOx Road Transport	9,066	817	34,742	2%

443. Air quality impacts are discounted in line with Health discount factors, in line with Transport Appraisal Guidance and as a result, we estimate net air quality benefits to society, despite potential increases in non-exhaust emissions driving some social costs. These impacts are presented above in 'Section 2.0: Air Quality Benefits'.

Annex B – Assumptions Log

444. The table below presents the assumptions used in this analysis. It is not always possible to present values in this tabular format, as some assumptions relate to a large number of unique values.

Table 93 Assumptions log

No	Category	Assumption	Value/Description	Source:
1	Fleet Assumptions	Fleet volume	Size and composition of car and van fleet.	DVLA statistics
2	Fleet Assumptions	Fleet sales per year	Number of new sales of cars and vans.	DVLA

[52] Table 3 of: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1907101151_20190709_Non_Exhaust_Emissions_typeset_Final.pdf

[53] Full detail of impacts: https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-impact-pathways-approach

3	Fleet Assumptions	Fleet survival rates	Proportion of vehicles of given age leaving the fleet each year.	DVLA
4	Fleet Assumptions	Fleet growth forecast	Fleet growth forecast	NATCOP
5	Greenbook values	Energy Conversion Factors	Energy Conversion Factors	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/806027/Conversion-Factors-2019-Full-set-for-advanced-users.xls Sheet: Fuel properties, Cells: M33:N33, M23:N23
6	Transport Appraisal Guidance	MECs	High MECs are used as these better reflect a world with higher EV penetration.	TAG A5.4.2.2
7	Greenbook values	GDP Deflators	2022 price years	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685912/Discount_Factors.xlsx
8	Greenbook values	Discount Rate	<30 years Standard: 3.5% Intergenerational: 3% Health: 1.5% >30 years Standard: 3% Intergenerational: 2.6% Health: 1.3%	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685912/Discount_Factors.xlsx
9		Air Quality: Average speed	Average speed on roads in England (2021 year-end) Local A Road = 24.1 mph (39 kph) Strategic Road (motorway) = 58.9 mph (95 kph) Road traffic estimates in Great Britain: 2020 A Road = 69% Strategic Road (motorway) = 31% Weighted Average speed = 56.34 kph	Road Congestion Statistics Table CGN0503d Table CGN0404a Traffic (www.gov.uk/government/organisations/department-for-transport/series/road-traffic-statistics) Table TRA0102

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<tr>
<td>10</td>
<td>Greenbook values</td>
<td>Air Quality Damage Costs</td>
<td><table>
<tr><td>PM2.5 Road Transport</td><td>£/tonne</td><td>203,331</td></tr>
<tr><td>NOx Road Transport</td><td>£/tonne</td><td>10,699</td></tr>
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In 2017 prices.
With an annual 2% uplift</td>
<td>https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance
Section 6.1, Table 10</td>
</tr>
<tr>
<td>11</td>
<td>TAG/Defra values</td>
<td>Air Quality factors</td>
<td>Car euro 6d NOx emissions:
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<tr><th>Fuel type</th><th>Vehicle segment</th><th>Technology</th><th>gNOx/km</th></tr>
<tr><td>Petrol</td><td>Medium</td><td>GDI</td><td>0.0226</td></tr>
<tr><td>Petrol Hybrid</td><td>Medium</td><td>GDI</td><td>0.0149</td></tr>
<tr><td>Petrol PHEV ~ Petrol</td><td>Medium</td><td>GDI</td><td>0.0149</td></tr>
<tr><td>Diesel</td><td>Medium</td><td>DPF+SCR</td><td>0.0511</td></tr>
<tr><td>Diesel PHEV ~ Diesel</td><td>Large-SUV-Executive</td><td>DPF+SCR</td><td>0.1563</td></tr>
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Car euro 6d PM emissions:
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<tr><td>Petrol Hybrid</td><td>Medium</td><td>GDI</td><td>0.0008</td></tr>
<tr><td>Petrol PHEV ~ Petrol</td><td>Medium</td><td>GDI</td><td>0.0008</td></tr>
<tr><td>Diesel</td><td>Medium</td><td>DPF+SCR</td><td>0.0014</td></tr>
<tr><td>Diesel PHEV ~ Diesel</td><td>Large-SUV-Executive</td><td>DPF+SCR</td><td>0.0014</td></tr>
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Van euro 6d NOx emissions:
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Van euro 6d PM emissions:
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<tr><td>Petrol</td><td>N1-II</td><td>GDI</td><td>0.0008</td></tr>
<tr><td>Diesel</td><td>N1-II</td><td>DPF+SCR</td><td>0.001</td></tr>
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</td>
<td>Exhaust: DEFRA NAEI 2020 October

Non-exhaust: TAG databook, A3.5</td>
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12	Greenbook values	CO_2e/CO_2 conversion		UK 2018 GHG Statistics Table 3, Rows 29:46
13	Greenbook values	Carbon values		Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal Table 3
14	Greenbook values	Electricity emissions factors ($kgCO_2e/kWh$)		Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal Table 1: Grid Average: Consumption-based: Domestic
15	Greenbook values	Fuel cost impacts: Long-run Variable costs of energy supply	Note: LRVC are used to represent factor costs rather than market prices in line with Greenbook Guidance.	Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal Table 9-13
16	Sensitivity scenario	Market Shrinkage	10% sales reduction in 2027-2029.	Assumption.
17	Cost	Vehicle maintenance	Costs of upkeep of ZEV versus ICEV cars and vans.	Regression analysis of 2020 Fleet data.
18	Cost	Manufacturer administrative costs	Bottom-up estimate of familiarisation costs per obligated manufacturer.	Annual Survey of Hours and Earnings
19	Cost	Government administrative costs	£7.4m set-up; £1.9m ongoing (£2019) This is based on early estimate of RTFO costs, inflated to 2019£. Also matches estimates in other published CBAs fairly well.	https://www.legislation.gov.uk/uksi/2007/3072/pdfs/uksiem_20073072_en.pdf
20		Energy Systems impacts: Long-run Variable costs of energy supply	LRVCs for consultation, DDM average costs for gov response.	Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal Table 9-13
21	Cost	Car/Van capital costs sensitivity	High and low cost values for cars and vans.	Several – see Annex C.
22	Cost	Infrastructure capital	Up-front costs from OZEV demand modelling and LEVI cost data.	Several: CCC; DESNZ; EESI
23	Cost	Infrastructure reinstallation	Costs of replacing infrastructure after functional lifetime	Several: CCC; DESNZ; EESI

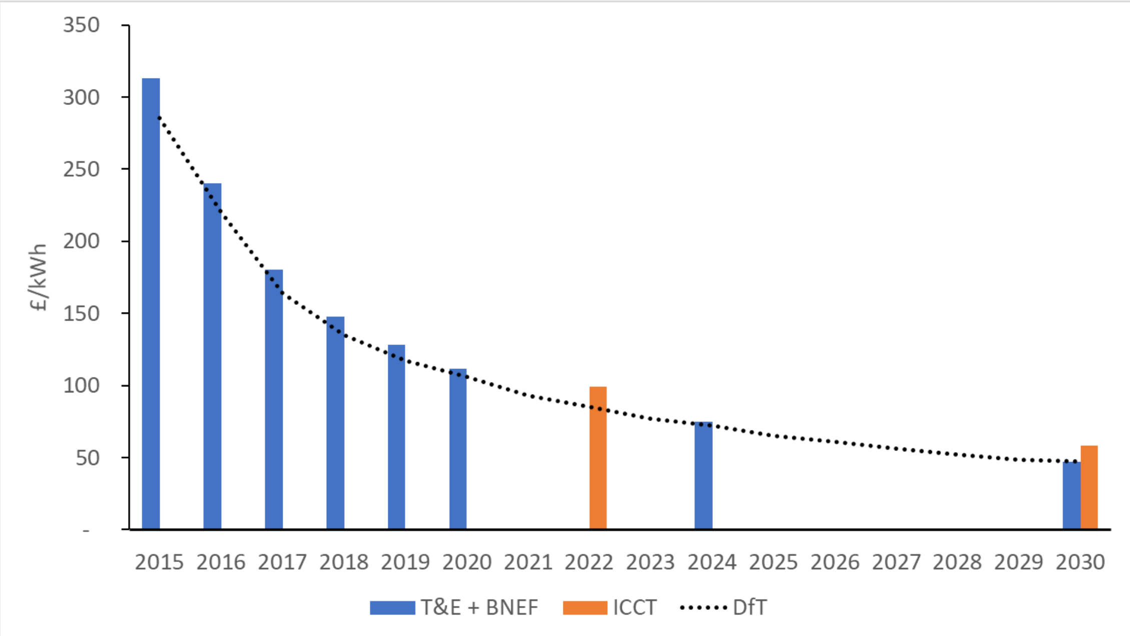
24	Cost	Infrastructure maintenance	Cost of upkeep of chargepoints required by ZEVM	DESNZ
25	Model assumption	Real-world uplifts	Adjustment for performance gap between real-world driving emissions and WLTP values.	ICEV/HEV/BEV ANNEX 2.1 & 2.2: https://climate.ec.europa.eu/system/files/2018-03/ldv_post_2020_co2_en.pdf PHEV: https://theicct.org/wp-content/uploads/2022/06/real-world-phev-use-jun22-1.pdf

Annex C – Cost Assumptions

Battery Prices

445. A significant component of the cost difference between ZEVs and ICEVs is the cost of batteries. However, this is a nascent technology and as such costs are forecast the decline significantly as battery technology improves and sales grow. Figure 94 shows that the assumptions used in this analysis aligns closely with forecasts from Transport and Environment/Bloomberg New Energy Finance and the International Council on Clean Transportation, all of which expect battery costs to decline significantly over this decade.

Figure 94 Forecast battery costs estimates



Cost Sensitivity Scenario Inputs

446. Cost benefit analysis is highly uncertain, particularly for nascent technologies where innovation and supply chain development can significantly affect future costs. To give a fair representation

of the cost benefit analysis of the ZEV mandate, and to stress-test the appraised efficacy of the policy, some key costs and benefits are assigned a low/central/high sensitivity range. The inputs which have been varied for this sensitivity analysis are presented in Table 95.

Table 95 Sensitivities and input values

Sensitivity (impact on NPV)	Fossil fuel prices	Electric fuel prices	Carbon Values	Capital Costs	Admin Cost	MECs	Air Quality Costs	Discount Rate	Induced emissions factors
Source	Green book	Green book	Green book	DfT modelling	DfT modelling	TAG	Defra AQ guidance	Green book	Green book
Downside (Low)	Low	Low	Low	High (slowCon)	Low	High	Low	Standard	Greenbook
Central	Central	Central	Central	Central	Central	High	Central	Standard	Greenbook
Upside (High)	High	High	High	Low (fastCon)	High	High	High	Intergenerational	Greenbook

447. For some input values, evidence-based high and low values are available. For instance, fuel costs, carbon values, air quality damage costs, and discount rates are all standard sensitivities published in HMG Green book appraisal guidance or Defra's Air Quality guidance. For other inputs, it has been necessary to compute bespoke high and low values, for use in this sensitivity analysis.

448. A key source of uncertainty for which evidence-based high and low values are not publicly available are the expected future capital cost values for ZEVs versus ICEVs.

Capital Cost Sensitivity

449. A number of factors are typically considered in electric vehicle capital cost forecasting: platform efficiency (economies of scale of electric vehicle adoption for vehicle bases), varying battery price forecasts, driving range of EVs (and therefore battery size). Additionally, assumptions need to be made on the cost implications of Euro 7 emissions standards and continued efficiency improvements for ICEVs – they may need new exhaust technologies, more efficient engines etc.

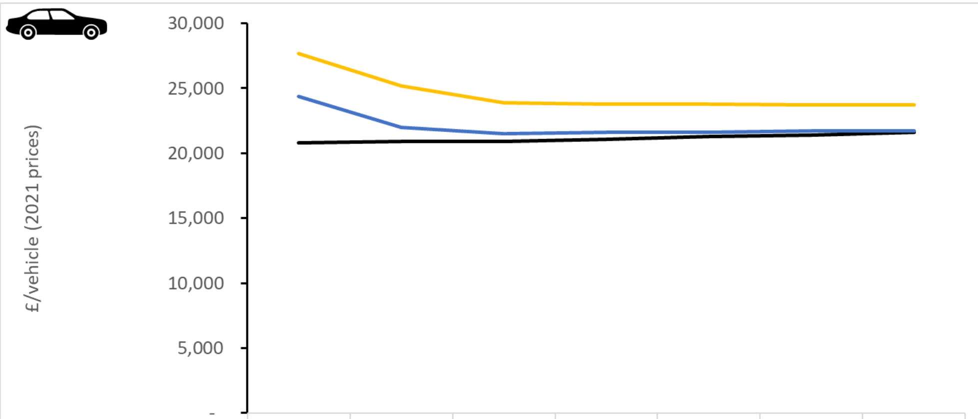
450. For DfT's central assessment, we do not include the potential cost of Euro 7 requirements for three key reasons. (1) this is an undecided policy which the EU has not yet finalised. (2) as the UK has left the EU, the UK will not necessarily align with new EU legislation on future Euro 7 emissions standards (although it has been argued that manufacturers may decide to follow the Euro 7 regulations in the UK market to avoid the need for multiple product lines). (3) Because this is not yet a 'firm and funded' policy, it should not be included in our firm and funded baseline. We also do not assume further efficiency improvements to ICEVs as the preferred regulatory option assumes manufacturers maintain non-ZEV emissions at the same level. Instead, additional Euro 7 costs are included in the upside cost sensitivity, making the cost of EVs more attractive relative to ICEVs.

