Zero Emission Vehicle Mandate and CO_2 Regulations

Joint Government Response Cost Benefit Analysis

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1. Executive summary

1.1 The UK is committed to delivering our legal obligations to achieve net zero CO_2e[1] 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.

The problem under consideration

1.2 There are several causes of market failure which warrant government intervention. Greenhouse gas emissions (GHGs) 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

1.3 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 economic ecosystem.

Policy development

1.4 Following a Green Paper on a New Road Vehicle CO_2 Emissions Regulatory Framework for the United Kingdom (2021), a technical consultation on ZEV mandate policy design (2022), and the latest consultation on a ZEV mandate and CO2 emissions regulation for

[1] Carbon dioxide equivalent (CO_2e) refers to the carbon dioxide equivalent including other greenhouse gases. When CO_2 is referred to later in this document it is referring to the CO_2 equivalent of all greenhouse gases.

new cars and vans in the UK (2023), the UK Government, alongside devolved administrations, has come to a final position on its proposal to establish a new regulatory framework for new cars and vans. The analysis detailed within this document builds on the consultation-stage Cost Benefit Analysis published in March 2023; from the short-list of options explored in that document, and based on policy refinement through consultation responses, a single policy option is being taken forward for the joint final position. 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 ZEV grants also the potential to offer substantial savings, but are unlikely to be affordable at the scale required to meet net zero by 2050.

Summary of policy

1.5 The ZEV mandate sets a target as a percentage of vehicle manufacturer's total annual sales to transition to zero tailpipe emissions. The regulation will require that for each non-ZEV sold, the manufacturer must have a ZEV allowance. Manufacturers will receive enough allowances that if they meet their target, they will not need additional allowances. If a manufacturer sells more ZEVs than their target, they will have a surplus of allowances they can sell, bank, or convert their excess allowances for use in the non-ZEV CO_2 emissions scheme. If a manufacturer sells fewer ZEVs than their target, they can buy, borrow, use banked allowances, or convert CO_2 emissions allowances to meet their obligation, or make a final compliance payment.

1.6 The CO_2 emission regulations provides manufacturers with a baseline target for CO_2 emissions based on 2021 data, which will remain constant for the duration of the regulation. Manufacturers will receive allowances each year according to their average non-ZEV CO_2 performance in 2021, multiplied by the number of vehicles they sell in the relevant year. Manufacturers must have enough CO_2 emissions allowances so that they have one for every gram of CO_2/km that they emit on a fleetwide basis, as measured according to the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) CO_2 measurement for each vehicle. Manufacturers will be awarded enough allowances so that if they meet their baseline target, they will not require additional allowances. If a manufacturer beats their target, they can sell or convert spare allowances. If a manufacturer misses their target, they can buy allowances or convert ZEV allowances into CO_2 emissions allowances to meet their obligation or make a final compliance payment.

Expected impacts

1.7 The policy is expected to achieve non-traded emissions savings of 28, 77 and 411 $MtCO_2e$ in carbon budgets 5, 6, and 2024-2050, respectively. It offers high value for money, with a best estimate social Net Present Value of £39bn, as well as supporting growth and employment in the low-carbon economy. This estimate rises to £116bn if no growth in traffic levels is assumed to result from the regulations.

Notes

1.8 These regulations are treated as imputed tax and spend and are therefore outside the remit of the Regulatory Policy Committee.

Summary: analysis and evidence

Price Base Year 2021	PV Base Year 2022	Time Period Years 50 (2021 - 2071)	Net Benefit (Present Value (PV)) (£m) Low: £-40bn	High: £183bn	Best Estimate: £39bn

COSTS (£m)	Average Annual (Constant Price)	Total Cost (Present Value)
Low	£2.6bn	£138bn
High	£2bn	£99bn
Best Estimate	£2.5bn	£127bn

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 (£78bn in congestion and £7bn in accidents). There are also social costs relating to increased traded emissions (£2bn from 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 indirect costs to downstream businesses (e.g. car dealers). Differences in the production emissions of ZEVs and Internal Combustion Engine Vehicles (ICEVs) are not quantified.

BENEFITS (£m)	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	£2bn	£98bn
High	£5.6bn	£282bn
Best Estimate	£3.3bn	£166bn

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 £54bn in reduced running costs (c.£39bn and c.£15bn in reduced fuel costs and maintenance costs, respectively); in addition there are anticipated to be significant indirect tax (c.£6bn), air quality (c.£1bn), and consumer surplus benefits (c.£2bn).

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. Benefits from reduced upstream GHG emissions from fuel production are not included.

Key assumptions/sensitivities/risks

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 3: Policy analysis*.

Standard STPR:	3.5%
Long-term STPR:	3.0%
Health discount rate	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 3: Policy analysis* and discussed in *Section 4: Policy risks.*

2. Policy and analysis overview

Policy background

2.1 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.

2.2 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 UK Government has committed to all new car and van sales being composed of zero emission vehicles (ZEVs) by 2035.

2.3 In recent years, UK Government has published multiple consultations[2] 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.

2.4 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.

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

2.6 Based on the responses to consultation and the detailed analysis, the UK Government, Scottish Government, Welsh Government, and Department for Infrastructure (Northern Ireland) announced that they 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).

2.7 Initial views on the design of the ZEV mandate were set out for consideration in a Technical Consultation in April 2022. The final consultation ran from 30 March to 24 May

[2] Green Paper; Technical Consultation, Final Consultation.

2023, accompanied with the release of a comprehensive cost-benefit analysis document detailing the analysis underpinning each policy option.

2.8 During the final consultation, we conducted an extensive stakeholder engagement programme to understand better the views and opinions on the various design features, which included Ministerial roundtables, official-led workshops and bilateral meetings.

2.9 Based on the views received across 148 stakeholder responses, the UK Government and devolved administrations have finalised their position on the policy design. The overall design of the ZEV mandate trading scheme is unchanged from the consultation, with some small, technical, and targeted updates.

Problem under consideration

2.10 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 shows over the 10 years to 2019, domestic emissions fell by roughly 25%, but transport emissions have fallen by less than 5%. In 2020 during COVID-19, transport emissions were suppressed by 28%, but have more recently bounced back as restrictions have passed. 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 Q3 2022 show road traffic on an upward trend back to pre-pandemic levels.[3] 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.[4]

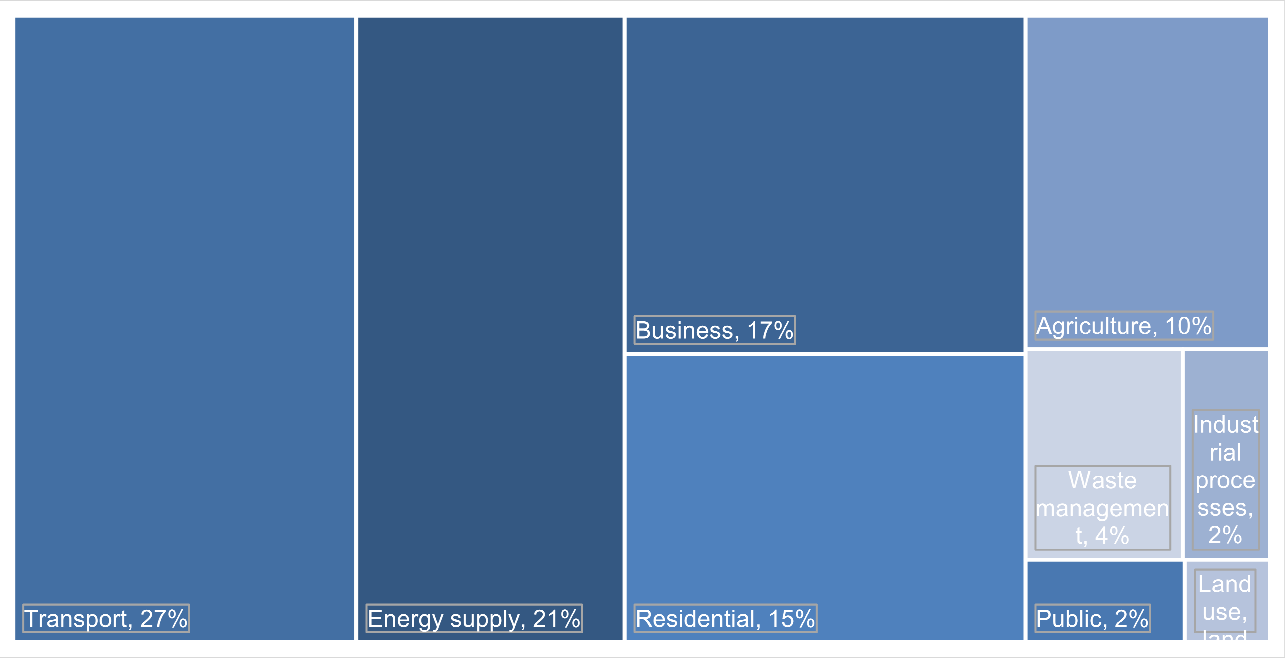

Figure 1 UK emissions breakdown by sector, 2019[5]

2.11 Within transport, cars and taxis are by far the single greatest source of emissions; as shown in Figure 1, these modes accounted for more than half of all UK domestic transport

[3] https://www.gov.uk/government/statistics/provisional-road-traffic-estimates-great-britain-october-2021-to-september-2022/provisional-road-traffic-estimates-great-britain-october-2021-to-september-2022

[4] 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)

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

emissions in 2019. Light vans contribute an additional 15%, meaning that together these modes make up nearly three-quarters of UK domestic transport emissions; these equate to roughly 87 $MtCO_2e$ in 2019.

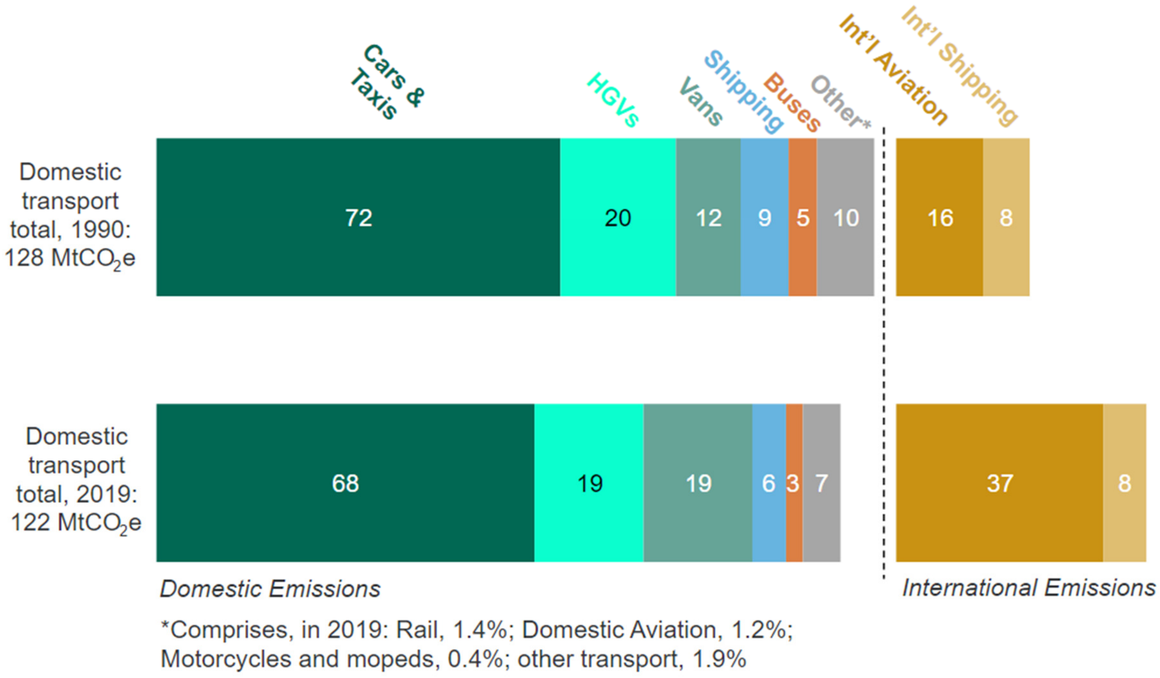

Figure 2 UK domestic transport emissions breakdown by mode, 1990 and 2019[6]

2.12 Furthermore, overall emissions from cars, taxis, and light vans have fallen by just 0.3% over the decade prior to 2019. Car and taxi emissions fell by 5%, but 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

2.13 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

2.14 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 an allocation of resources which differ from the socially optimal level. Where this occurs, government intervention is justified to bring the consumption or production of goods into line with the optimal level.

2.15 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,

[6] Transport and environment statistics: Autumn 2021

water shortages, and rising sea levels, many of which may be irreversible and lead to severe environmental and economic damage.[7]

2.16 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.

2.17 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).[8],[9]

2.18 DESNZ (the department for Energy Security and Net Zero) produces estimates of the societal value of carbon. This value sits at a cost of around £245 per tonne of carbon equivalent emitted in 2021 (in 2020 prices), reflecting a rough scale of the external cost of 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 much lower emissions on a lifecycle basis[10]), which means they can dramatically reduce external costs.

2.19 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 are estimated at ~50 pence per litre meanwhile fuel duty is set at 59 pence per litre. However, there are many other significant externalities of fuel consumption such as air quality, congestion, accidents, road wear and tear which DESNZ carbon valuations do not include.

2.20 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, but they can 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.

2.21 This policy package includes alternative policy levers which are expected to be effective at addressing these externalities, thereby reducing emissions while supporting economic growth.

Legal rationale

2.22 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 emissions and avoid the

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[7] What are the risks? - Climate Change Committee (theccc.org.uk)

[8] VEH0156: Provisional average reported carbon dioxide (CO_2) emission figures of vehicles registered for the first time by body type, fuel type and measure: Great Britain and United Kingdom

[9] 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

[10] Lifecycle Analysis of UK Road Vehicles - Ricardo 2021

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.

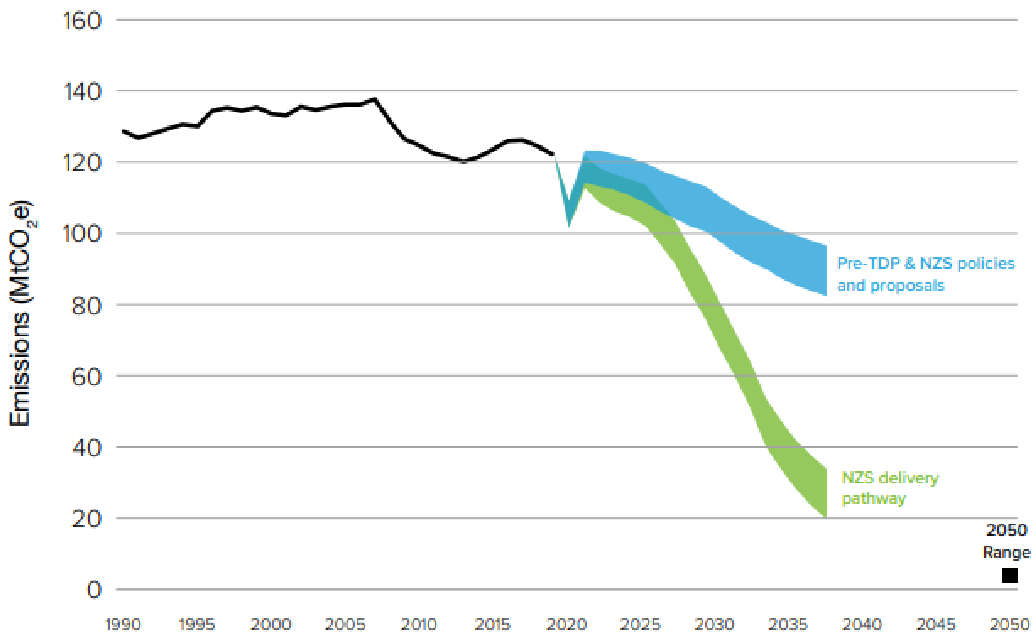
2.23 Achieving net zero requires action from all sectors of the economy. For road transport it effectively requires all vehicles to be zero emission at the exhaust by 2050, combined with the decarbonisation of upstream electricity generation. Regulatory intervention is critical to guaranteeing the rapid uptake of ZEVs to ensure contribution towards legally binding interim carbon reduction requirements on the pathway to net zero.

2.24 However, DfT's current baseline 'do-nothing' projections suggest that roughly 42% of new car and 12% of van sales in 2030 will be zero emission without further intervention. Under this baseline, we expect 67% of car mileage to be zero emission by 2050, and 45% of van mileage. This is inconsistent with the UK Government's Net Zero Strategy and would risk non-compliance with its legally-binding carbon budgets and net zero 2050 commitment.

2.25 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.

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

Figure 3 UK emission reduction commitments



Source: BEIS analysis

Figure 4 Indicative domestic transport emissions pathways to net zero by 2050

Information/coordination failure

2.26 There also exists a coordination challenge with regard to the transition to zero emission transport: ZEVs require a new refuelling network 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.

2.27 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.

2.28 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.

2.29 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).

2.30 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

2.31 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. Research by the International Council on Clean Transportation (ICCT) 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.

2.32 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 up to 5 times higher than the performance measured at the test cycle for company cars and up to 3 times for private cars.

2.33 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

2.34 To ascertain whether government intervention is necessary, evidence has been gathered from manufacturers on their ZEV commitments by 2030 (as of announcements made by September 2023). Figure 5 shows these commitments by the relative market share of each manufacturer within the UK car sales market.

2.35 Based on these commitments and the 2021 market share of each manufacturer, it is estimated that ~67% of car sales in 2030 fall under a commitment to be zero-emission, but we recognise that 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.

2.36 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 the supply of ZEVs away to other markets, leaving the UK behind in the global transition.

2.37 Furthermore, current ZEV production costs exceed those of internal combustion engine (ICE) vehicles which may disincentivise high levels of ZEV production (see Capital Costs 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.

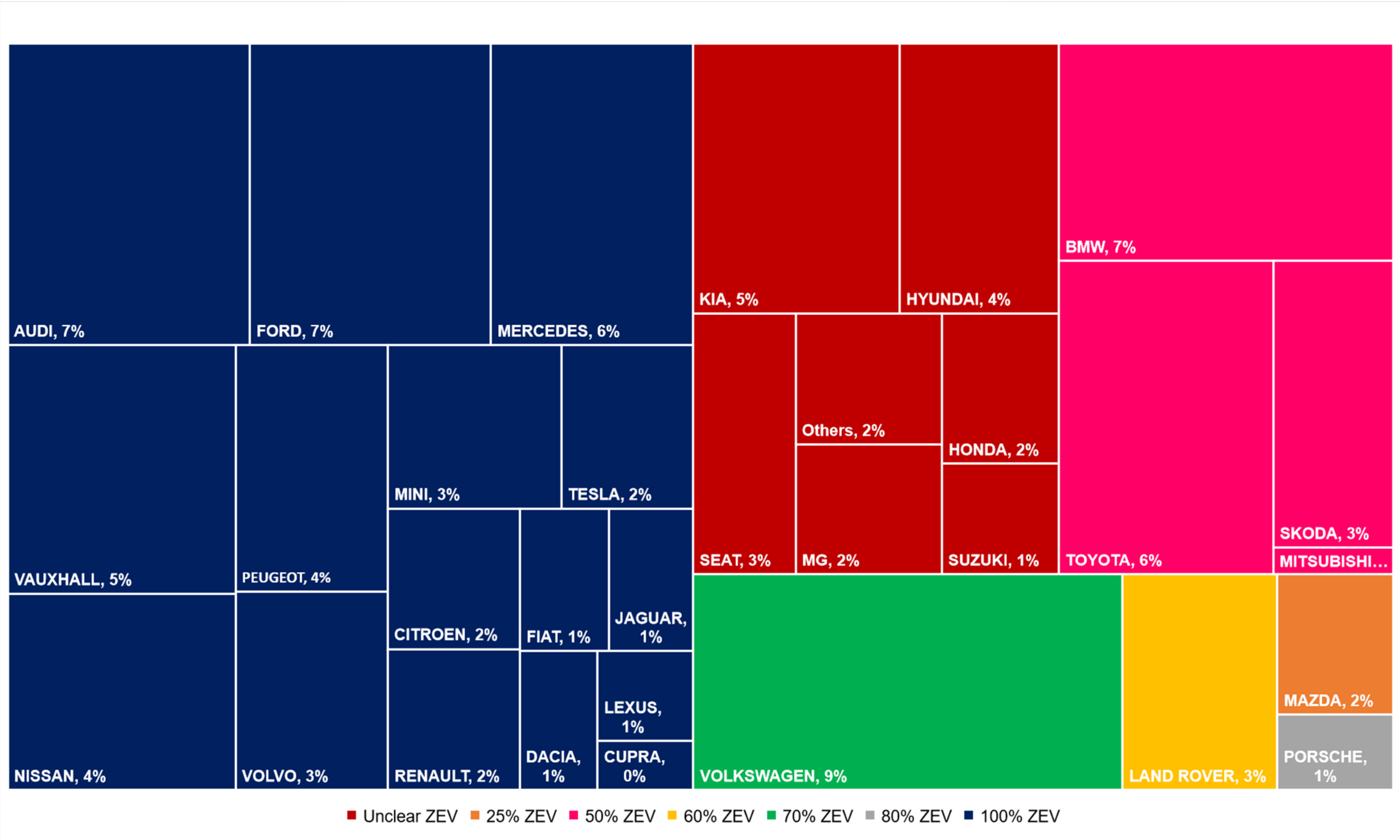


Figure 5 Zero emission car manufacturing expectations by 2030 (as of September 2023 announcements)[11]

[11] ZEV manufacturer expectations represent what manufacturers have publicly announced up to September 2023. The areas of boxes reflect the UK registration market share for each manufacturer based on the 2021 DVLA vehicle registration by make statistics.

2.38 The ZEV mandate will set legally binding annual targets for the share of new cars and vans that are sold in Great Britain 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.

2.39 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. 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.

2.40 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 non-ZEVs vehicles do not become less efficient over time.

2.41 Taken as a whole, this new regulatory framework is intended to significantly reduce emissions from cars and vans. In addition, we anticipate the policy will: encourage investment in infrastructure provision; bring increased consumer confidence; ensure we are less reliant on imported fossil fuels; and ensure domestic manufacturing is well placed for a zero-emission future delivering inward investment, growth and jobs.

Summary of the final policy position

2.42 This section sets out the final ZEV mandate and CO_2 regulations policy position, addressing the problem under consideration. Per HMT Green Book guidance, the counterfactual represents a 'do-nothing' scenario whereby the ZEV mandate and CO_2 regulations are not introduced, and retained EU regulations remain.

Category	Option	Details
Do Nothing – trajectory & non-ZEV CO_2 requirements	0 - baseline	In the do-nothing scenario, Great Britain maintains the existing retained EU CO_2 regulations. For cars, this results in 15% and 37.5% gCO_2/km reductions in 2025 and 2030 respectively compared to a 2021 baseline. For vans, this results in a 15% and 31% gCO_2/km reductions in 2025 and 2030 compared to a 2021 baseline. Manufacturers can comply via deploying ZEVs or more efficient non-ZEVs.
ZEV targets trajectory	1 – ZEV mandate trajectory + non-ZEV CO_2 requirements	A trajectory of annual ZEV sales targets, plus a flat non-ZEV CO_2 requirement for each manufacturer, based on 2021 data. Trading, banking, two-way credit transfers, and borrowing permitted, with final compliance payments.