451. We recognise our assumptions are relatively conservative versus other stakeholders, and therefore we include an additional maximum optimistic cost scenario which assumes cost parity is achieved in 2027 for cars, 2026 for vans – matching the sentiment of T&E/BNEF modelling. This is an equally plausible cost scenario depending on the implementation of Euro 7, vehicle characteristics and cost reductions.

Figure 96 Battery electric vehicle price sensitivity parameters

	Parameter	Upside (High NPV value)	Downside (Low NPV value)
DfT Assumptions	Platform	Dedicated platform efficiency -£1500 for BEVs[54]	-
	Battery Price	-	+30% in 2030 vs BNEF central battery price forecast
	Driving range	-	-
	Vehicle efficiency	-	-
	Euro 7 costs on ICEs	+£1000 for ICEs[55,56,57,58]	-
T&E & Bloomberg assumptions[59]	Platform	Dedicated platform efficiency -1500 euros in 2030 for BEVs vs central[60]	Modified +5,500 euros in 2030 for BEV vs central
	Battery Price	-15% in 2030 vs BNEF central battery price forecast	+75% in 2030 vs BNEF central battery price forecast
	Driving range	-50% vs central scenario	+50% vs central scenario
	Vehicle efficiency	+12% vs central scenario	-12% vs central scenario
	Euro 7 costs on ICEs	+1,500 euros for ICEs	-

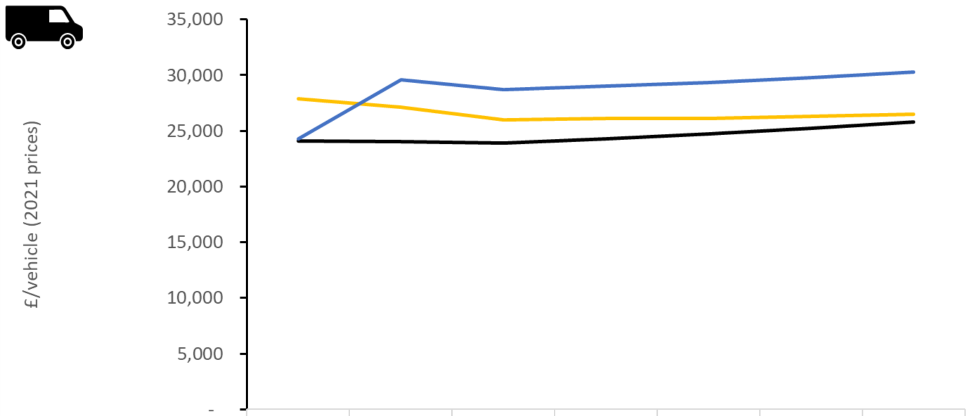
Figure 97 Central capital cost assumptions for cars



	2020	2025	2030	2035	2040	2045	2050
Central BEV	27,700	25,200	23,900	23,800	23,800	23,700	23,700
Central Average ICEV	20,800	20,900	20,900	21,100	21,300	21,400	21,600
Central Average PHEV	24,400	22,000	21,500	21,600	21,600	21,700	21,700

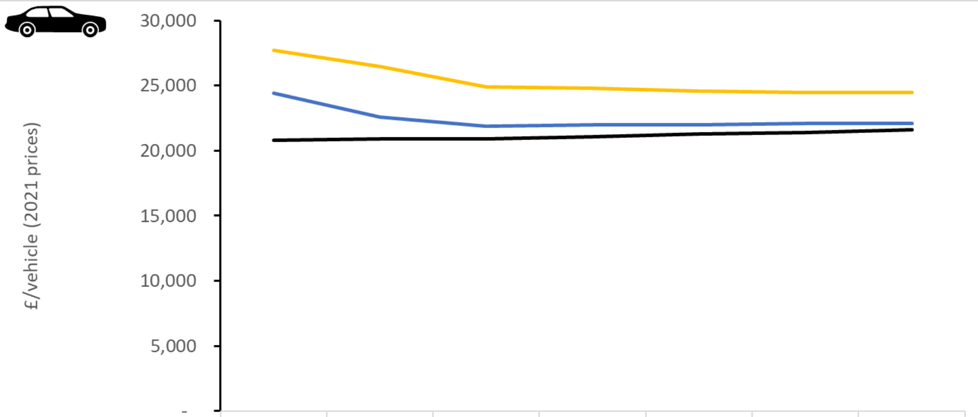
[54] Figure 35.
[55] Sources show this cost can be around 150 for petrol and more like 1500 euros above a euro 6d diesel vehicle.
[56] https://mobilitynotes.com/wp-content/uploads/2021/04/WCX-2021-Emission-Regulations-and-Technologies-AmeyaJoshi-Final.pdf
[57] https://www.automotiveworld.com/news-releases/the-ongoing-battle-for-stricter-vehicle-emission-limits-in-europe/
[58] The ICCT also estimate an incremental cost of ~1600 euros in their lowest cost configuration in 2021. Source: Table 15, https://theicct.org/wp-content/uploads/2021/06/tech-cost-euro-vii-210428.pdf
[59] https://www.transportenvironment.org/wp-content/uploads/2021/08/2021_05_05_Electric_vehicle_price_parity_and_adoption_in_Europe_Final.pdf
[60] Figure 35.

Figure 98 Central capital cost assumptions for vans



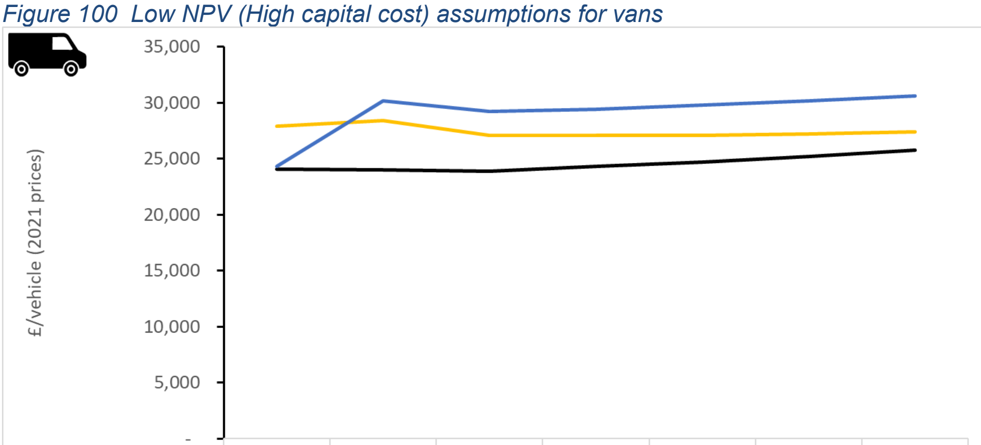
	2020	2025	2030	2035	2040	2045	2050
Central BEV	27,900	27,100	26,000	26,100	26,100	26,300	26,500
Central Average ICEV	24,100	24,000	23,900	24,300	24,700	25,200	25,800
Central Average PHEV	24,300	29,600	28,700	29,000	29,300	29,800	30,300

Figure 99 Low NPV (High capital cost) assumptions for cars



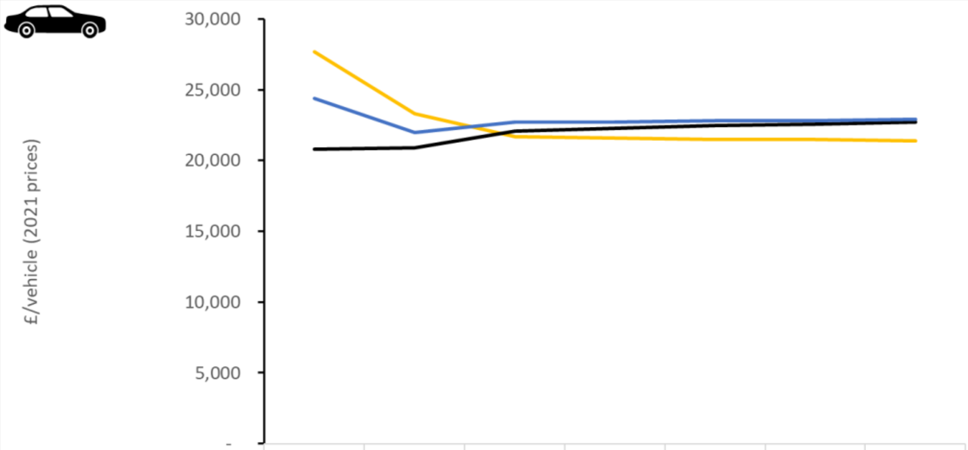
	2020	2025	2030	2035	2040	2045	2050
Low BEV	27,700	26,500	24,900	24,800	24,600	24,500	24,500
Low Average ICEV	20,800	20,900	20,900	21,100	21,300	21,400	21,600
Low Average PHEV	24,400	22,600	21,900	22,000	22,000	22,100	22,100

Figure 100 Low NPV (High capital cost) assumptions for vans



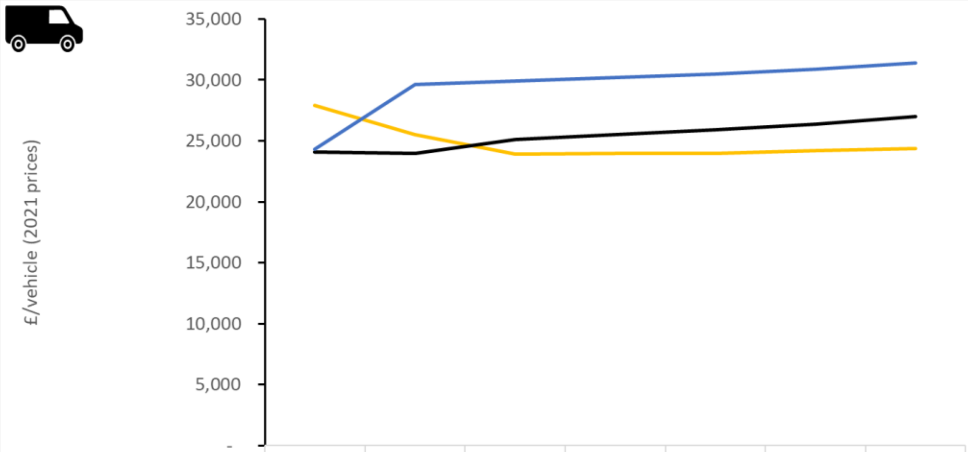
	2020	2025	2030	2035	2040	2045	2050
Low BEV	27,900	28,400	27,100	27,100	27,100	27,200	27,400
Low Average ICEV	24,100	24,000	23,900	24,300	24,700	25,200	25,800
Low Average PHEV	24,300	30,200	29,200	29,400	29,800	30,200	30,600

Figure 101 Very High NPV (Very low capital cost) assumptions for cars



	2020	2025	2030	2035	2040	2045	2050
Very High BEV	27,700	23,300	21,700	21,600	21,500	21,500	21,400
Very High Average ICEV	20,800	20,900	22,100	22,300	22,500	22,600	22,700
Very High Average PHEV	24,400	22,000	22,700	22,700	22,800	22,800	22,900

Figure 102 Very High NPV (Very low capital cost) assumptions for vans



	2020	2025	2030	2035	2040	2045	2050
Very High BEV	27,900	25,500	23,900	24,000	24,000	24,200	24,400
Very High Average ICEV	24,100	24,000	25,100	25,500	25,900	26,400	27,000
Very High Average PHEV	24,300	29,600	29,900	30,200	30,500	30,900	31,400

Marginal External Costs

452. As set out in Section 2, this analysis applies the ‘high’ marginal external costs, published in the Transport Analytical Guidance data tables. The cost estimates are based on a ‘core analytical scenario’ taken from DfT’s Road Traffic Forecast modelling which represents high levels of ZEV uptake, assuming that all new car and van sales are zero emission by 2040. These figures were published in 2018 and therefore reflect a lower level of ZEV ambition than the Government’s current stated ambition. These estimates will be updated as more recent forecasts become available.

453. These proposals cover the first phase of the trajectory, legislating up to 80% of sales made-up by ZEVs in 2030 onwards. This stops short of the 100% from 2040 which underpins the cost estimates presented below, nonetheless this scenario is considered to be considerably closer aligned with the ZEV mandate proposals than the Road Traffic Forecast scenarios, which assume significantly lower ZEV uptake.