Figure 6 Summary of the final policy position

2.43 The policy position summarised in the table above has been refined through extensive stakeholder engagement during both the technical consultation and the final consultation. Further information on the justification for the final policy position can be found in the supporting Government response to the consultation.

2.44 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, but the Government is clear that the second phase of the ZEV mandate (including subsequent annual targets from 2031 to 2035) will be implemented. This is set out in the joint response to the consultation.

Counterfactual scenario

2.45 Under the current 'Do nothing' policy option, current retained EU CO_2 regulations remain[12]; this is the baseline against which the final policy position is 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.

2.46 The details of this option are set out in Table 7. 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 to mitigate disproportionate impacts for smaller businesses and reduce costs.

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 (defined as a manufacturer responsible for registering fewer than 10,000 cars or less than 22,000 vans newly registered per year, multiplied by the % of EU sales occurring in the UK in 2017)) 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 in the combined EU and UK market, multiplied by the % of EU sales occurring in the UK in 2017) can apply for a derogation for the years until 2028 (inclusive). 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.

[12] https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-CO₂-emissions-vehicles/CO₂-emission-performance-standards-cars-and-vans_en

Flexibility mechanism	
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.

Table 7 Summary of the retained EU regulations

Zero emission vehicle uptake in the baseline

2.47 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. Figure 8 and Figure 9 present SMMT's April 2023 registrations outlook for cars and vans respectively.

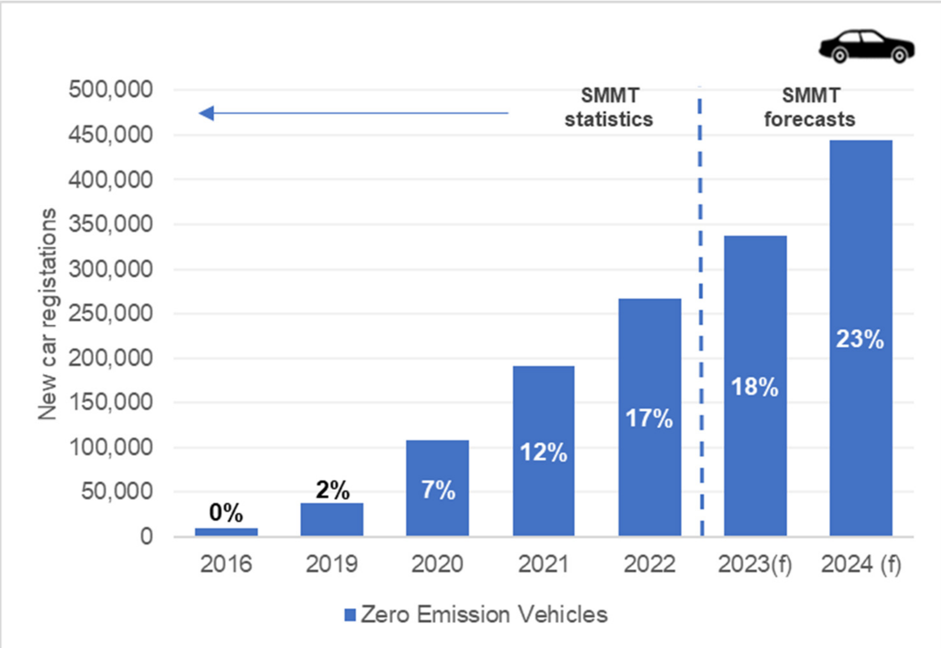


Figure 8 SMMT Zero emission car uptake statistics and forecasts

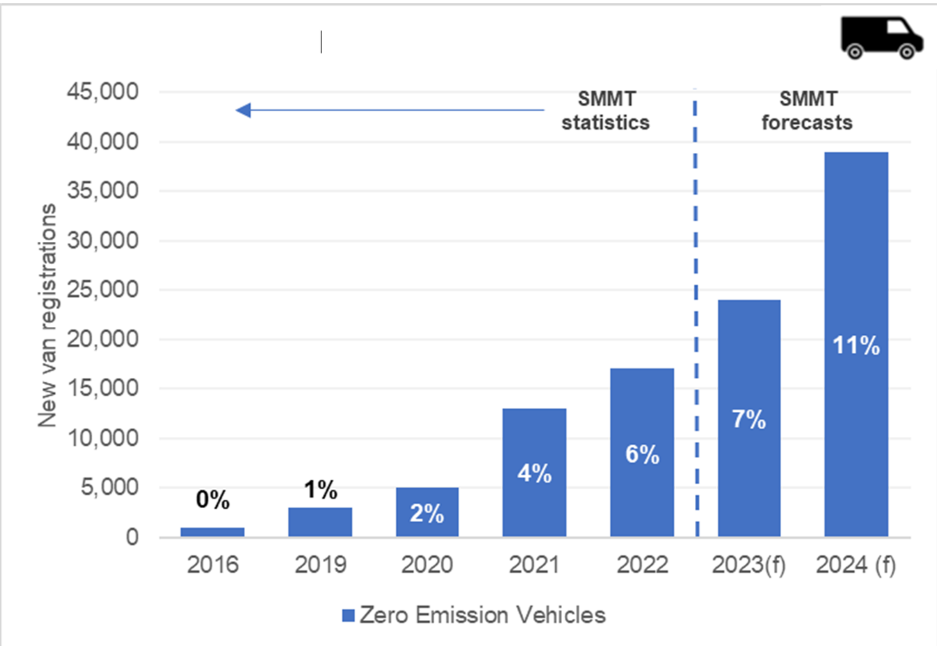


Figure 9 SMMT Zero emission van uptake statistics and forecasts

2.48 DfT produces bespoke projections of ZEV uptake based on vehicle and running costs and a 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).

2.49 These projections are the same as those presented in the final consultation stage analysis. This baseline projection results in an estimate that 42% of new car sales will be ZEVs in 2030, and 12% of vans.

2.50 Since the DfT forecast was last updated, van makes and models have come forward quicker than previously expected, with the SMMT now expecting 11% of van sales to be ZEV by 2024. While DfT is confident in its evidence base and modelling approaches, we will continue to review and develop our approach as the evidence base evolves. The projections of baseline car and van uptake and average carbon intensity are provided in Table 10 and Table 11.

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

Table 10 ZEV baseline uptake for cars and vans (% of new sales)

	2024	2025	2026	2027	2028	2029	2030
Car	158	155	154	153	153	153	153
Van	213	192	192	192	192	192	171

Table 11 Carbon intensity of non-ZEVs in baseline for cars and vans (gCO_2/km).

2.51 Within this baseline, we expect a significant proportion of mileage to come from ZEVs, with 60% of car mileage to be zero emission by 2050, and 44% for vans. However, under this baseline, there is an inadequate reduction in CO_2 emissions from cars and vans; significantly lower than that assumed in the Carbon Budget Delivery Plan (CBDP). Therefore, the baseline position is incompatible with the Government's plans to achieve the UK's legally binding net zero commitments and interim carbon targets.

Changes to the policy since the consultation

2.52 The Government's final policy position has been informed based on extensive feedback from stakeholders throughout the final consultation. For both the ZEV mandate and CO_2 regulations, scheme functions are unchanged, but there are some small, technical, and targeted updates. Table 12 summarises the changes that have had implications for the analysis.

Component of policy design	Change to the policy
CO_2 emissions baseline target	Some vehicle manufacturers have devoted significant resources to reducing the CO_2 emissions of their non-zero emission vehicles in the years leading up to 2024: it is reasonable to consider these efforts in the non-ZEV CO_2 emissions standard baseline. Those manufacturers who complied with their target in 2021 (i.e., did not receive a penalty in 2021) will have a baseline set at the higher of their non-ZEV average emissions in 2021 or their 2021 regulated target. A manufacturer who failed to meet their 2021 target (i.e., received an excess emissions premium in 2021) will receive a baseline as per the above, reduced by the percent by which they exceeded their 2021 target. This methodology for the baseline will provide short term support for manufacturers on the transition to ZEVs.
Van targets	The ZEV mandate van targets proposed in the consultation followed a non-linear trajectory between 2024-2027. The van targets for 2025 and 2026 have now been amended to produce a smoother path.
2-way transfers	The cap on 2-way transfers has been increased to 65% in 2024 and 45% in 2025. This will provide manufacturers more flexibility in the transition to ZEVs in the early years of the scheme.

Component of policy design	Change to the policy
Banking/borrowing	The cap on borrowing of van allowances has increased to 90% in 2024. This recognises the current challenges faced in this segment of the market by offering additional flexibility in the first year of the ZEV mandate for vans.
Final compliance payment	For vans, payments are reduced to £9,000 for vans only in 2024 only, rising to £18,000 for the rest of the regulation's timeframe. As a last resort, this reduction in the final compliance payment will reduce the risk to manufacturers of non-compliance.
Regulatory scope	The new regulations will initially apply to England, Wales and Scotland only. Northern Ireland will remain subject to an appropriately scaled version of the existing New Car and Van CO_2 regulations.

Table 12 Significant policy amendments since the final consultation preferred proposal

2.53 All other additional changes included as part of the Government's response to the final consultation are not expected to have a significant impact on the analysis. Further detail can be *Section 3: Policy analysis - Summary assessment of impacts.*

Policy scenario

2.54 This section sets out the final policy scenario. For the car and van market, a set of legally binding annual minimum sales proportions for ZEVs[13] will be placed on vehicle manufacturers. Each year, manufacturers will receive allowances to sell non-ZEVs up to a given percentage of their fleet, with ZEVs accounting for the remainder of sales (the ZEV target). For cars, the ZEV target rises from 22% in 2024 to 80% in 2030, and for vans from 10% in 2024 to 70% in 2030.

2.55 These annual targets raise ZEV sales in each year, relative to the expected baseline level of sales. This will alter the composition of the car and van fleets, 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 target trajectories can be seen in Figure 13, Figure 14, and Table 15.

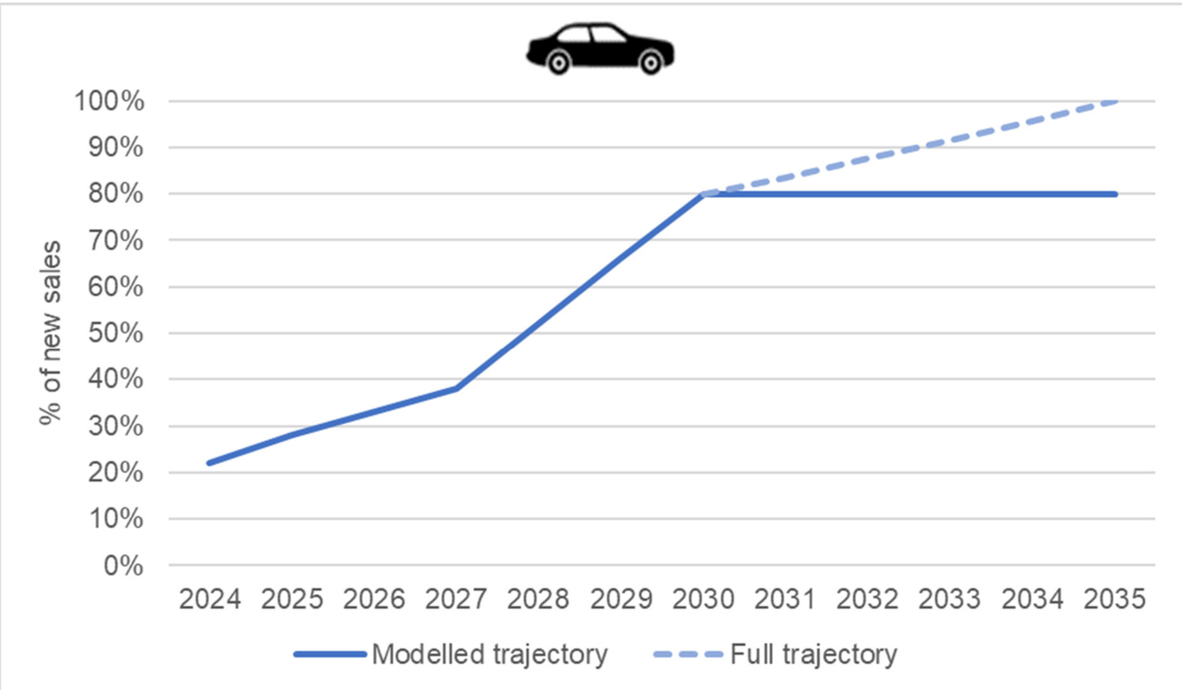


Figure 13 Car manufacturers' annual ZEV targets

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

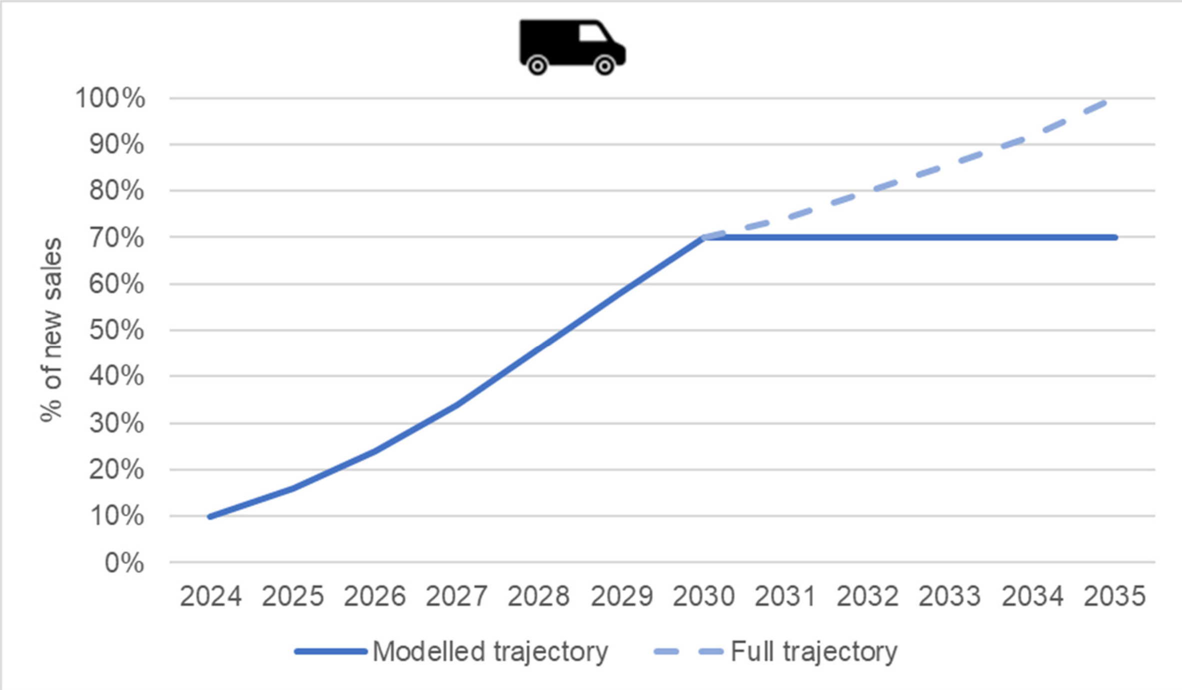


Figure 14 Van manufacturers' annual ZEV targets

	2024	2025	2026	2027	2028	2029	2030
Car	22%	28%	33%	38%	52%	66%	80%
Van	10%	16%	24%	34%	46%	58%	70%

Table 15 Car and van manufacturers' annual ZEV targets

2.56 The proposed targets to be introduced in the second phase of legislation, described as 'full trajectory' in Figure 13 and 14, are shown for illustrative purposes only and are not modelled within this analysis.

2.57 In addition, new non-ZEV CO_2 regulations will be introduced alongside the ZEV mandate. Manufacturers will be set a baseline average CO_2 emissions target (gCO_2e/km) for the non-ZEV sales in each year. Those manufacturers who complied with their target in 2021 (i.e., did not receive a penalty in 2021) will have a baseline set at the higher of their non-ZEV average emissions in 2021 or their 2021 regulated target. A manufacturer who failed to meet their 2021 target (i.e., received an excess emissions premium in 2021) will receive a baseline as per the above, reduced by the percent by which they exceeded their 2021 target. This will remain constant out to 2030. 2021 is chosen in order to give the necessary time needed to process emissions performance data by the intended implementation year of 2024.

2.58 Manufacturers will be permitted to meet their targets in each scheme by increasing ZEV sales each year, whilst also ensuring no regression on their non-ZEV CO_2 efficiencies. Small and micro volume manufacturers may be derogated from targets, with some further exemptions for special purpose vehicles (SPVs).

2.59 A tradeable element of the scheme is also required under the Climate Change Act 2008. In accordance with these powers, 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 new regulatory framework, without limit. 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.

2.60 There are also several additional policy flexibilities that will provide manufacturers with alternative options to meet compliance; intended to mitigate risks associated with product investment cycles and uncertainty regarding sales volumes.

2.61 Manufacturers are permitted to ‘bank’ surplus allowances for use in subsequent years, or ‘borrow’ a limited number of allowances from future years for a time-limited period, subject to a 3.5% compounding interest rate.

2.62 Manufacturers will also be permitted to transfer surplus allowances between the ZEV and non-ZEV elements of the scheme, subject to certain limitations.

2.63 Some manufacturers may be considered to be a group of connected entities; if a manufacturer has voting rights, inter alia, over one or more other manufacturer’s 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 pool together and be treated as a single participant under the scheme, rather than multiple individual entities.

2.64 Manufacturers failing to meet compliance through this mix of opportunities would be required to make a final compliance payment for each vehicle sold that is not covered by an allowance or a credit. The payments may lead to additional costs to business, but it is required to provide sufficient incentive for firms to comply with the regulation. It should be noted that, as set out in Table 7, similar payments exist in the current baseline regulations.

2.65 Further information on the specifics of each flexibility measure can be found in the Joint Government response to the consultation.

3. Policy analysis

Analytical approach

3.1 This section includes a comprehensive assessment of the carbon savings achieved by the policy, and a cost-benefit analysis. The underlying analysis utilises the same core modelling pipeline and evidence base as in the consultation stage analysis, with some small refinements. Nevertheless, the conclusions of our analysis remain unchanged; the policy is expected to deliver significant carbon savings and net social benefits in the billions of pounds. For proportionality, this analysis avoids duplication and references the consultation analysis where relevant.

Updates to the analysis

3.2 The refinements to our analysis have been made based on an assessment of proportionality and robustness. We look to continually develop our evidence base and assumptions to ensure that the analysis continues to provide decision makers with the confidence in expected policy outcomes. This analysis incorporates all changes to the policy position from the consultation position.

3.3 We have also expanded our modelling tools to include energy systems modelling, in order to highlight the upstream implications of changes to the energy system. This analysis has been undertaken in collaboration with DESNZ, using two core strategic models: the Dynamic Dispatch Model, which estimates the social impacts of electricity generation, dispatch and transmission; and the Distribution Network Model, which estimates the social impacts of maintaining the electricity distribution network. While the energy system impacts can be directly attributed to the ZEV Mandate, broader net-zero planning already accounts for the full electrification of zero emission cars and vans. Consequently, these costs are not strictly ‘additional’ to society and the exchequer as they are included in the forecast long run variable costs (LRVCs) of energy supply used in the central modelling. Therefore these costs have been included as a sensitivity.

Scope of the analysis

3.4 The scope of analysis covers the impacts delivered by these regulations. This policy implements a ZEV mandate which begins in 2024, increasing ZEV targets up to and including 2030 and includes requirements for the non-ZEV fleet to either make limited improvements or to maintain the current level of efficiency from a 2021 baseline.

3.5 For the purposes of the Cost Benefit Analysis (CBA), as we are solely considering this first phase of legislation: trajectories are assumed flat after 2030. We will introduce further legislation covering the period post-2030 at a future date.

3.6 Equally, this analysis does not include the impact of requiring all new cars and vans to be fully zero emission by 2035. The implementation of this will require separate future legislation, and therefore it has not been incorporated into this analysis.

3.7 As noted in *Section 2: Policy and analysis overview*, the regulations will apply across England, Wales and Scotland. Therefore, the scope of this analysis covers Great Britain, as opposed to the consultation stage analysis which assumed a policy proposal for the United Kingdom. It remains the policy intention of the Department for Infrastructure in Northern Ireland, along with the UK Government, Scottish Government, and Welsh Government, for Northern Ireland to join the ZEV mandate and for it to be a UK-wide scheme. Given this, results for a future UK-wide scheme are presented as a sensitivity in *Section 3: Policy analysis - Sensitivity analysis*.

3.8 For simplicity and proportionality, this analysis monetises the costs and benefits of the deployment of zero emission vehicles assuming all ZEVs are Battery Electric Vehicles (BEVs). This assumption is considered appropriate as currently ZEV cars and vans deployed in the UK are almost exclusively BEVs. Furthermore, manufacturer strategies for future deployment of zero emission vehicles in the UK and the rest of Europe are also currently dominated by battery electric vehicles. However, other ZEV technologies are available and could be deployed under this mandate.

3.9 The evidence base on BEVs is also the most well developed and therefore it is easiest to quantify the impacts of these powertrains. However, the Government remains technologically neutral and results focussed in terms of decarbonisation; powertrains must be zero emission at the tailpipe, but there is limitation on the technology that powertrain uses.

3.10 This document reports the environmental impacts of car sales from 2024 – 2050, resulting from the targets set in these regulations. This is intended to reflect the direct impact of the regulations in this consultation on the UK's progress against its emissions reduction targets, up to net zero in 2050. Nevertheless, there is a recognition that reducing carbon emissions post-2050 will remain critically important in order to mitigate the effects of long-term climate change. Therefore, environmental impacts post-2050 are included in the underlying analysis.

3.11 The policy's costs and benefits are appraised over 2021-2071 to account for the impacts of a vehicle (a capital asset) through its lifetime as they drive on the roads. 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.[14]

3.12 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. The temporal parameters of the analysis are set out in Table 16 below.

Modelling time horizon assumptions	Year

[14] 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.

Policy development + consultations + laid in parliament	2020 – 2023
First Year policy is in force	2024
Switching the composition of new car and van sales towards 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 as estimated in DfT 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

Table 16 Analysis temporal parameters

Summary of impacts

3.13 Our analysis separates quantified costs and benefits from the ZEV mandate into two categories of impacts. Direct impacts are the impacts forecast if there is no behaviour change from those affected. It measures the costs and benefits of replacing ICEVs with ZEVs, the cost of recharging infrastructure plus the costs of administering the scheme.

3.14 In addition, some impacts can be identified as 'indirect', as they result from behaviour change which may follow 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).

3.15 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 indicates the costs and benefits that might occur if future policy interventions were designed to mitigate the potential congestion impacts of electric vehicles.

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

3.17 Table 17 sets out the estimated direct, monetised costs of the regulations. These include costs to society, business, and Government, and both transitional and ongoing costs.

3.18 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.

Impact	Transition/On-going	Impact on	Description
Capital cost[15]	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.
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/	Cost to install necessary charging infrastructure.

[15] 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.