Figure 103 Transport Analytical Guidance 'High' Congestion Marginal External Costs

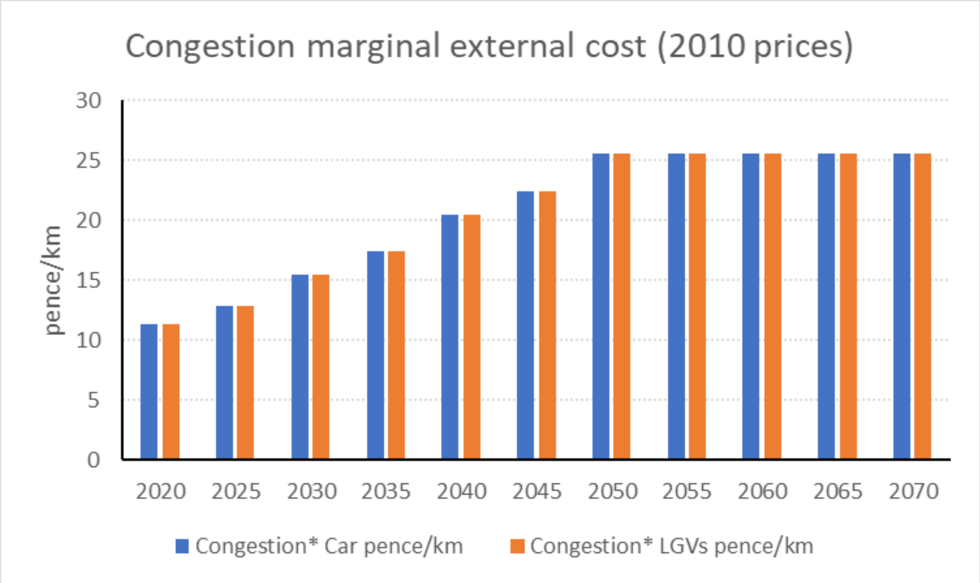
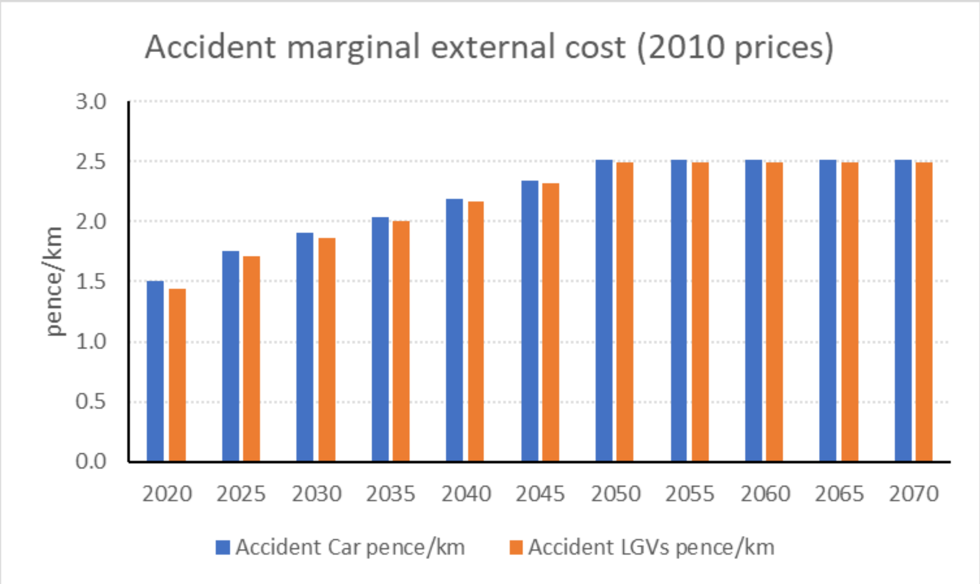


Figure 104 Transport Analytical Guidance 'High' Accident Marginal External Costs



Annex D – Detailed Model Output Tables

NPV CBA Summary Of Policy Options

Table 105 Detailed cost benefit analysis of central policy options (present value; 2021 prices; £m)

Vehicle type	Impact	Policy Option 1	Policy Option 2	Policy Option 3	Policy Option 4
Car	Congestion	-39,879	-8,181	-65,955	-37,058
Car	Capital	-26,382	-6,955	-47,546	-29,611
Car	Infr. Capex	-8,985	-2,396	-13,892	-9,054
Car	Infr. Opex	-1,848	-432	-2,831	-1,864
Car	Accident	-3,749	-758	-6,260	-3,497
Car	Traded Carbon	-1,614	-707	-2,914	-1,931
Car	Admin	-30	-30	-30	-30
Car	Indirect Tax	2,436	697	2,634	2,255
Car	Consumer Surplus	906	44	2,407	809
Car	NOx	455	-141	1,159	919
Car	PM	-256	-117	-311	-99
Car	Operating	9,301	4,431	12,591	7,095
Car	Fuel	18,898	267	33,778	16,557
Car	CO_2e	83,319	25,065	136,729	88,447
Car	PVB (Discounted)	115,315	30,504	189,298	116,082
Car	PVC (Discounted) (excl. rebound)	-42,429	-11,488	-72,536	-45,623
Car	PVC (Discounted)	-82,744	-19,716	-139,739	-83,144
Car	NPV (Discounted) (excl. rebound)	72,857	18,986	116,732	70,430
Car	NPV (Discounted)	32,571	10,787	49,559	32,938
Car	Abatement Cost (excl. rebound)	22	42	25	35
Car	Abatement Cost	105	98	111	108
Van	Congestion	-12,347	15,101	-39,437	-16,161
Van	Capital	-1,055	678	-3,036	-1,312
Van	Infr. Capex	-2,155	-435	-3,900	-2,086
Van	Infr. Opex	-477	-82	-880	-462
Van	Accident	-1,218	1,395	-3,762	-1,608
Van	Traded Carbon	-861	-229	-1,434	-861
Van	Admin	-5	-5	-5	-5
Van	Indirect Tax	1,663	-2,344	2,597	2,165
Van	Consumer Surplus	163	217	1,424	287
Van	NOx	843	234	1,546	830
Van	PM	-72	222	-349	-125
Van	Operating	6,116	1,285	10,726	6,116
Van	Fuel	1,101	-5,570	7,519	2,549
Van	CO_2e	19,867	-4,109	46,587	21,683
Van	PVB (Discounted)	29,752	19,133	70,400	33,630
Van	PVC (Discounted) (excl. rebound)	-6,447	-27,138	-13,621	-7,299
Van	PVC (Discounted)	-18,191	-12,774	-52,803	-22,619
Van	NPV (Discounted) (excl. rebound)	23,301	-8,010	56,774	26,327
Van	NPV (Discounted)	11,561	6,359	17,597	11,011
Van	Abatement Cost (excl. rebound)	-32	-141	-39	-40
Van	Abatement Cost	77	379	111	91
Both	Congestion	-52,227	6,920	-105,392	-53,219
Both	Capital	-27,438	-6,277	-50,582	-30,922
Both	Infr. Capex	-11,140	-2,831	-17,792	-11,140

Vehicle type	Impact	Policy Option 1	Policy Option 2	Policy Option 3	Policy Option 4
Both	Infr. Opex	-2,325	-514	-3,711	-2,325
Both	Accident	-4,967	637	-10,022	-5,105
Both	Traded Carbon	-2,476	-936	-4,348	-2,793
Both	Admin	-34	-34	-34	-34
Both	Indirect Tax	4,100	-1,648	5,231	4,420
Both	Consumer Surplus	1,069	261	3,832	1,096
Both	NOx	1,297	94	2,704	1,749
Both	PM	-328	105	-661	-224
Both	Operating	15,417	5,716	23,317	13,211
Both	Fuel	19,999	-5,303	41,297	19,106
Both	CO_2e	103,185	20,956	183,316	110,130
Both	PVB (Discounted)	145,068	34,689	259,698	149,712
Both	PVC (Discounted) (excl. rebound)	-48,875	-23,713	-86,157	-52,921
Both	PVC (Discounted)	-100,935	-17,543	-192,542	-105,762
Both	NPV (Discounted) (excl. rebound)	96,158	10,976	173,506	96,757
Both	NPV (Discounted)	44,133	17,146	67,156	43,950
Both	Abatement Cost (excl. rebound)	12	84	9	21
Both	Abatement Cost	100	32	111	105

NPV CBA Summary Of Cost Sensitivities

Table 106 Detailed cost benefit analysis of Policy Option 1 sensitivities (present value; 2021 prices; £m)

Vehicle type	Impact	Low	Central	High	Very high
Car	Congestion	-39,879	-39,879	-39,879	-39,879
Car	Capital	-32,976	-26,382	9,433	15,588
Car	Infr. Capex	-11,231	-8,985	-6,739	-6,739
Car	Infr. Opex	-2,311	-1,848	-1,386	-1,386
Car	Accident	-3,749	-3,749	-3,749	-3,749
Car	Traded Carbon	-807	-1,614	-2,666	-2,666
Car	Admin	-22	-30	-37	-37
Car	Indirect Tax	2,332	2,436	2,551	2,551
Car	Consumer Surplus	906	906	906	906
Car	NOx	41	455	1,981	1,981
Car	PM	-55	-256	-872	-872
Car	Operating	9,301	9,301	9,301	9,301
Car	Fuel	9,066	18,898	33,137	33,137
Car	CO_2e	41,659	83,319	139,817	139,817
Car	PVB (Discounted)	63,305	115,315	197,126	203,281
Car	PVC (Discounted) (excl. rebound)	-50,618	-42,429	-15,120	-15,120
Car	PVC (Discounted)	-91,031	-82,744	-55,328	-55,328
Car	NPV (Discounted) (excl. rebound)	12,665	72,857	181,968	188,123
Car	NPV (Discounted)	-27,726	32,571	141,797	147,952
Car	Abatement Cost (excl. rebound)	60	22	-87	-100
Car	Abatement Cost	144	105	-4	-17
Van	Congestion	-12,347	-12,347	-12,347	-12,347
Van	Capital	-3,042	-1,055	4,247	4,907
Van	Infr. Capex	-2,694	-2,155	-1,616	-1,616
Van	Infr. Opex	-596	-477	-358	-358
Van	Accident	-1,218	-1,218	-1,218	-1,218
Van	Traded Carbon	-431	-861	-1,381	-1,381
Van	Admin	-3	-5	-6	-6

Vehicle type	Impact	Low	Central	High	Very high
Van	Indirect Tax	1,592	1,663	1,746	1,746
Van	Consumer Surplus	163	163	163	163
Van	NOx	76	843	3,513	3,513
Van	PM	-16	-72	-239	-239
Van	Operating	6,116	6,116	6,116	6,116
Van	Fuel	-757	1,101	4,386	4,386
Van	CO_2e	9,933	19,867	32,736	32,736
Van	PVB (Discounted)	17,879	29,752	52,907	53,567
Van	PVC (Discounted) (excl. rebound)	-9,290	-6,447	-5,503	-5,503
Van	PVC (Discounted)	-21,104	-18,191	-17,165	-17,165
Van	NPV (Discounted) (excl. rebound)	8,586	23,301	47,399	48,059
Van	NPV (Discounted)	-3,225	11,561	35,743	36,402
Van	Abatement Cost (excl. rebound)	13	-32	-136	-143
Van	Abatement Cost	122	77	-28	-34
Both	Congestion	-52,227	-52,227	-52,227	-52,227
Both	Capital	-36,018	-27,438	13,680	20,495
Both	Infr. Capex	-13,925	-11,140	-8,355	-8,355
Both	Infr. Opex	-2,907	-2,325	-1,744	-1,744
Both	Accident	-4,967	-4,967	-4,967	-4,967
Both	Traded Carbon	-1,238	-2,476	-4,047	-4,047
Both	Admin	-26	-34	-43	-43
Both	Indirect Tax	3,923	4,100	4,298	4,298
Both	Consumer Surplus	1,069	1,069	1,069	1,069
Both	NOx	117	1,297	5,494	5,494
Both	PM	-71	-328	-1,110	-1,110
Both	Operating	15,417	15,417	15,417	15,417
Both	Fuel	8,309	19,999	37,523	37,523
Both	CO_2e	51,593	103,185	172,553	172,553
Both	PVB (Discounted)	81,185	145,068	250,033	256,848
Both	PVC (Discounted) (excl. rebound)	-59,908	-48,875	-20,623	-20,623
Both	PVC (Discounted)	-112,135	-100,935	-72,493	-72,493
Both	NPV (Discounted) (excl. rebound)	21,251	96,158	229,367	236,182
Both	NPV (Discounted)	-30,950	44,133	177,540	184,355
Both	Abatement Cost (excl. rebound)	51	12	-96	-108
Both	Abatement Cost	140	100	-8	-20

Annex E – Cost Of Living Depreciation Sensitivities

454. The relative cost of ownership between ZEVs and non-ZEVs presented in 'Section 4.0 Wider impacts' is sensitive to the assumed rate of depreciation. In particular, differences in the *relative* rate of depreciation imply losses/gains to the owner, which has an effect on the overall cost of ownership given the significant up-front cost of vehicles. As set out in 'Section 4: Cost of Living', the central assumption is that ZEVs depreciate at the same rate as the ICEV they replace, because technological advances in battery technology and assumptions around vehicle mileage mean that lower depreciation rates may be expected in the future (for more detail see paragraph 389 to 392).

455. However, this section presents the cost of ownership using BEV-specific depreciation rates provided by AutoTrader based on BEVs first-sold between 2017 and 2022.Table 107 shows the cumulative cashflow of owning a BEV compared to a petrol/diesel ICEV and the weighted average of all ICEVs, for two scenarios: 'BEV-specific depreciation' corresponds to the scenario in which depreciation data for *every powertrain* is taken from AutoTrader; 'Corresponding ICEV depreciation' relates to the central scenario presented in 'Section 4.0 Wider impacts', in which BEVs are assumed to depreciate at the same rate as the corresponding ICEV they replace. As shown, for vehicles bought in each period, the former scenario leads to a worse cumulative cashflow. This is because the AutoTrader data suggests BEVs bought in the past depreciate at a greater rate, on average, than their ICEV counterparts.

456. If BEVs are assumed to depreciate at a different rate than ICEVs, it appears that households purchasing a first-hand BEV instead of a petrol car may not achieve a positive net cumulative cashflow within 5 years of ownership, for vehicles bought in 2025, 2030, or 2035. That said, a BEV purchased instead of a petrol car in 2035 would be expected to break-even and achieve positive cashflows in just over 6 years.

457. However, those purchasing a BEV instead of a diesel car are expected to be significantly better off within 5 years, for purchases in any year from 2025. Furthermore, the magnitude of the savings increases substantially and exceeds £5,000 over 5 years for vehicles bought in 2030 and 2035.

458. The key driver of the difference between petrol and diesel cars relates to the number of miles expected to be driven by petrol/diesel car owners: petrol cars are expected to cover roughly 12,000 km per year over their first five years, whereas diesel cars are expected to cover more than 20,000. In addition, and relatedly, diesel cars are expected to depreciate at a greater rate than petrol cars, narrowing the gap between the cars' resale values. If petrol cars were to be driven around 18,000 miles per year over the first five years, a household purchasing a BEV instead of a petrol ICEV would be expected to be better off if they bought the vehicle in 2030 or 2035 (by roughly £1,000 and more than £1,700, respectively), though they would still likely be worse off if they bought the car in 2025 (by roughly £2,400).

459. However, second-hand BEV owners are expected to be significantly better off in all cases than if they had instead bought an ICEV. This is because depreciation acts as a transfer between first- and second- hand owners, so the greater depreciation rate applied to BEV purchases leads to a much lower up-front price for the second-hand purchaser. The magnitude of the positive cashflow for second-hand owners has two key implications: firstly, it is clear that the large majority of second-hand purchasers will be significantly better-off than if they had bought a comparable ICEV instead; secondly, even if the depreciation rate for BEVs were to fall substantially (as it is likely to) BEVs are still likely to represent significant cost-effectiveness benefits on the second-hand market.

Table 107 Cumulative cashflow after 5 years of ownership for cars, for 1st and 2nd owners

		2025	2030	2035	Depreciation assumption
1st owner	BEV:Petrol	- 4,396	- 1,202	- 682	BEV-specific depreciation
		- 141	2,531	3,039	Corresponding ICEV depreciation
	BEV:Diesel	2,350	5,931	6,702	BEV-specific depreciation
		4,313	7,654	8,420	Corresponding ICEV depreciation
	Weighted average	- 2,941	336	910	BEV-specific depreciation
		820	3,635	4,199	Corresponding ICEV depreciation
2nd owner	BEV:Petrol	3,840	4,659	4,730	BEV-specific depreciation
		4,211	4,985	5,055	Corresponding ICEV depreciation
	BEV:Diesel	7,289	8,287	8,374	BEV-specific depreciation
		7,622	8,580	8,666	Corresponding ICEV depreciation
	Weighted average	4,583	5,441	5,516	BEV-specific depreciation
		4,946	5,760	5,833	Corresponding ICEV depreciation

460. The picture is similar for vans, in that applying the greater BEV-specific depreciation rates leads to a worse cumulative cash flow for the first-hand owner. That said, only for petrol first-hand van owners is the cumulative cashflow negative after 5 years; for all diesel owners and all petrol owners except this group, BEVs are expected to save money compared to a corresponding diesel/petrol ICEV. The magnitude of savings is expected to be slightly lower than when BEVs are assumed to depreciate at the same rate as the vehicle they replace, though in the large majority of cases and periods the savings run into thousands of Pounds over 5 years.

Table 108 Cumulative cashflow after 5 years of ownership for vans, for 1st and 2nd owners

		2025	2030	2035	Graph label
1st owner	BEV:Petrol	- 8,915	- 4,548	- 3,684	BEV-specific depreciation
		- 4,121	- 387	483	Corresponding ICEV depreciation
	BEV:Diesel	547	5,059	6,118	BEV-specific depreciation
		2,760	6,979	8,041	Corresponding ICEV depreciation
	Weighted average	389	4,898	5,953	BEV-specific depreciation
		2,644	6,856	7,914	Corresponding ICEV depreciation
2nd owner	BEV:Petrol	3,407	4,569	4,640	BEV-specific depreciation
		3,826	4,932	5,004	Corresponding ICEV depreciation
	BEV:Diesel	6,482	7,730	7,812	BEV-specific depreciation
		6,857	8,056	8,138	Corresponding ICEV depreciation
	Weighted average	6,430	7,677	7,759	BEV-specific depreciation
		6,807	8,003	8,086	Corresponding ICEV depreciation

461. The reason for the greater cost-effectiveness of BEV vans, compared to BEV cars, is average mileage: vans achieve roughly 35% more miles per year over the 1st 5 years of ownership than the average diesel car, and more than twice as many than the average petrol car.

Annex F – Non-Traded Cost-Effectiveness Comparator (NTCC)

462. In order to ascertain whether these proposals represent good value-for-money, it is important to understand how their costs of decarbonisation compare against the marginal cost of decarbonisation across the economy. This can be done using the non-traded cost-effectiveness comparator, which is the weighted average value of carbon abatement, based on the proportion of carbon savings achieved and the discounted carbon price in each year of the appraisal period.

463. This gives an indication of the maximum amount that society should be willing to pay to achieve a one-tonne reduction in carbon emissions. If the policy's cost of non-traded carbon abatement falls below this value, then the carbon abatement is deemed to improve social welfare and achieve good value-for-money. The NTCC values for the low, central, and high carbon prices and vehicle type are presented in Table 109.

Table 109 Non-traded cost-effectiveness comparator (NTCC) to other climate policies, under different carbon prices

Vehicle type	Scenario	Low	Central	High
Car	Central	86	172	259
Van	Central	92	185	277
Both	Central	87	175	262

Table 110 Carbon abatement costs for the central scenario

Vehicle type	Including rebound effect	Excluding rebound effect	Mid-point
Car	105	22	64
Van	77	-32	23
Both	100	12	56

464. Comparing Table 109 and Table 110, it is clear that these proposals are likely to be cost-effective in reducing emissions. Only when the low carbon price series are used and the full rebound effect is included do abatement costs exceed the NTCC benchmark, and even in this case abatement for vans is expected to be cost-effective.

465. When the rebound effect is excluded, both cars and vans abatement is expected to be positive. Furthermore, the same is true when taking the mid-point, which is used as a proxy for a rebound effect of a smaller magnitude (which, as discussed from paragraphs 253 to 264, is expected to be more likely).

466. Additional scenarios are tested against the NTCC benchmarks in 'Section 2.0: Quantified Impacts' and 'Sensitivity Analysis'. More detail on the NTCC and the underlying methodology can be found on gov.uk.

Annex G – Real-World Emissions Evidence

467. There is significant evidence of a performance gap between manufacturers' test cycles (WLTP) and vehicles' real-world performance. It is important to reflect the gap between test cycle and real-world emissions, in order to accurately model the fleet's emissions and the likely effect of policy proposals. This section summarises some of the recent evidence on this performance gap and details the approach taken in this analysis.

PHEVs

468. For PHEVs, real-world emissions assumptions are taken from the ICCT's 2022 report, which suggests an approximate 263% real-world performance gap to type approval for UK cars. The ICCT use the greatest breadth and depth of evidence in this area given the range of international evidence accrued across multiple EU countries including the UK, which is backed up by their 2020 research across even more large countries with significant PHEV penetration such as the US, Canada and China. They also utilise a range of primary data gathering methods which could influence the reliability of observations, illustrating consistent results.

469. The PHEV real-world uplift applied in the analysis of these proposals is adjusted for the share of private versus company car mileage in the UK (to reflect the difference in charging and driving behaviour between these ownership models).[61,62] This results in a weighted average 243% real-world gap which is broadly reflective of the composition of the UK car fleet. These figures are set out in Table 112, below.

ICEVs and HEVs

470. ICEV and HEV real-world emissions are estimated using assumptions taken from Ricardo & JRC (2018).[63] These are the only readily available published values disaggregated by vehicle segment and fuel types, allowing granular understanding given the fleet composition changes over time. They are, however, somewhat less recent than the PHEV performance data being sources from 2014 real-world emissions gaps.

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[61] Mileage of ownership models by age is taken from: MOToring_along_Dr_Sally_Cairns_et_al_November2017.pdf (racfoundation.org)

[62] Internal DVLA statistics are used to understand licenced company cars by age to reflect by which ages they switch to private hands.

[63] Appendix 2.1 and 2.2: CLIMA.C.4 (2016) 2709294 (Service Request 15 under framework contract Ref: CLIMA.C.2/FRA/2012/0006)

471. The ICCT also publish the observed real-world emission gaps of ICEVs, which are less granular but much more recent than Ricardo & JRC. As validation, Ricardo & JRCs estimates, once aggregated, are comparable to more recent ICCT evidence. The ICCT find average emissions gaps have been relatively stable from 2014 – 2018 (changing from 38% in 2014 to 39% in 2018.[64,65] Overall, this suggests ICEV real-world performance data from Ricardo & JRC remains relatively robust.

472. Table 111 shows the distribution of PHEV ownership by private and company car. As shown, company cars are attributed a smaller weight than their share of ownership, based on new registrations in 2020. This is because they are typically resold on the second-hand market after several years of use, after which point they are expected to be driven more similarly to other privately-owned vehicles. Table 112 shows real-world uplifts for private and company cars, taken from the ICCT data, and the UK weighted average real-world uplift for PHEVs overall. It is important to note that the ICCT UK data covers only privately-owned vehicles; therefore, company car real-world uplifts are inferred based on the ratio of UK:EU private PHEV real-world uplifts. As UK privately-owned PHEVs appear to have a slightly greater performance gap, the real-world uplift for both UK privately- and company- owned PHEVs are also slightly higher.

Table 111 PHEV distribution by keepership type, and mileage weight applied to each

Ownership type	Ownership share	Vkms when privately owned	Vkms when company owned	Weighted vkms for ownership type
Private cars	43%	100%	0%	61% = *(43% + 57% * (100% - 69%))*
Company cars	57%	69%	31%	39% = *(57% * 69%)*

Table 112 PHEV Central real-world emissions gaps and uplift factors with uncertainty bounds

Real-world gap**	Source	Low	Central	High
Private Car	ICCT 2022 (EU-wide)	140%	150%	160%
Company Car	ICCT 2022 (EU-wide)	320%	340%	360%
Private Car	ICCT 2022 (UK)	153%*	163%[66]	173%*
Company Car (estimated)	ICCT 2022 (UK)	349%*	369%	389%*
UK weighted-average	DfT Estimate	229%*	243% *= (61% * 163% + 39% * 369%)*	257%*
Real-world uplift factor				
UK weighted-average	DfT Estimate	329%*	343%	357%*

** The same low/high uncertainty range from the EU wide data is applied to the central UK data. These uncertainty bounds reflect statistical uncertainty in the observation of a sample of data versus a total population of PHEVs by the ICCT. These therefore do not reflect the wider uncertainty of real-world emissions of PHEVs. E.g. in the future drivers could fully charge their PHEVs up more than observe today resulting in lower real-world emissions gaps to the emissions test cycle and this is not reflected within this range.*

*** Real world uplift factors in this assessment refer to the factor to multiply test cycle emissions by to give an estimate of real-world emissions. Some evidence refers to a real-world gap as a difference to the test cycle. For example, a 20% gap in this context would result in an uplift factor of 20% + 100%.*

64 From laboratory to road: A 2018 update of official and "real-world" fuel consumption and CO2 values for passenger cars in Europe (theicct.org)

65 https://theicct.org/wp-content/uploads/2021/06/On-the-way-to-real-world-WLTP_May2020.pdf

66 This UK number is estimated directly from the ICCT evidence. No UK company car PHEV data was observed so this is estimated from the EU wide difference from company:private car real-world emissions gaps.

Annex H – Payments

Stakeholder Views

473. The recent technical consultation on design parameters of the ZEV mandate (closed 10 June) did not provide any details on the expected payment price, noting only that payments “could most easily apply on a ‘per credit’ basis, i.e., a certain £ payment per certificate.” No specific questions were asked on the topic, and therefore stakeholders did not provide input during the consultation process.

Treatment Under Existing UK Regulations

474. The CO_2 emissions of new cars and vans are currently regulated according to the fleetwide average for each manufacturer, an approach retained following our exit from the EU. If manufacturers miss their fleetwide target, they must make a payment of £86 per gram of exceedance multiplied by the number of vehicles registered.[67] The average non-zero emission car (including internal combustion engine vehicles [ICEVs], hybrids, and plug-in hybrid vehicles [PHEVs]) sold in the UK in 2021 emitted ~140 gCO_2/km (WLTP). This suggests that, for the average vehicle, selling a non-ZEV car instead of a ZEV would lead to a payment of £86*140 = £12,079. For the average non-ZEV van (201 gCO_2/km) the payment would be £17,262.

International Comparisons

475. The ZEV mandate in the UK shares similarities to policies in place in California and 16 other states, the Canadian provinces of Québec and British Columbia, and China, which have each been effective in increasing ZEV sales and the introduction of new models. The penalty mechanisms in these programs are summarised below. Note that in the existing regulations in California and Canada, one ZEV can earn up to 4 credits. In the updated regulations taking effect in 2026, one ZEV will earn one credit (as in the proposed UK ZEV mandate).