Impact	Transition/On-going	Impact on	Description
		Business/ Government	
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.[16]
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.
Distribution Network Changes	Transition + On-going	Social/Government	Additional costs associated with reinforcement of the high and low voltage distribution network, and associated disruption costs. This impact has been considered as a sensitivity test, set out in *Section 3: Policy analysis - Sensitivity analysis.*

Table 17 Summary of direct monetised costs of the regulations

3.19 Equally, Table 18 shows the indirect, monetised costs of the regulations. In theory, both energy system and traded carbon costs are direct and indirect costs; this is because 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.

Impact	Transition/On-going	Impact on	Description
Congestion	On-going	Social	The time and reliability externality impact of higher road congestion due to greater miles travelled through the switch to ZEVs.
Traded carbon – additional consumption	On-going	Social	As above, but this relates to the additional social cost caused greater miles travelled through the switch to ZEVs.
Accidents	On-going	Social	The damage cost externality of a higher frequency of accidents on the roads due to more miles travelled from the lower fuel cost of driving ZEVs.
Additional Tax	On-going	Government	Changes in tax revenue caused by changes in driving behaviour and subsequent changes in fuel duty/VAT revenue.[17]

Table 18 Summary of indirect monetised costs of the regulations

3.20 There are also impacts that have not been monetised as part of this analysis. This is due to either gaps in the evidence-base, or in the interest of proportionality. These are listed in Table 19.

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

[16] 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.

[17] 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).

Impact	Transition/On-going	Impact on	Description
			become heavier due to battery sizes) and additional induced driving demand.[18]
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).[19]
Garages, traders, dealerships	On-going	Business	Additional training required to sell ZEVs. Additional training required to maintain, repair, and service ZEVs.

Table 19 Summary of unmonetised costs of the regulations

3.21 Table 20 presents the direct, monetised benefits of the policy. As set out above, capital costs feature as both benefits and costs. Several benefits (e.g. operating cost savings, fuel savings) are identified as 'social' benefits, but these will also have a material benefit on individual households, in the form of greater disposable income due to overall vehicle cost savings, in many cases. These net savings are discussed in greater detail in *Section 5: Wider Impacts.*

Impact	Transition/On-going	Impact on	Description
Carbon savings (traded and non-traded)	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. This also captures costs associated with increasing the capacity of the electricity generation network. The alternative method for calculating fuel savings has been consider in a sensitivity set out in *Section 3: Policy analysis - Sensitivity analysis.*
Capital cost savings[20]	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.

Table 20 Summary of direct monetised benefits of the regulations

3.22 Table 21 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.

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.

[18] 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. Given this scale it was also not deemed proportionate to quantify the impact of EVs making the fleet heavier, and the impact this has on road wear and tear.

[19] 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

[20] 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.

Impact	Transition/On-going	Impact on	Description
Indirect tax	On-going	Social	Additional benefit of increased tax revenue from additional ZEV trips.

Table 21 Summary of indirect monetised benefits of the regulations

3.23 Finally, Table 22 sets out the unmonetised benefits of the regulations. 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.

Impact	Transition/On-going	Impact on	Description
Jobs/Growth	On-going	Social	Additional jobs in the economy / additional gross-value added to the 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.

Table 22 Summary of unmonetised benefits of the regulations

3.24 Costs and benefits are calculated in 2021 prices and discounted to 2022 values, in accordance with Green Book guidance. The core policy appraisal assumes full, on-time compliance. Furthermore, there is significant uncertainty associated to individual manufacturer's compliance strategies, and the degree to which they may utilise flexibilities. For this reason, flexibilities are not included in the core policy assessment of carbon impacts or the appraisal and are considered separately as a sensitivity. More detail can be found in *Section 4: Policy risks.*

Summary assessment of impacts

3.25 The primary strategic objective of this policy is to reduce carbon emissions. Table 23 presents the total non-traded carbon savings, estimated net of the counterfactual. The final policy position is estimated to have a significant impact in reducing carbon emissions over carbon budget period 5 and 6 and between the period 2024-2050.

	Policy carbon savings $MtCO_2e$ (non-traded)
CB4 (2023-2027)	0
CB5 (2028-2032)	28
CB6 (2033-2037)	77
2024 – 2050	411

Table 23 Total non-traded carbon savings from cars and vans

3.26 The cost-benefit analysis appraisal estimates that these carbon savings are both cost-effective and contribute to net social benefits achieved after accounting for all impacts. See *Section 3: Policy analysis - Non-traded cost comparator benchmark* for detail on the cost-effectiveness of the emission reductions.

3.27 A cost range is provided to reflect uncertainty associated with the magnitude of the rebound effect. In this context, the rebound effect is the change in travel demand induced due to a lower cost of travel. As ZEVs typically have lower running costs than non-ZEVs there may be a resultant increase in miles driven. Further discussion on this effect can be found in *Section 3: Policy analysis - Indirect costs and benefits.*

3.28 Table 24 shows the direct monetised impacts for the policy when excluding the rebound effect. The combined benefits for cars and vans delivers a Net Present Value (NPV) of £116 billion, with Present Value Benefits (PVB) of £166 billion and Present Value Costs (PVC) of £50 billion. Both the cars and van markets deliver positive Net Present Value over the appraisal period.

	Impact £m (present value, discounted; 2021 prices)	Policy Impact
Car	Benefits	128,652
Car	Costs	-41,444
Car	Net present value	87,208
Van	Benefits	37,833
Van	Costs	-8,974
Van	Net present value	28,859
Both	Benefits	166,485
Both	Costs	-50,418
Both	Net present value	116,067

Table 24 Expected present value direct monetised impacts excluding the rebound effect (£m, 2021 prices)

3.29 Similarly, Table 25 presents the same impacts but includes the indirect impacts associated with the rebound effect – the most important of which is increased congestion. Even with a significant increase in costs as a result of the rebound effect, the combined benefits for cars and vans deliver a Net Present Value (NPV) of £39 billion. This includes Present Value Benefits (PVB) of £166 billion and Present Value Costs (PVC) of £127 billion. Again, both the cars and van markets deliver positive Net Present Value over the appraisal period.

	Impact (present value, discounted; 2021 prices)	Policy impact
Car	Benefits	128,652
Car	Costs	-95,474
Car	Net present value	33,178
Van	Benefits	37,833
Van	Costs	-31,790
Van	Net present value	6,043
Both	Benefits	166,485
Both	Costs	-127,264
Both	Net present value	39,221

Table 25 Expected present value direct monetised impacts including the rebound effect (£m, 2021 prices)

3.30 In both cases, the policy is expected to achieve good value for money. To test the resilience of the policy's efficacy and value for money, alternative cost scenarios have been considered in *Section 3: Policy analysis - Sensitivity analysis*.

3.31 This analysis of the final policy position broadly accords with the results of the consultation stage analysis. Table 26 presents the impact on carbon savings driven solely by the

limited number of analytical refinements (see Annex B for detail), without changes to policy assumptions.

	Change in carbon savings $MtCO_2e$
CB4 (2023-2027)	0
CB5 (2028-2032)	-2
CB6 (2033-2037)	-2
2024 – 2050	7

Table 26 Change in carbon savings ($MtCO_2e$) due to analytical refinements

3.32 In addition to the analytical refinements, amendments to the policy following the consultation stage have resulted in relatively small impacts. The change in carbon savings and monetised impacts from policy amendments is presented in Table 27 and Table 28 respectively.

	Change in carbon savings $MtCO_2e$
CB4 (2023-2027)	0
CB5 (2028-2032)	-1
CB6 (2033-2037)	-2
2024 – 2050	-12

Table 27 Change in carbon savings ($MtCO_2e$) since the final consultation preferred proposal, accounting for analytical refinements

		Change in policy impact (with rebound effect)	Change in policy impact (without rebound effect)
Car and van	Benefits	-5	-5
Car and van	Costs	-3	-1
Car and van	Net present value	-1	-2

Table 28 Change in the net present value since the final consultation preferred proposal, accounting for analytical refinements (£bn, 2021 prices) [21]

3.33 The majority of this change is driven by moving from a proposed UK wide scheme to a GB only scheme. A sensitivity test assessing the future UK wide scheme is presented in *Section 3: Policy analysis - Sensitivity analysis.*

Detailed analysis of the policy

3.34 This section sets out a detailed explanation of the anticipated impacts of the policy.

Costs

Administration costs

3.35 The regulations 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.

[21] Figures may not sum to total due to rounding

3.36 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.

3.37 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.

3.38 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.

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

3.40 The UK Government will be responsible for meeting the costs associated with both administering and monitoring 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.

3.41 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.

3.42 The central costs expected to be faced by manufacturers and Government are presented in Table 29. Also presented are the low and high estimates of administrative costs used in the overall cost sensitivities.

		Set-up costs	Ongoing	Total
Manufacturer	Cars	8	0	8
Manufacturer	Vans	1	0	1
Manufacturer	Total	9	0	9
Government	Cars	6	15	21
Government	Vans	1	2	3
Government	Total	7	17	24

Table 29 Net administrative costs for cars and vans (present value, 2021 prices; £m)

Capital costs

3.43 A direct impact of the regulated targets is the cost of supplying more ZEVs into the market. A price differential exists for ZEVs vs non-ZEVs currently on the market. Although this

differential is expected to decrease significantly in coming years, primarily driven by the continued development of battery packs, this analysis assumes that a small cost premium will persist (see assumptions in Annex C for more detail).

3.44 Any indirect effect – cost 'pass-through' – could occur through higher consumer prices 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 to model this second order effect, given the differences in individual manufacturer competition strategies and heterogeneity of vehicle products.

3.45 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 5: Wider Impacts.* 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 are expected to be even greater for those purchasing BEVs on the second-hand market.

3.46 The impact to industry is quantified in each year by estimating the total capital value of the sales mandated to switch to ZEVs versus those non-ZEVs they replace in the baseline.

3.47 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 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 estimate a central impact of ~£27bn (2021 prices, discounted) increased cost to industry across the appraisal period.

Vehicle type	Value	Net cost, £m
Car	Capital Cost	25,294
Van	Capital Cost	1,827

Table 30 Present value capital costs for cars and vans (present value; 2021 prices; £m)

3.48 These costs are significant, but it is important to consider their scale relative to the overall car and van market. 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 published by industry bodies; for instance, SMMT suggests that in 2021 UK automotive manufacturing turnover was roughly £67bn in 2021 prices; approximately 80% of UK car production is exported.[22]

3.49 Accounting for the large size of the UK auto sector shows that, while significant, the marginal increase in capital costs is small relative to overall UK car manufacturing costs and turnover. It is estimated that ZEV mandate capital costs are equivalent to 2.7% of overall capital costs from 2024 – 2050, which constitutes 1.9% of expected turnover. For vans, the figures are 0.4% and 1.0%, respectively. Given that nearly 90% of new UK car registrations are imported[23], it is highly unlikely that all of these costs would fall on UK manufacturers. As such this presents a significant overestimate of the potential

[22] https://www.smmt.co.uk/industry-topics/europe-and-international-trade/key-exports-data/#:~:text=Key%20Exports%20Data%201%20Countries%20all%20over%20the,2020%2C%2061%25%20of%20all%20engines%20made%20in%20Britain

[23] https://www.smmt.co.uk/wp-content/uploads/sites/2/SMMT-Automotive-Trade-Report-2020.pdf

proportional impact, but this provides an indication of the relative cost and suggests that the overall impact on the automotive manufacturing sector is not likely to be disproportionate.

3.50 Under 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 3: Policy analysis - Sensitivity analysis.*

Infrastructure costs

3.51 The ramp-up in ZEV sales will require significant infrastructure investment to provide sufficient charging capacity. As this policy imposes a direct increase in demand for chargepoints, estimates of the associated costs are included in the cost benefit analysis.

3.52 This analysis focuses on electric chargepoints, which are the dominant form of ZEV infrastructure in 2023. However the Government recognises that infrastructure to support other types of ZEVs such as hydrogen refuelling stations or battery swapping may also be developed and deployed.