Table 113 Summary of penalties under existing ZEV regulations worldwide[68]

Jurisdiction	Penalty
California (current)	USD $5,000 (£4,248) per credit deficit (up to 4 credits per vehicle), with deficit carrying over. Source: ICCT.
California (2026-2035)	USD $20,000 (£16,992) per ZEV value deficit. Source: ARB.
China (dual credit system)	No financial penalty specified; government will not provide type-approval to models not meeting CO_2 targets if there is a sustained credit deficit.[69]
Québec (existing regulation)	CAD $5,000 (£3,262) per credit deficit (up to 4 credits per vehicle), with deficit carrying over. Source: Québec Ministry of the Environment.
British Columbia (existing regulation)	CAD $5,000 (£3,262) per credit deficit (up to 4 credits per vehicle), with deficit carrying over or CAD $5,500 (£3,588) to purchase credit from government. Source: University of Ottawa.[70]

476. In the American and Canadian examples, penalties are $20,000 per ZEV, equivalent to £16,992 for the California policy and £13,048 for the Canadian policies. In contrast to the proposed ZEV mandate in the UK, these are penalties rather than payment prices; any deficit will be rolled over to the following year’s target in addition to the fine. Only British Columbia offers an option for a buy-out for an additional CAD$500 (£320), although this regulation is being updated.

[67] https://www.vehicle-certification-agency.gov.uk/download-publication/3899/New-Car-and-Van-CO2-Regulations-Guidance-2022/
[68] Currency equivalents using exchange rates from 23 August 2022.
[69] Tom Kang, “China’s ‘dual Credit’ Policy, What You Need to Know,” *CnEVPost* (blog), July 25, 2021, https://cnevpost.com/2021/07/25/chinas-dual-credit-policy-what-you-need-to-know/; Zhinan Chen and Hui He, “How Will the Dual-Credit Policy Help China Boost New Energy Vehicle Growth?,” *ICCT Staff Blog* (blog), February 10, 2022, https://theicct.org/china-dual-credit-policy-feb22/.
[70] In 2022, British Columbia committed to updating their ZEV Act to align with the national targets of 100% new light-duty ZEV sales by 2035. The legal Act has not yet been modified to reflect this commitment. It is not known whether the penalties will also change in this new iteration.

Considerations For Setting Payment Price

Test 1: Cost Premium Of Producing A ZEV

477. To incentivise compliance with the mandate, the minimum bound on payments should ensure it is more expensive for a manufacturer to sell a petrol or diesel vehicle (ICEV) rather than a BEV if they are below their ZEV target in that year.

Test 2: Carbon prices

478. As the ZEV mandate is a carbon-saving measure, payment prices should be roughly tethered to the loss in carbon savings of not delivering a ZEV (directly reflecting the social value of the externalities). Using cross government carbon valuation guidance to estimate the cost to abate carbon across the economy, DfT's analysis results in a range of £4,450 – £13,400 with the upper bound rising to £14,400 by 2029 for cars. For vans, because each van emits more CO_2e per mile and drive more miles, this value is higher at £6,850 – £20,500, rising to £22,200 by 2029.

479. The Non-Governmental Organisation (NGO) Transport & Environment (T&E) conducted a similar analysis for cars which was shared with DfT, but with some simplifications, assuming vehicle lifetime mileage of 112,500 miles, average real-world emissions levels from 2019, and high carbon prices from the HM Treasury Green Book. Their resulting price suggestions begin at £13,600 in 2024 and rise to £14,700 by 2029. T&E also recommended the same logic for vans.

Test 3: Consideration of international markets

480. The UK's ZEV mandate is being developed at the same time as the EU's new car and van CO_2 emissions standards are being extended to 2035, with both policies setting a target of all new light-duty vehicles being zero emission by 2035.

481. The UK and the European Free Trade Area (including the EU) functionally operate as a single vehicle market, with vehicles manufactured in one region exported to the other. As of 2020, SMMT data suggests that 54% of the UK automotive production is exported to the EU, and 78% of the UK's new vehicles are imported.

482. Manufacturers allocate supply of their vehicles to different countries according to several market features. One of these features is the relative cost of supplying (or foregoing the supply of) ZEVs in different markets. This suggests that, in order to safeguard supply of ZEVs and compliance with the ZEV mandate, the costs of non-compliance must be at least as high as those in other, connected markets with similar regulations, such as the European Free Trade Area.

483. Current UK vehicle CO_2 regulations also implicitly place the same value on each ZEV sold, as this is enshrined in retained EU legislation. The equivalent value in retained EU legislation is £12,079 and £17,262 for the average non-ZEV car and van respectively. However, if this is taken into account in setting the rate it may be beneficial to provide a greater buffer to ensure a clear gap to account for many sources of uncertainty (such as exchange rate fluctuations).

Further consideration: Ceiling on ZEV credit trading price

484. A manufacturer that cannot meet its target in a given year has several options: they may make the non-compliance payment, purchase credits from another manufacturer who has an excess, or, in the first years of the regulation, borrow and earn additional credits in a future year (possibly with interest).The opportunity to sell extra credits through trading may encourage manufacturers to exceed their targets in early years, providing greater supply for consumers. This will be especially attractive for manufacturers receiving small or micro volume derogations or

exemptions, who would otherwise face no additional incentive through the mandate to introduce new ZEVs.

485. Although the trading price of credits is difficult to predict, it is very unlikely to exceed the stated non-compliance payment price because a manufacturer would most likely choose the lowest-cost option of making a buy-out payment if the cost to purchase credits on the market were greater. Therefore, setting a higher non-compliance payment price has the potential to increase revenue for manufacturers who proactively invest in ZEVs and make it more attractive to bring additional ZEVs to the UK market beyond the minimum required targets. However, it would also lead to greater costs for manufacturers who fail to produce sufficient numbers of ZEVs of their own, which could translate into greater costs and/or reduced choice for consumers.

Annex I – Banking and Borrowing

486. There is significant appetite from manufacturers for flexibility in the timing of the targets. One way in which we can provide flexibility (and for which there is international precedent) is by allowing manufacturers to 'bank' and 'borrow' ZEVM allowances in order to smooth their performance against annual targets. This will likely improve the achievability of the policy and mitigate anti-competitive impacts (for instance, due to differential impacts for manufacturers based on historic investment decisions), however there are also potential risks.

487. If manufacturers under-deliver and compensate by borrowing from future years' over-delivery, for any given *finite* time horizon (for instance Carbon Budget 6, or 2050), carbon savings will be lost because the number of vehicle kilometres abated will be lower at any given point in time. This means that borrowing, without any form of adjustment, could lead to under-delivery against our Carbon Budget targets, based on the current trajectory.

488. In order to meet the policy’s objectives, it is important to balance the competing priorities of maintaining a healthy, competitive market for cars and vans and progress against the Government's legally binding emissions reductions targets. In addition, any perverse incentives potentially introduced by the mandate and/or flexibility measures need to be mitigated.

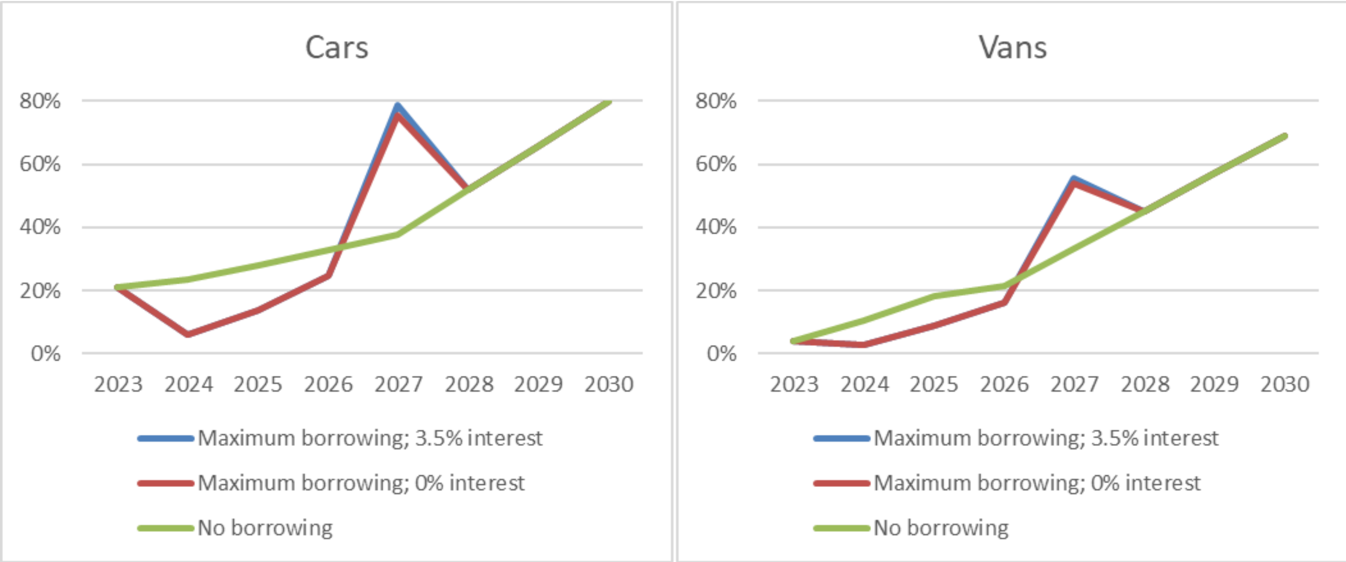
489. As set out in Section 1, there are several facets of policy design which aim to mitigate the risks introduced by banking and borrowing. Firstly, caps on the amount of permitted borrowing and a repayment deadline limit the potential scale of under-delivery.

490. Secondly, interest charged on borrowed ZEVM allowances is intended to internalise the social cost of late delivery in manufacturers’ decision-making process. This is intended to strengthen incentives for the socially-preferred outcome, while allowing manufacturers flexibility where it is not possible to meet the annual targets at proportionate cost.

491. The proposed interest rate is the HMT Green Book’s Social Time Preference Rate. This rate quantifies the amount by which society is expected to prefer a benefit now as opposed to in one year’s time, or the additional cost society would be willing to pay to bear a cost in one year’s time, as opposed to now.

492. Figure 114 shows the ZEVs’ shares of annual sales in the car and van markets for two borrowing scenarios, one in which no interest is charged and one where which applies a rate of 3.5% per year. In each of the ‘maximum borrowing’ scenarios, it is assumed that all manufacturers maximise the volume and duration of their permitted borrowing.

Figure 114 ZEV shares of annual sales for borrowing scenarios



493. This maximal scenario is presented in order to illustrate the full potential scale of lost carbon savings resulting from this flexibility; however, several manufacturers have indicated that the proposed annual targets are achievable and that they intend to meet them, even in these earlier years of the scheme. Therefore, it is likely that the scale of borrowing and lost carbon savings is lesser than presented here.

494. As shown, this leads to a significant reduction in ZEV delivery over the first three years of the scheme, although this is offset by much higher deliver in 2027.The annual ZEV share is slightly higher in the scenarios where interest is applied; this is because, for every 1,000 credits borrowed for one year, 1,035 credits are required to be repaid. Although the difference appears to be fairly marginal, this amounts to nearly 80,000 additional ZEV cars and more than 5,000 additional ZEV vans over the delivery period. This goes some way to mitigate the risk to carbon savings posed by delayed delivery.

495. It is also proposed that manufacturers be permitted to bank any excess annual ZEVM allowance delivery, in order to remove disincentives for over-performance. However, banked allowances will not receive interest payments. This is because there are benefits to higher availability of allowances on the trading market, most notably in terms of competition and reducing overall costs of compliance. Awarding interest to banked allowances is therefore not proposed, as this would strengthen incentives for over-performing manufacturers to retain their over-delivered allowances, instead of trading them.

496. This analysis does not pre-suppose any strategic manufacturer behaviour; per HMT's Green Book guidance, the central scenarios assume that manufacturers in-scope of the regulation meet the ZEV mandate trajectory targets fully and on-time. However, sensitivities are presented in order to reflect the inherent uncertainty caused by the inclusion of flexibilities for manufacturers struggling to meet their targets on-time.

Annex J – Detailed Distributional Analysis

497. This section follows on from 'Section 4.0 Wider impacts: Equality impact assessment'. It sets out in greater detail the expected impact of these proposals on the protected characteristics covered by the Equalities Act 2010. In addition, evidence on the readiness of island communities to take up and benefit from ZEVs is presented.

498. This quantitative analysis focuses on the economic implications for discrimination – if the policy and its impacts could put groups of protected characteristics at a (economic and financial) disadvantage. It also considers equality of opportunity – if individuals have the same financial and economic opportunities and outcomes given their protected characteristics as compared to the status quo, and whether particular groups may face barriers to participation.

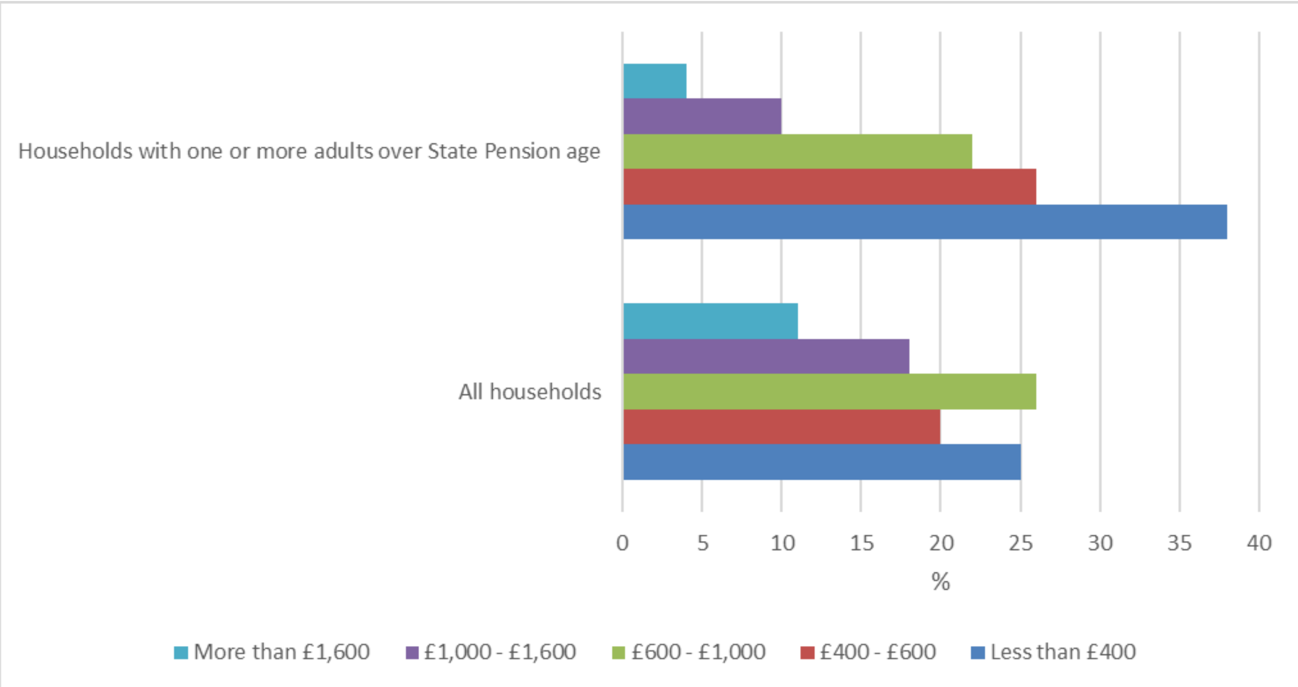
499. To quantify this, distributions of income and savings for protected characteristic groups are compared to the financial implications of the policy (the higher upfront cost of ZEVs, especially in the shorter-term). As such, an individual with lower income and-/or- savings may find it harder to afford the additional upfront cost. But these individuals are also less likely to own a vehicle, or if they do, more likely to buy one second-hand, at a lower price. Those on lower incomes, who do need to own a car or van, may be less able to absorb additional costs of ZEVs which is analysed using incoming and savings in the sections below.

Age

500. Detailed data on the relationship between age and household income is not readily available, however the differential effect of these proposals on households of different ages can be proxied using the state pension age. Figure 115 shows the distribution of gross weekly household income for all households, versus those with at least one adult over state pension age. As shown, households with an adult over state pension age tend to have lower weekly income.

501. However, some evidence provided by the English Housing Survey (EHS) suggests that lower household incomes may be at least partly offset by reduced outgoings. Most notably, this group of households, and households towards the top of the age distribution more generally, are far more likely than other groups to own their homes and more likely to do so without a mortgage. The EHS also suggests that housing costs constitute more than 17% of mortgagors' income, on average; for private renters the average proportion of income taken up by rent exceeds 37%. Taken together, this suggests that the difference in disposable income between the two groups is likely significantly lesser than illustrated below.

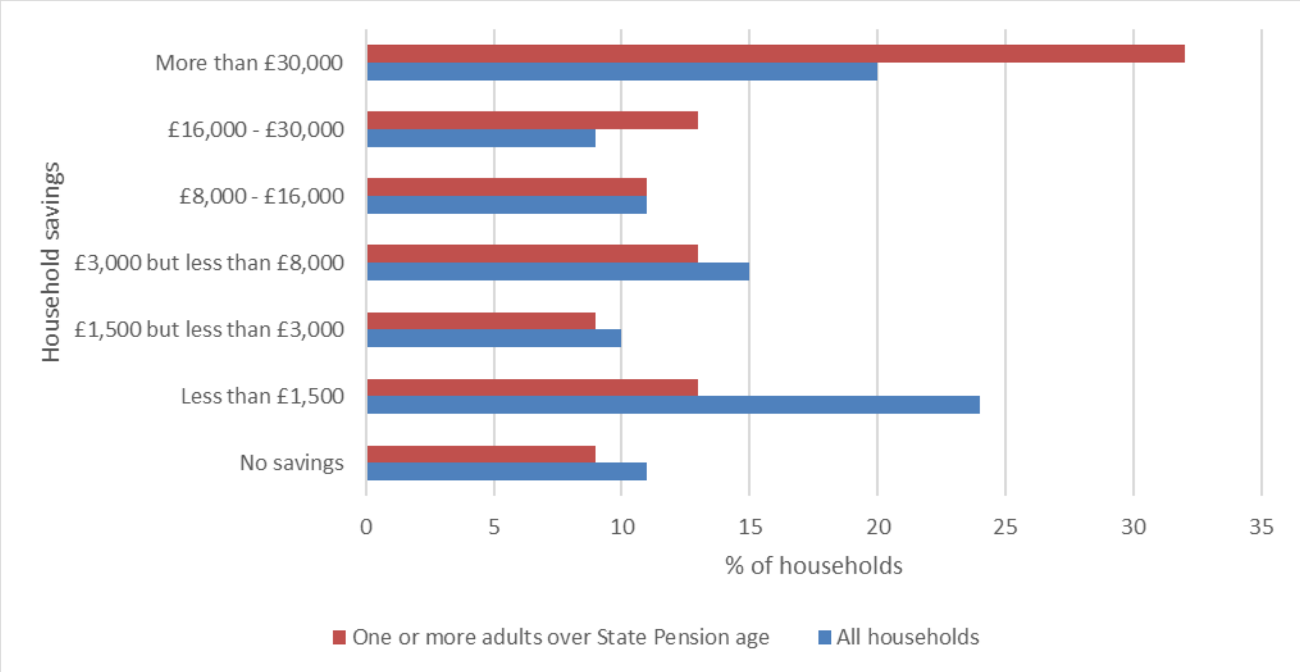
Figure 115 Gross weekly household income for all households versus those with at least one adult over state pension age



502. Furthermore, Figure 116 shows that older households are generally more likely to have greater household savings. The same data also suggest that the median level of household savings for

those with at least one adult over state pension age is £8,000 - £16,000, compared to £3,000 - £8,000 for all households.

Figure 116 Household savings for all households versus those with at least one adult over state pension age



503. On balance, it seems unlikely that older households would face significant barriers to car ownership as a result of these proposals, compared to the general population.

Disability

504. For this analysis, disability status is proxied using the category 'Households with one or more disabled adults under State Pension age', which is compared against all households' gross weekly household income.

505. As shown in Figure 117, households with a disabled adult under the state pension age are less likely to fall in the top income category and more likely to be in the bottom income group. Additionally, Figure 118 shows that households with at least one disabled adult under state pension age are on average likely to hold significantly less savings than the general population. They may also face greater living and housing costs as a result of their disability.

506. All this suggests that Government should be cognisant of the potential barriers faced by these households. Therefore, it is important that these risks are monitored, and mitigating actions are put in place as appropriate.

507. The most direct way in which these proposals could impact on disabled households' access to ZEVs is through affecting the supply of wheelchair-accessible vehicles. For this reason, incentives to support the production of wheelchair-accessible ZEVs are proposed. These incentives are set out in greater detail in 'Section 1: Additional policy details'; their broad aim is to increase the relative benefit of the production of wheelchair-accessible ZEVs to reduce the likelihood of insufficient supply.

508. However, many disabled households do not require wheelchair-accessible vehicles, but may face other barriers to participation; for instance, if these households have similar income and savings distribution to *all* households containing at least one disabled adult (including those requiring wheelchair-accessible vehicles), they may face financial barriers to purchasing ZEVs in the shorter-term. This risk will be monitored through the monitoring and evaluation of the proposals.

Figure 117 Gross weekly household income for all households versus those with at least one disabled adult under state pension age

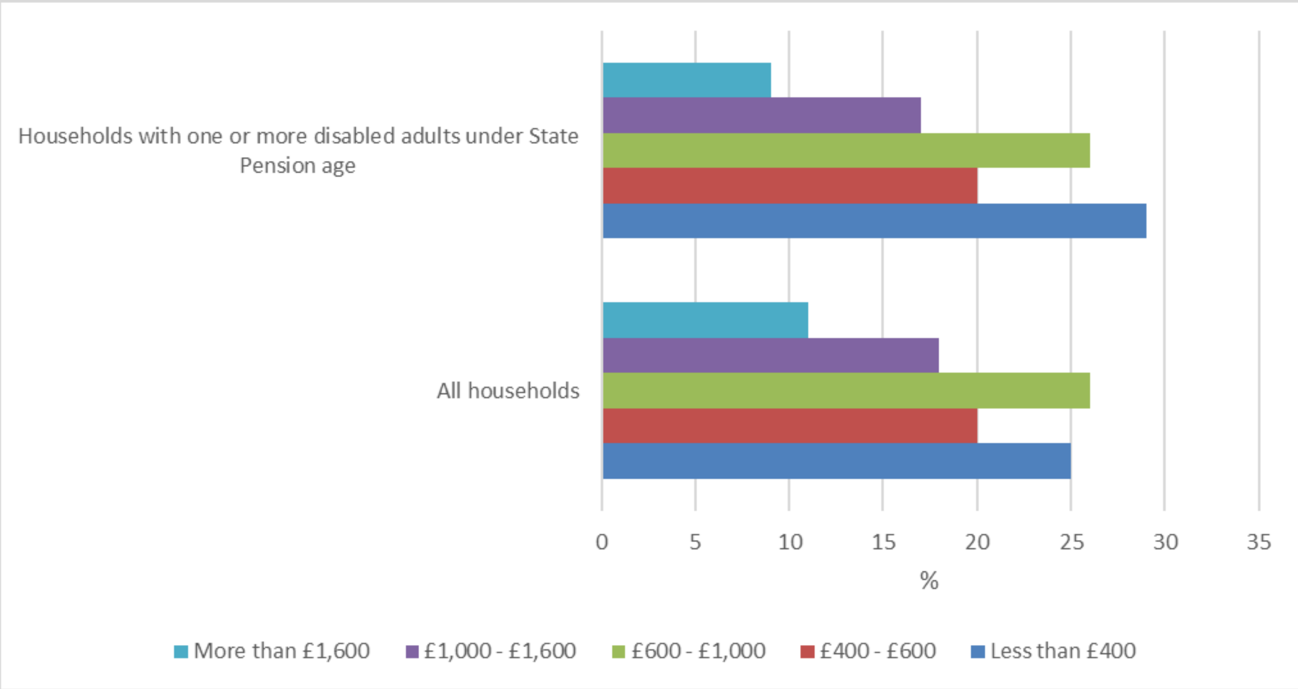
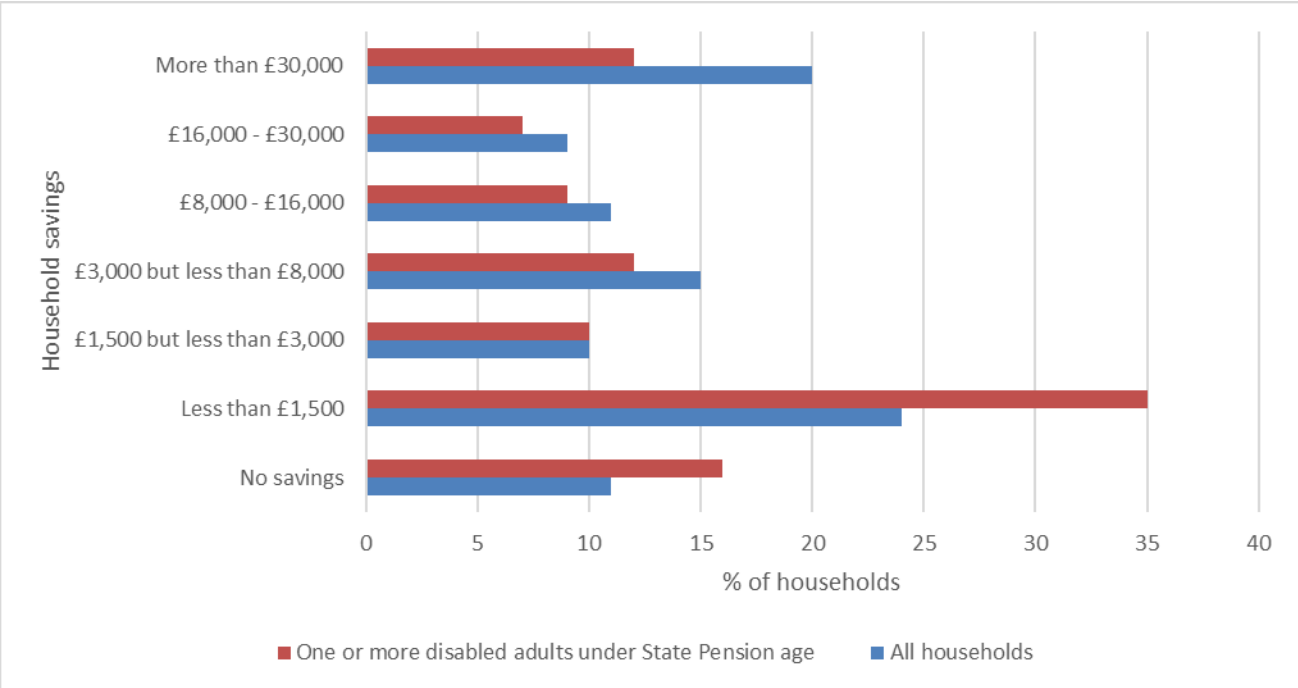