3.53 Chargepoint demand is estimated based on internal government analysis that combines the expected increase in take-up of electric-powered vehicles, with a range of assumptions regarding consumer charging behaviour. It should be noted that chargepoint demand could vary depending on a number of variables, such as current and future consumer behaviour, and the state of future battery technology. These determinants are inherently uncertain and subject to change over time. Nevertheless, the modelling utilises the best currently available evidence and the assumption that current charging behaviour is representative of future behaviour to estimate chargepoint requirements.

3.54 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 to estimate the up-front and ongoing infrastructure costs.

3.55 A ‘baseline’ chargepoint cost trajectory is deducted from the policy scenario’s trajectory 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 the absence of the ZEV mandate.

3.56 Table 31 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 assumed to be replaced every 10 years). Maintenance costs are incurred annually.

3.57 To reflect the inherent uncertainty surrounding costs of nascent technologies, infrastructure cost sensitivities are included in the upside and downside sensitivities presented in *Section 3: Policy analysis - 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.

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

Table 31 Chargepoint cost assumptions[24]

3.58 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 driven. However, in keeping with HMT Green Book guidance, this policy is appraised over a fixed time period, ending in 2071.

3.59 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.

3.60 The resulting present value costs associated with infrastructure requirements are presented in Table 32, below. It should be noted that these costs include the private costs borne by those installing and maintaining the chargepoints, i.e. predominantly households and businesses; these are not costs to Distribution Network Operators (DNOs). There are also additional costs of reinforcing the electricity grid that are captured within the electricity price forecasts used in this analysis. These costs are discussed in more detail in *Section 3: Policy analysis - Sensitivity analysis* and Annex L.

Vehicle type	Cost type	Net cost (£m)
Car	Capex	8,467
	Opex	1,722
	Total	10,189
Van	Capex	2,434
	Opex	554
	Total	2,988

Table 32 Present value infrastructure costs (present value; 2021 prices; £m)

Tax impacts

3.61 There are a number of anticipated changes in tax revenues as a result of the policy. 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.

3.62 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 to the benefit to the other, leading to no net change in social welfare.

[24] 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.

3.63 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.

3.64 In line with the Transport Analysis 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.

Power train	Unit	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Car	£m	107	138	144	111	-119	-544	-1123	-1634	-2077	-2458	-2784	-3066
Van	£m	-29	-27	-70	-161	-309	-508	-653	-787	-896	-985	-1057	-1122

Table 33 Tax revenue transfers, fuel duty and VAT (2021 prices, discounted; negative values imply a reduction in tax revenue)

3.65 Following the 2022 Autumn statement, Vehicle Excise Duty (VED) has been updated to broadly equalise the average amount of tax paid for ZEVs and non-ZEVs. This update from 2025 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 due to VED.

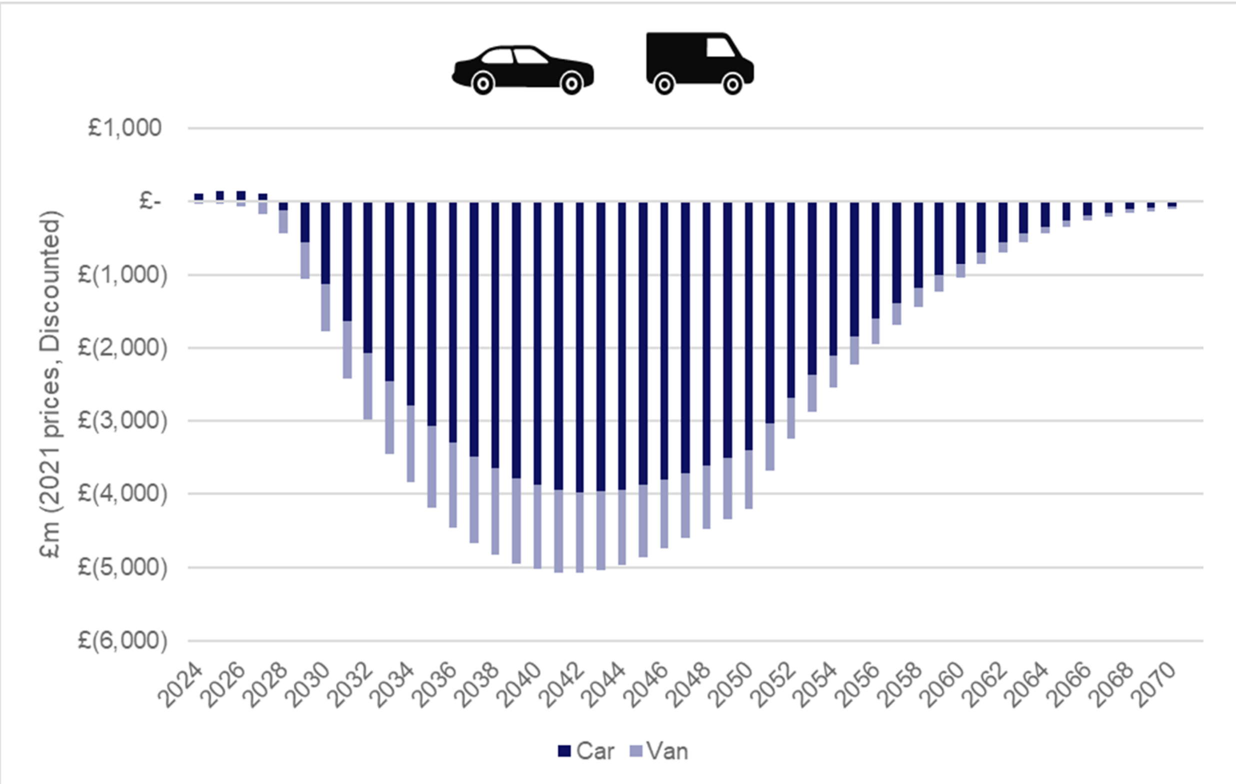


Figure 34 Tax revenue transfers (VED + fuel duty) under the ZEV mandate

3.66 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 the rebound effect[25] is expected to lead to an increase in

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

Government VAT revenues from electricity consumption, compared to a world with no ZEV Mandate.

3.67 Unlike the change in fuel duty and VAT revenues described above, this increase in VAT revenue and fuel duty from additional mileage 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 and fuel duty (for the switch to a lower running cost non-ZEV), there is an increase in tax revenue in addition to the private cost and benefit (which are equal) to the consumer.

3.68 The increase in VAT revenue resulting from increased electric mileage per driver is therefore included in the monetised appraisal and shown in Table 35. Unlike tax transfers, this additional impact is included in the monetised appraisal.

Vehicle type	Net cost (£m)
Car	-3,222
Van	-2,529

Table 35 VAT revenue associated with the rebound effect (Present value; 2021 prices; £m)

Benefits

Carbon impacts

3.69 These regulations lead to a significant change in the fuel consumption of the 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 shown in Figure 36, the net impact is a significant reduction in total Terrawatt hours (TWh) energy demand – driven by the greater fuel efficiency of electric vehicles.

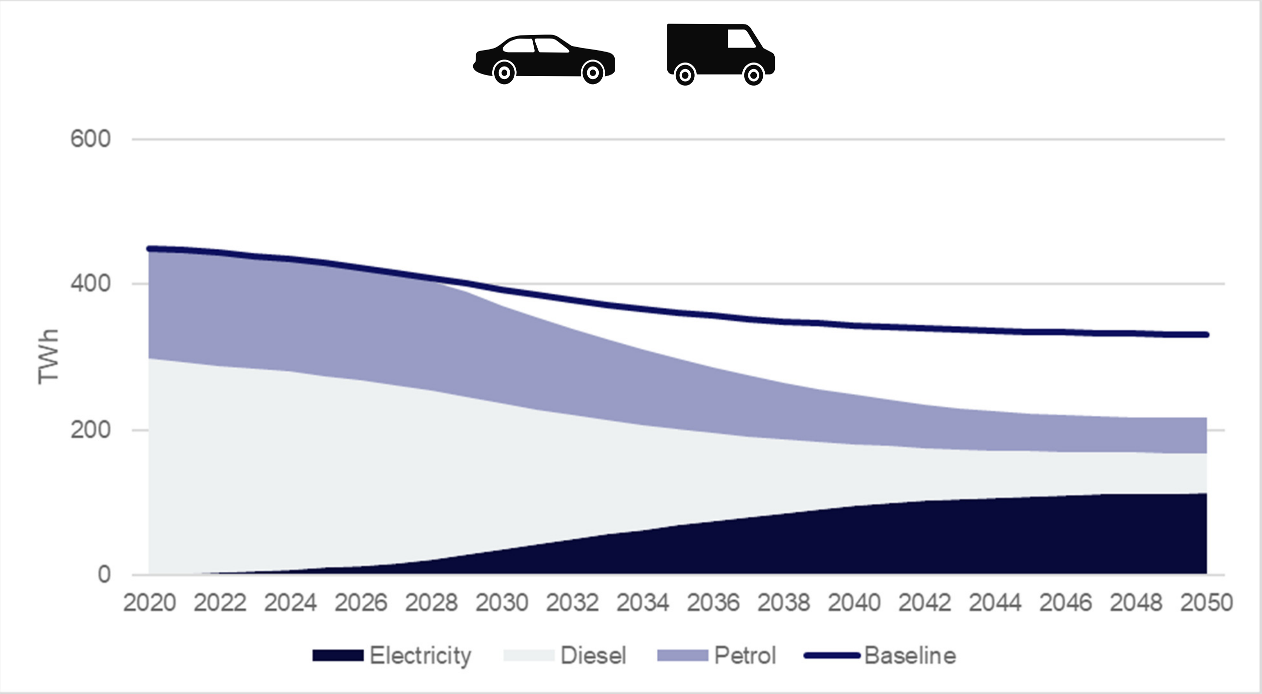


Figure 36 Changes in energy demand by fuel type for cars and vans (TWh)

3.70 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 are classified as traded emissions.

3.71 The transition in energy consumption shown in Figure 37 leads to significant changes in emissions: the reduction in consumption of petrol and diesel reduces non-traded emissions, whereas the increase in electricity demand will come with an additional, albeit much smaller, cost of increased traded emissions (shown in Figure 39 and Figure 40), until electricity generation completely decarbonises.

3.72 The increase in traded emissions is quantified using DESNZ published electric grid intensity factors (shown in Figure 37) and estimates of increased electricity demand.