Figure 118 Household savings for all households versus those with at least one disabled adult under state pension age

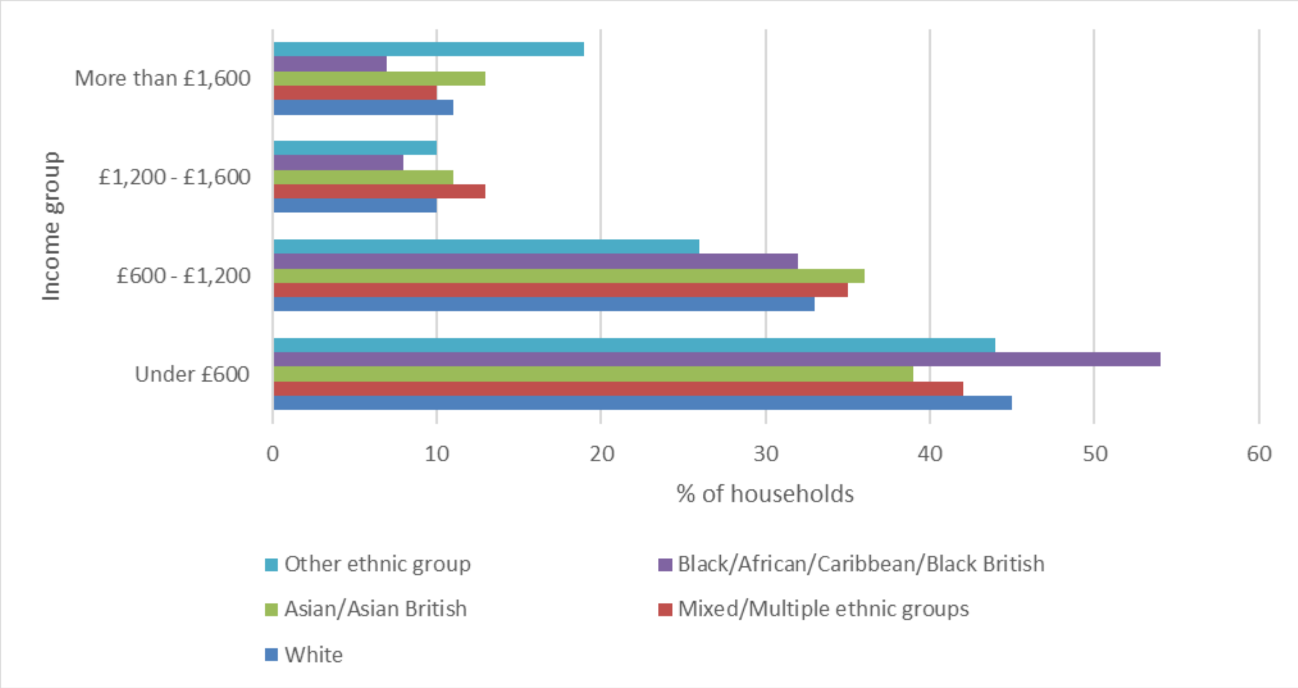


Race and Ethnicity

509. Figure 119 shows the distribution of gross weekly household income, split by the ethnicity of the survey respondent. Some ethnic groups are aggregated (e.g. Mixed/Multiple ethnic groups households) due to small sample sizes, issues with data collection, and in the interests of proportionality and clarity of the analysis.

510. There are broad similarities in the income distribution of Mixed, White, and Asian/Asian British households, although some variation remains. However, Black/African/Caribbean/Black British households are significantly over-represented in the lowest income group, being the only group to show median income under £600 per week, compared to £600 - £1,200 per week for all other groups.

Figure 119 Gross weekly household income by ethnicity



511. The Family Resources survey contains data on the type of savings and investments held by different ethnic groups, but not their value. Given the evidence presented in paragraph 417, it seems reasonable to expect that Black/African/Caribbean/Black British households also hold relatively low values of savings and investments, and may face barriers to taking up BEVs, especially first-hand.

512. However, as set out in the main body of the report, it is important to note that the opportunity to save money over a relatively short time horizon, especially on the secondary market, means that the net effect of these proposals on disadvantaged groups may not be negative.

Pregnancy and Maternity

513. The Family Resources Survey does not collect income and savings figures specifically relating to pregnancy and/or motherhood. However, household composition data can be used to provide a broadly useful proxy for this protected characteristic.

514. As shown in Figure 120, household income exhibits a broadly positive relationship with the number of adults and the number of children in the household. It is likely that income rises with the number of adults due to increased earning potential, as discussed above. It is likely the broadly positive relationship between number of children and income has several determinants; one of these may be that households earning more income feel able to and choose to have more children. In addition, there is likely a relationship with life-stage, age, and earning potential, as younger people entering the workforce are more likely to earn less and less likely to have children.

515. Generally speaking, two- and three or more- adult households with children are likely to have greater than average household income. For one-adult households, the distribution is more mixed: two- and three or more- children households are less likely to earn less than £400 per week than the general population, more likely to earn £400 - £600 per week, but much less likely to earn more than £1,600 per week. However, single-adult, single-child households appear to be significantly lower-income, on average; nearly 45% earn less than £400 per week and only 6% earning more than £1,000 a week, compared to 29% of the general population.

Figure 120 Gross weekly household income by household composition

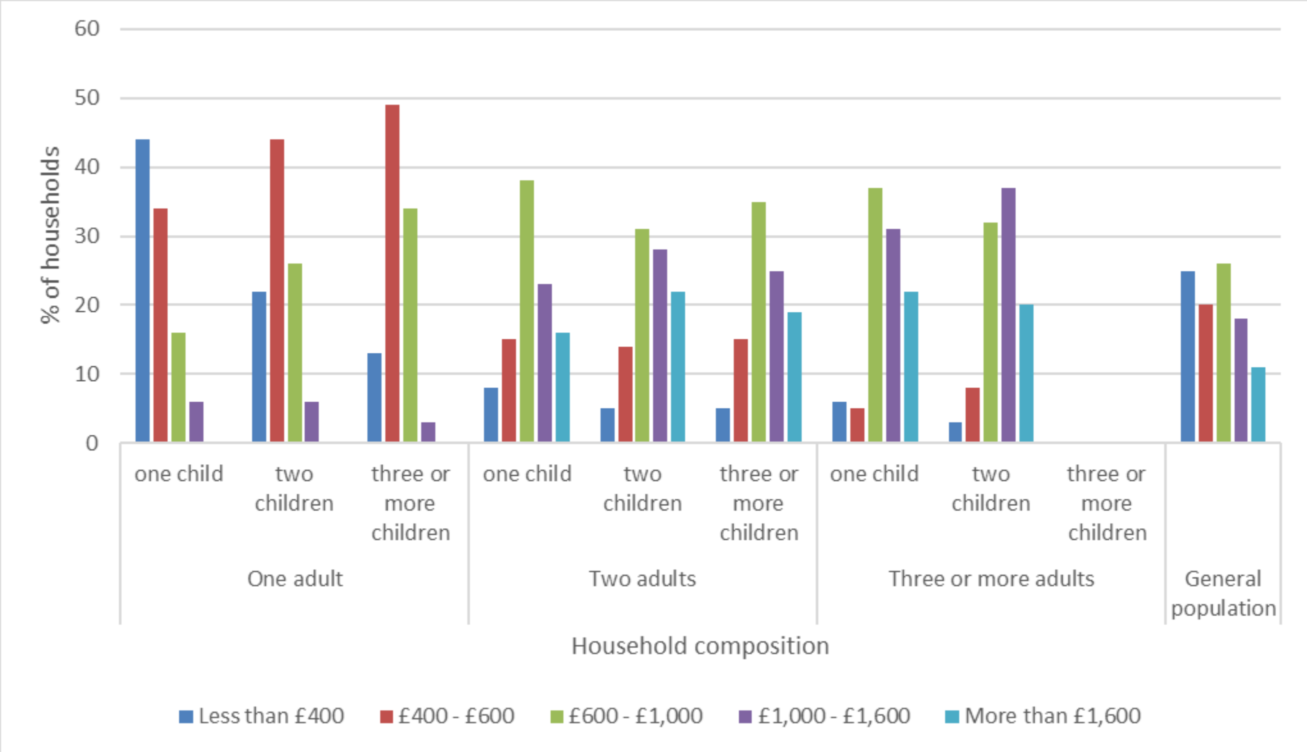
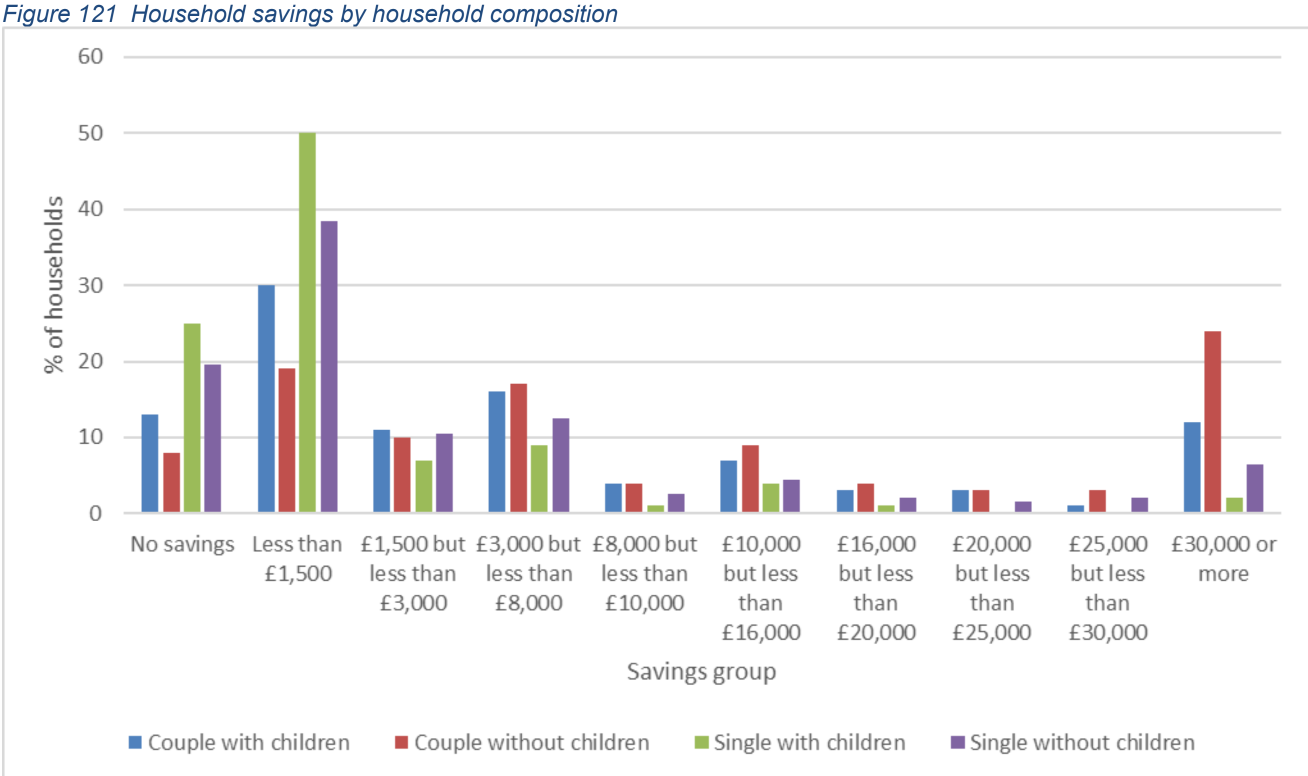


Figure 121 Household savings by household composition



516. On the other hand, households with a greater number of dependent children are also likely to have greater outgoings. There may be some economies of scale with household size, nonetheless increased costs of a greater number of dependents may limit the purchasing power of these larger households.

517. Therefore, it is unclear whether there are likely to be differential effects, with regard to pregnancy, maternity, or household composition. Those with constrained purchasing power may face barriers to purchasing ZEVs, especially in the short-term; however, these barriers are likely to be reduced in the longer-term, as ZEV costs are expected to fall and more ZEVs become available on the second-hand market.