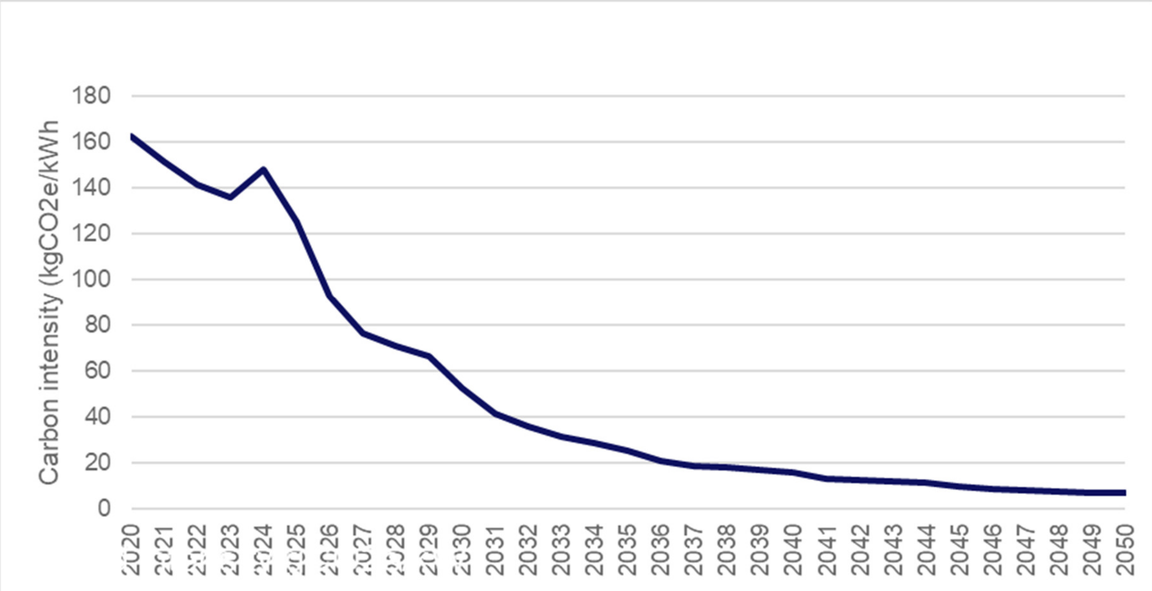


Figure 37 Electricity generation emissions intensity[26]

3.73 As shown in Figure 38 and Figure 39 non-traded emissions savings far outweigh traded emissions costs, leading to overall emissions savings which peak at roughly 25 $MtCO_2e$ around 2045.There are several drivers of this: firstly, ZEV fuels are more efficient than ICEVs in joules; 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 less than that of petrol and diesel consumption and is expected to decline significantly over the next few decades, with increasing grid decarbonisation. This is the reason that traded emissions peak and begin to decline around 2035, despite that the number of ZEVs in the fleet continuing to grow.

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

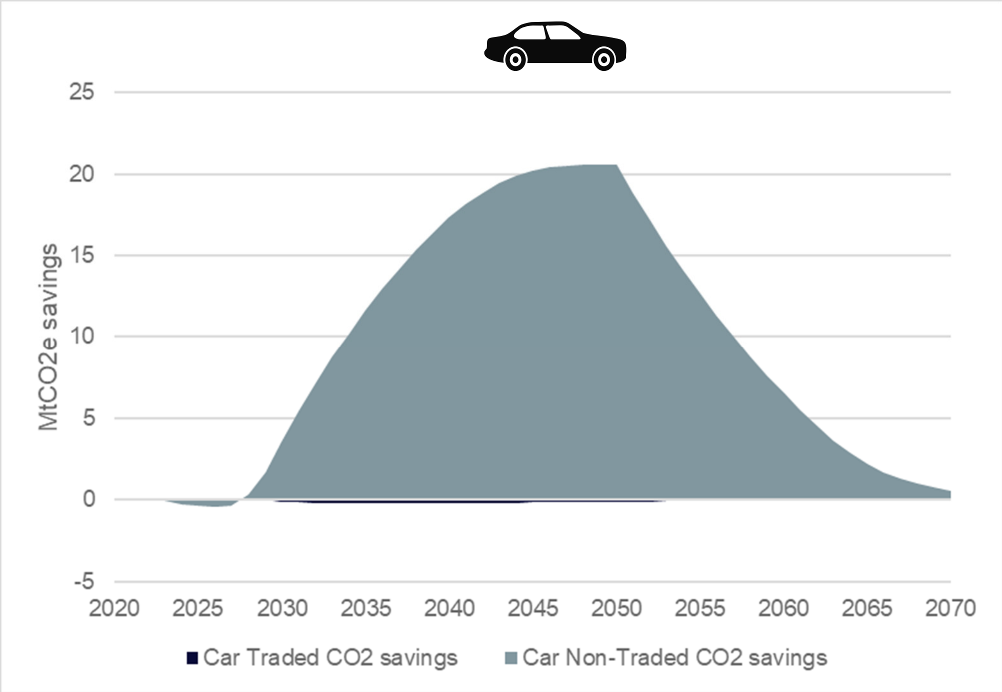


Figure 38 Annual car traded and non-traded emissions savings for the ZEV mandate

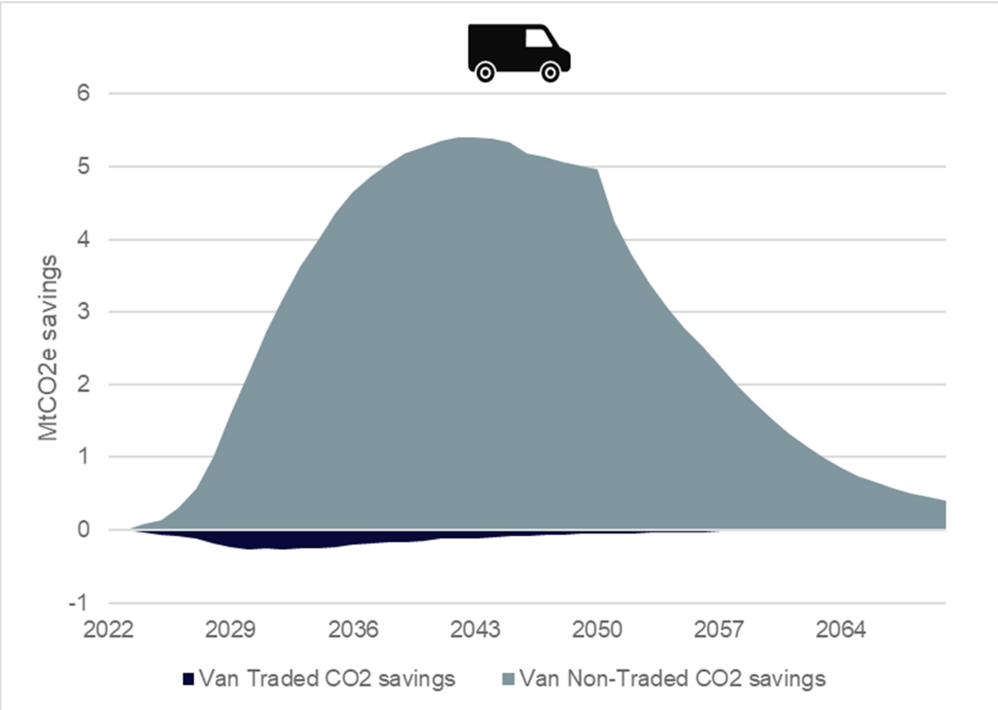


Figure 39 Annual car traded and non-traded emissions savings for the ZEV mandate

Vehicle type	Emission type	Net benefit (£m)
Car	Traded CO_2e	-727
Van	Traded CO_2e	-862
Car	Non-Traded CO_2e	79,083
Van	Non-Traded CO_2e	23,859
Car	Net impact	78,355
Van	Net impact	22,996
Both	Net impact	101,351

Table 40 Traded and non-traded monetised impacts for cars and vans (present value; 2021 prices; £m)

3.74 These impacts are monetised using the cross government carbon appraisal values and are discounted in line with Green Book Appraisal Guidance.

3.75 The traded and non-traded carbon abatement and monetised impacts are presented in Table 40. As shown, non-traded emissions savings and benefits far outweigh the increase in traded emissions. The net effect is expected to be just over £100bn in social benefits (for cars plus vans), and 27 $MtCO_2e$, 75$MtCO_2e$, and 407 $MtCO_2e$ in CB5, CB6, and 2024 – 2050, respectively.

Fuel impacts

3.76 The regulations 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 Green Book and Transport Analysis Guidance.[27]

3.77 Under the ZEV mandate, 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 regulations lead to a resource benefit to society.

Vehicle type	Value	Net benefit (£m)
Car	Fuel Cost	34,583
Van	Fuel Cost	4,151

Table 41 Fuel cost to society (present value; 2021 prices; £m)

3.78 However, there are uncertainties associated to the relative forecasts of different fuel costs, due to a range of global shocks which could affect both supply and demand for each fuel. These shocks are largely transient and result in fluctuations around a long-run trend. Given the ZEV mandate represents only a marginal proportion of an overall rise global ZEV demand, it likely that global supply and demand for these fuels will be more closely aligned with DESNZ's baseline projections, which reflect the long-term supply capacity for these fuels.

Vehicle operation impacts

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

3.80 Analysis published by EDF Energy suggests that features such as regenerative braking (which reduces wear and tear on wheel brakes) and the smaller number of moving parts leads to lower costs of servicing and replacing worn components for ZEVs. 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.

[27] DESNZ have since updated their long run variable costs of energy supply. The new series shows larger differences in the value of petrol/diesel relative to electric fuel costs, in all future years, than those assumed in this analysis, and therefore it is likely that fuel benefits are underestimated.

3.81 Because these regulations 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 savings for the Preferred Option are shown in Table 42. As shown, the cost savings are significant for both cars and vans. In combination with the fuel costs savings set out previously 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 5: Wider impacts - Cost of living.*

3.82 Estimated net operating cost savings are presented in Table 42. As shown, these are expected to amount to more than £15bn over the appraisal period, representing a significant cost saving to drivers.

Vehicle type	Value	Net benefit (£m)
Car	Operating Cost Savings	9,370
Van	Operating Cost Savings	5,974

Table 42 Operation cost savings for cars and vans (present value; 2021 prices; £m)

Air quality impacts

3.83 An uptake in ZEV policies 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.[28] Differences in air quality impacts stemming from non-exhaust PM are more complex, uncertain, and mixed. Air quality impacts have been calculated using the National Transport Model. Further detail on the uncertainty around this issue can be found in Annex A.

3.84 Air quality impacts are discounted using Health discount factors, in line with DfT's Transport Analysis Guidance. The resulting estimated air quality impacts are presented in Table 43; 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.

3.85 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.

Vehicle type	Air quality impact type	Net benefit (£m)
Car	NOx cost	724
Car	PM cost	-312
Van	NOx cost	781
Van	PM cost	-223

Table 43 Present value air quality impacts under the Policy (present value; 2021 prices; £m)

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

Consumer surplus impacts

3.86 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'.[29] Electricity is cheaper at a resource cost level, currently has a 5% VAT rate (for home-consumption) and does not incur fuel duty, so this 'rebound effect' leads to an increase in expected trips and mileage.

3.87 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 44.

Vehicle type	Value	Net benefit (£m)
Car	Consumer Surplus	1670
Van	Consumer Surplus	540

Table 44 Present value consumer surplus benefits (present value; 2021 prices; £m)

3.88 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 5: Wider impacts - Cost of living.*

Unmonetised impacts

Indirect downstream business impacts

3.89 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 these are deemed indirect impacts.

3.90 The impact on these firms is expected to be related to familiarisation with the technology and the cost of training staff, but these one-off costs are deemed to be indirect and expected to be of a low magnitude.

3.91 To understand the scale of these potential indirect impacts, the number of firms related to the motor vehicles are taken from the ONS UK business activity, size, and location statistics. Table 45 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 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.

	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

[29] 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.

	Employment Size Band							
	0-4	5-9	10-19	20-49	50-99	100-249	250+	Total
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

Table 45 Count of businesses expected to be indirectly affected by the ZEV Mandate

Jobs and growth impacts

3.92 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.

3.93 An additional, significant simplifying assumption is that the ZEV mandate policy only affects 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, but it is likely an over-simplification of firms' investment decision. For this reason, as with the consultation analysis, we have not assessed the impact of the ZEV mandate on manufacturing jobs as part of this analysis.

3.94 However, 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, to develop the required infrastructure network and then to maintain it.

3.95 The ZEV chargepoint industry is nascent and therefore there is limited 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).

3.96 Employment and turnover data on the 'Low emission vehicles and infrastructure' sector suggests there are nearly three jobs supported per £m turnover for the industry as a whole, or around two per £m for manufacture and around ten 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) to estimate direct, marginal employment supported by the activity driven by the policy.

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

Table 46 Estimated infrastructure FTE employment supported

3.97 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 46.

3.98 As shown, this analysis suggests that by 2030, employment supported by the infrastructure network alone could total around 12,000 Full Time Equivalent (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, but there will be further reinstallation jobs supported by the replacement of existing chargepoints which have reached the end of their functional lifetime.