Sex

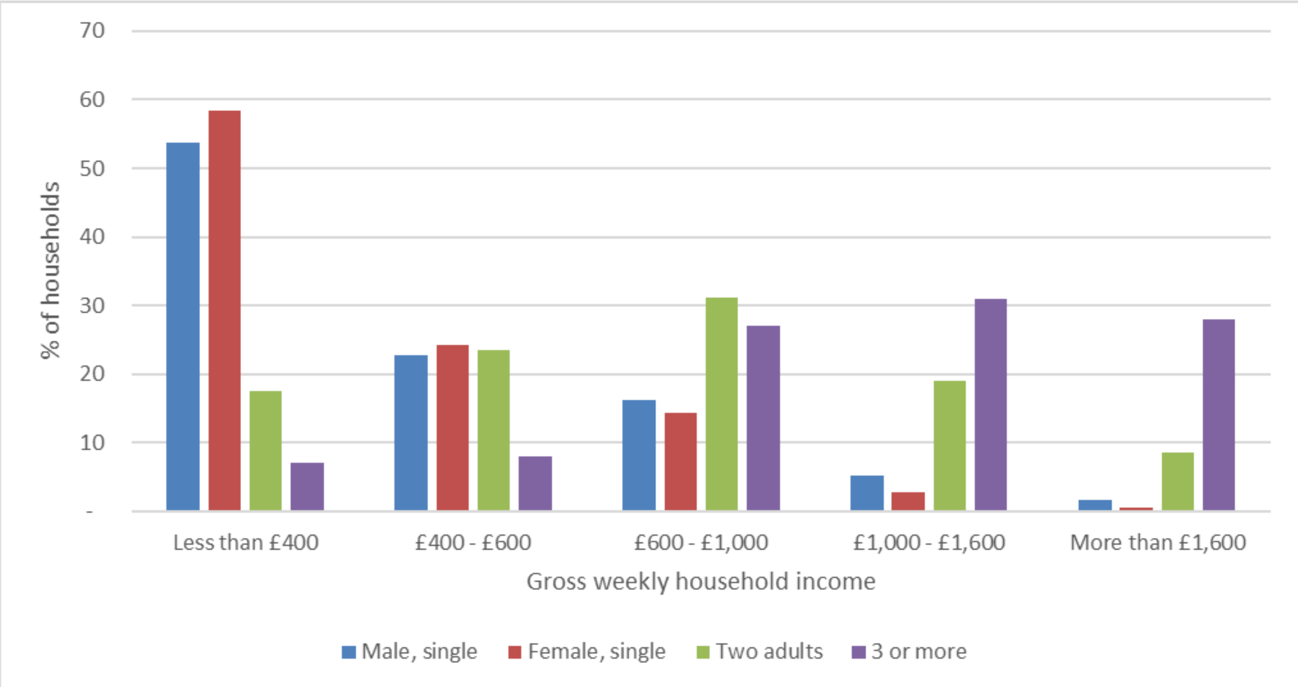
518. The Family Resource Survey collects data on household income for single adults of each sex, couples, and multi-person households (both including and excluding children). For multi-adult households, the gender of each is not presented. This analysis may therefore fail to capture differential impacts at the intersection of gender and same-sex couples.

519. Figure 122 shows the distribution of gross household weekly income by household type, comprising male/female 1-adult households, two-adult households, and three or more adult households. As shown, both male and female single-adult households are heavily over-represented in the bottom income group.

520. By contrast, multi-adult households, particularly those comprising three or more, are over-represented in the top income groups. To some extent this is unsurprising: multi-adult households are likely to contain a greater number of employed people, which, all other things being equal, would lead to significantly greater income.

521. It does appear that female single-adult households are slightly more likely to have lower incomes; 58% of female single-adult households earn less than £400 per week, compared to 54% of male single-adult households. What's more, male single-adult households are more likely to be in the top income groups.

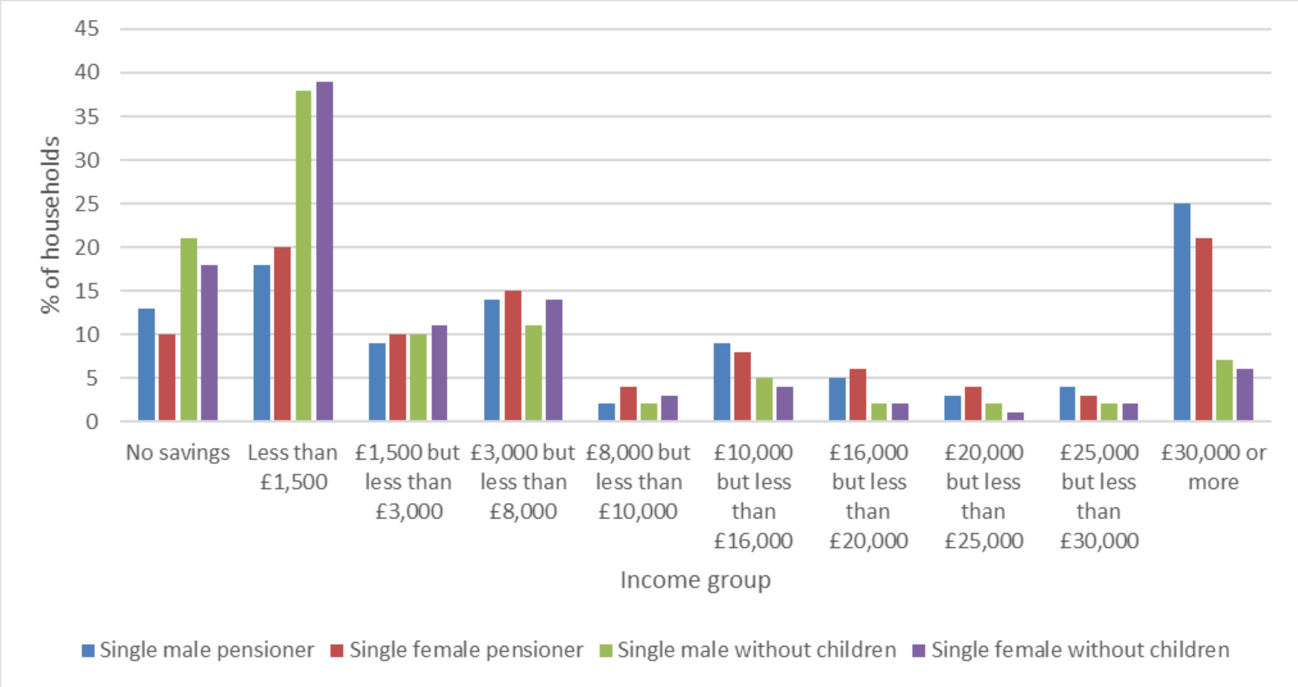
Figure 122 Gross household weekly income by household type and gender for single-person households



522. That said, it should be noted that for both groups, the first quartile (25th percentile) earns less than £400; the median household earns less than £400; the 3rd quartile (75th percentile) earns £400 - £600; and the 90th percentile earns £600 - £1,000. This indicates that although there are significant differences at some areas of the distribution, broadly the two income distributions are relatively similar.

523. Furthermore, the picture is less clear when analysing savings by income group, sex, and age. It should be noted that this data only distinguishes sex for single-adult households without children. As shown in Figure 123, single male pensioners and non-pensioners are more likely to have no savings than their female counterparts. Female pensioners and non-pensioners are also over-represented at several points higher up the distribution, for instance in the £3,000 – £8,000 and £8,000 - £10,000 groups.

Figure 123 Savings by gender and age



524. As with income data, the overall distributions are quite similar between genders. For single pensioners, the 1st quartile and median fall within the same band, with the 3rd quartile falling in adjacent bands. For single adults, the 1st quartile, median, and 3rd quartile all fall within the same bands between the two genders.

525. With regard to the ZEV mandate, the similarities in the income distributions of these two groups suggest it is unlikely the proposals will affect the large majority of households in a materially different way, although some differential impacts may occur on a case-by-case basis.

Sexuality and Gender Reassignment

526. The Family Resources Survey does not collect data on sexuality. Some research on household finances and sexuality does exist, although these sources note that the evidence base is limited. That said, the report 'Inequality among LGB&T Groups in the UK' indicates that although there is generally limited evidence on sexuality and equality, there is a relatively rich evidence base regarding employment and salaries. This report reviews a number of research papers investigating employment outcomes for LGB&T groups in the UK.

527. The UK Government recognises that sexuality and gender reassignment are separate characteristics which can affect members of these communities in different ways. Nonetheless, due to presently limited evidence on financial outcomes for these groups, they are often discussed as a collective group in the research. For this reason, and in order to avoid repetition, this section discusses the evidence on financial outcomes as it pertains to both lesbian, gay, bisexual, and trans groups.

528. The report mentioned in paragraph 526 suggests that there is limited evidence of unequal employment outcomes based on sexuality and that outcomes may in fact be 'better' than the general population, although there is variation between sectors. This definition of employment outcome includes employment rates, career progression, and salary.

529. That said, it should be noted that greater rates of bullying were reported and that this was linked to restricted opportunities for promotion. In addition, a greater proportion of transgender people were out of work for health reasons, although overall a greater proportion of transgender people were employed, compared to cisgender people.

530. Nonetheless, the overall finding is that on average LGB&T groups are unlikely to face barriers to engagement with these proposals, based on their financial status.

Religion or Belief

531. There is some evidence of different income and savings levels in different religious groups. For instance, research conducted by the Office for National Statistics suggests that although earnings are broadly similar for many groups, and the majority of the population, there are some disparities when comparing individual groups. As a result of these disparities, it is possible that certain groups are impacted by these proposals in different ways.

532. Consultation respondents are encouraged to provide any evidence which either supports or contradicts this assumption. Evidence provided through the consultation will be used to expand the breadth and depth of the equalities impact assessment, identify potential distributional risks, and determine whether any suitable mitigating actions exist to address those risks.

Island Communities Impacts

533. Island communities face unique circumstances which may affect households' and businesses' ability to comply with regulations. In addition, these unique circumstances may alter the relative impact of these regulations, compared to other mainland communities. This sub-section presents some qualitative analysis of potential differential effects for these communities.

534. With regard to infrastructure readiness, research on chargepoint availability suggests that several of the Scottish Islands are among the best-prepared for increasing ZEV uptake. Local authority-level data collection identifies the Orkney Islands, Shetland Islands, Na h-Eileanan Siar, Argyll and Bute (covering the Isle of Islay and Mull) and Highland (covering the Isle of Skye) as all falling within the top 7 best-prepared communities, with Orkney holding roughly 5 times as many chargepoints per person than Glasgow and Edinburgh. Nevertheless, this trend may not be the case for all island communities.

535. Island drivers may face higher operating costs than their mainland counterparts, pertinent to both ICEVs and ZEVs. Rural areas, such as the Scottish Islands, pay on average 1p-2p per litre more for road fuel, due to lower competition and higher supply costs[71]. The availability of rural fuel duty discounts in areas such as the Inner and Outer Hebrides, the Northern Isles, the Isles of Scilly, and parts of the rural mainland[72] is an indicator of the higher market costs these communities face. Equally, their unit cost of electricity may be greater. However, as set out in Section 4.0 and Annex E, ZEVs are expected to offer running cost savings of nearly 50% per kilometre compared to their ICEV counterparts, with this saving expected to increase as battery efficiency gains are realised. Therefore, island electricity costs would need to be more the twice the average p/kWh paid for island ZEV drivers to face the same price per km as running an ICEV. Evidence from 2015 suggests that electricity unit costs may only be approximately 25 – 30% higher for island communities relative to the national average. However, the recent trend of a rise in consumer and business investment in microgeneration may have since decreased this difference.

536. Finally, drivers on several Scottish islands are exempt from requiring an MOT on their vehicles, subject to certain conditions[73]. As a result, the car and van fleets on these islands are expected to be on average older, less efficient, and have greater adverse air quality impacts than their mainland counterparts. The marginal benefit of replacing island vehicles with ZEVs is therefore

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71 Road fuel review - GOV.UK (www.gov.uk)

72 Rural Fuel Duty Relief Scheme (Notice 2001) - GOV.UK (www.gov.uk)

73 The Motor Vehicles (Driving Licences) Regulations 1999 (legislation.gov.uk)

expected to be greater, thereby potentially offering greater net social benefits to island communities.

537. Nonetheless, there may be unique challenges faced by island communities in taking up ZEVs. For instance, median incomes across Argyll and Bute, Highland and the Orkney Islands are lower than the Scottish national average[74], and therefore up-front costs of ZEVs may be more prohibitive. That said, it should be noted that consumer uptake of ZEVs is not compulsory; for the period of these direct regulations, ICEVs will be permitted to be sold. Furthermore, the second-hand market for ICEVs will continue to operate, and ZEVs will become available at lesser cost on the second-hand market over time; as set out in Section 4.0, second-hand BEVs offer even greater cost savings than first-hand ones. Finally, ZEV costs are expected to decline over time. This is expected to further reduce the challenges faced by lower-income drivers, reducing barriers to participation.

538. On the balance of this evidence, island communities are not expected to be disproportionately adversely affected by these regulations. In fact, a combination of generally greater chargepoint availability, coupled with unique regulatory environments, means that many island communities may disproportionately benefit from these proposals. As ZEV costs decline, both through innovation for first-hand vehicles and greater availability of second-hand ZEVs, remaining barriers to participation are expected to be reduced.

539. Consultation respondents are encouraged to give feedback and provide evidence on potential differential effects experienced by island communities through this consultation.

[74] Analysis from the 2021 Earnings and hours worked, place of residence by local authority dataset. Earnings and hours worked, place of residence by local authority: ASHE Table 8 - Office for National Statistics (ons.gov.uk)