3.99 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.

3.100 However, 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 two 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), but it is recognised that this is likely an under-estimate of total jobs.

3.101 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.

3.102 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.

3.103 The overall picture is somewhat unclear, with both potential upside and downside uncertainties, but it is clear that increasing infrastructure demands is likely to support a significant number of jobs.[30] 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.

3.104 These impacts are presented at the national level, but there may be differences in the regional distribution of certain jobs. Employment associated with the installation and maintenance of the charging network is likely to be distributed, but changes in manufacturing may be more regionally concentrated.

Lifecycle emission impacts

3.105 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.

3.106 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.

3.107 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 less emissions associated with maintenance and in particular upstream emissions from fuel production, which is not captured in this assessment.

3.108 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 consulted on addressing 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.

Time saving impacts

3.109 The increase in ZEV uptake is likely to lead to differences in households' and businesses' refuelling behaviour. This is expected to lead to changes in the time required to refuel vehicles, and have subsequent utility impacts for households and cost impacts for businesses. In the consultation analysis, we presented high-level analysis on whether we expected these impacts to be costs or benefits. The analysis concluded that there would be overall benefits, as the vast majority of charging activity would take place while other activities are undertaken, such as overnight or during a shopping trip.

3.110 In the interests of proportionality, the analysis has not been reproduced again here, given we have not received any additional evidence to refine our previous estimates. The

[30] It is possible, however, that other related industries face a contraction if ZEVs have a materially different impact compared to ICEVs.

consultation analysis suggested relatively small time saving benefits of the order of £500m over the appraisal period (2022 prices; present value). As in the consultation analysis, this has not been included in the monetised appraisal.

Indirect costs and benefits

Rebound effect impacts

3.111 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 47 and Figure 48. As the cost of driving for ZEV owners falls, we expect additional driving demand, and therefore additional road traffic and associated costs.

3.112 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 a non-ZEV to a ZEV.

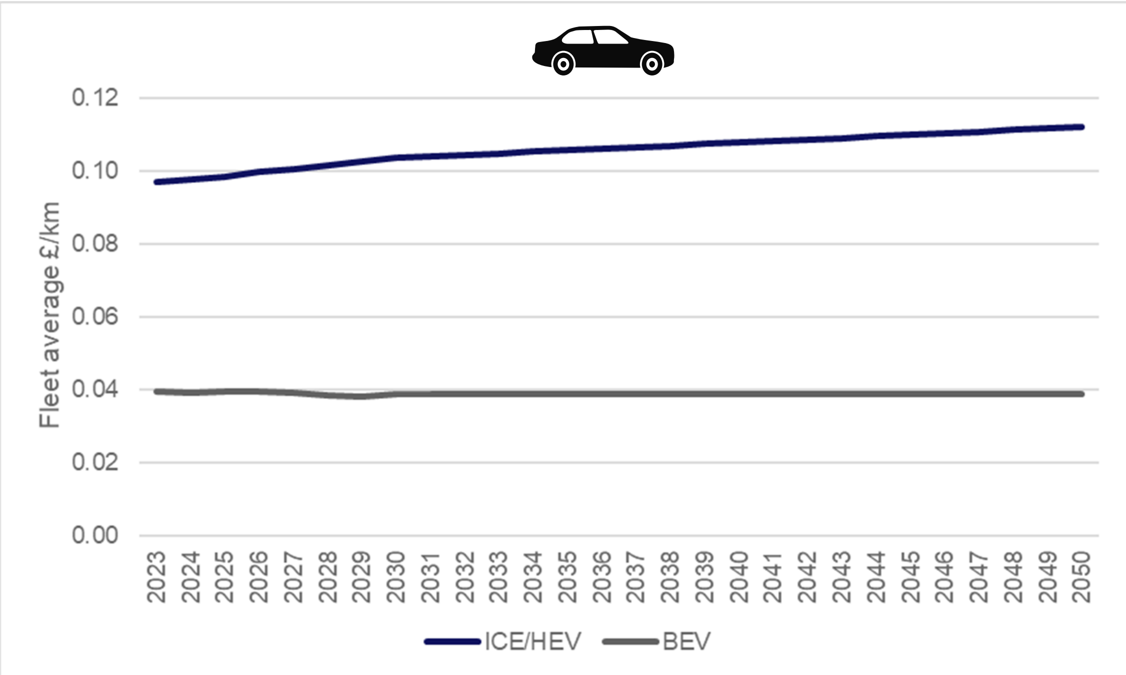


Figure 47 Market price of driving in terms of Pounds per kilometre for cars

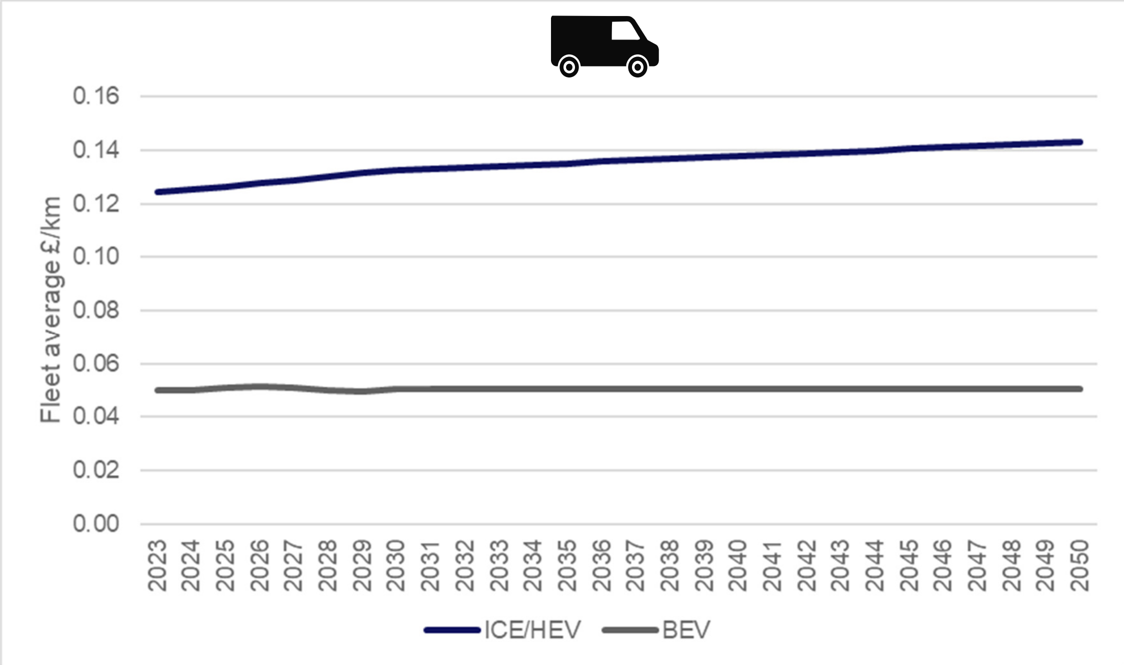


Figure 48 Market price of driving in terms of Pounds per kilometre for vans

3.113 The additional mileage 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. As shown in Table 49, the Congestion and Accident externalities are significant.

Vehicle type	Value	Net cost
Car	Accident Cost	-5,046
Car	Congestion Cost	-53,876
Van	Accident Cost	-2,210
Van	Congestion Cost	-23,676

Table 49 Marginal external costs due to the rebound effect (present value; 2021 prices; £m)

3.114 Quantified impacts associated with indirect VAT revenues and consumer surplus arise due to additional mileage from the rebound effect. Therefore, these are not included in the 'without rebound effect' NPV.

3.115 There is some uncertainty regarding the likely magnitude of any rebound 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.[31]

3.116 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,[32] and the proliferation of connected and autonomous vehicles could be expected to increase the available capacity on the road network, and improve the efficiency and safety of road transport.[33] All these

[31] See Fuel Benefits.

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

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

developments would therefore be expected to reduce the negative externalities associated with induced demand, compared to the direct impacts described here.

3.117 Thirdly, there is inherent uncertainty in the estimates of price elasticity of demand; it is likely the estimates presented here are upwardly biased. This is because the estimate is based on the estimated price-elasticity of demand for transport, which corresponds to the change in demand stemming from a small 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 £ per mile cost, although this varies over time and by fuel type). 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 overestimated.

3.118 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, which are outside the scope of this analysis, may go some way to curtail the increase in driving activity.

3.119 For these three reasons, it is likely that the rebound effect and associated social costs are an over-estimate. Nonetheless, they are included to reduce the risk of optimism bias. A sensitivity which excludes the rebound effect is also 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.

3.120 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 underpinning that scenario are that 97% of car and vans mileage powered by zero emission technologies by 2050 and 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.

3.121 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.

3.122 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. Although the ZEV uptake in the 'high' scenario does not exactly match the uptake that is expected to result from the ZEV mandate 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.

Non-traded cost comparator benchmark

3.123 In line with cross government guidance on appraising climate change policies, the abatement cost – the cost to offset one tonne of carbon dioxide equivalent – is presented as the environmental cost effectiveness indicator. This has been calculated following the approach set out in DESNZ Valuation of energy use and greenhouse gas emissions appraisal guidance.

3.124 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.[34] This reflects a benchmark comparison to an economy wide cost to decarbonise per tonne of carbon dioxide equivalent emissions.

			Abatement Cost
Car	Cost performance comparator benchmark (based on DESNZ carbon prices)	£/tCO_2e	172
Car	Cost-effectiveness	£/tCO_2e	(-18) - 100
Van	Cost performance comparator benchmark (based on DESNZ carbon prices)	£/tCO_2e	178
Van	Cost-effectiveness	£/tCO_2e	(-37) - 133
Both	Cost performance comparator benchmark (based on DESNZ carbon prices)	£/tCO_2e	174
Both	Cost-effectiveness	£/tCO_2e	(-22) - 107

Table 50 Non-Traded cost performance comparator benchmark versus policy cost-effectiveness, including and excluding rebound effects (2024-2071)

3.125 As shown in Table 50 for each vehicle type, the emissions expected to be saved by the policy are likely to be substantially more cost-effective than if the same amount of emissions were to be saved by alternative action across the non-traded emissions sector. This suggests that the policy provides the opportunity to abate carbon at a cost effective rate.

3.126 It is possible that carbon abatement costs are negative when the rebound effect is excluded. The combination of lower social costs and greater social benefits leads to a negative abatement costs for cars and vans, which indicates a net benefit to society even if non-traded carbon savings are excluded

3.127 As shown, this is significantly lower than the NTCC benchmark calculated for the policy, indicating that it is very likely to offer the opportunity to make significant, cost-effective carbon savings, relative to the decarbonisation of the broader non-traded economy. When the rebound effect is excluded, we expect net social benefits even when carbon savings are excluded.

Sensitivity analysis

UK wide scheme

3.128 It remains the policy intention of the Department for Infrastructure in Northern Ireland, along with the UK Government, Scottish Government, and Welsh Government, for Northern Ireland to join the ZEV mandate and for it to be a UK-wide scheme. It is a

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

requirement of the Climate Change Act 2008 that the regulation be approved by the Northern Ireland Assembly for it to apply in Northern Ireland. When the Assembly can approve the legislation and chooses to do so, Northern Ireland will adopt this regulation.

3.129 This section includes an assessment of policy impacts for a UK-wide scheme. The modelling approach utilises statistics by the DVLA on the proportion of UK new car and vans sales purchased in Northern Ireland to calibrate GB policy impacts.

3.130 It assumes the same direct and indirect monetised costs and benefits. Equally, the same assessment of unmonetised impacts apply.

3.131 Table 51 shows the expected non-traded carbon savings for a UK wide ZEV Mandate. This sensitivity analysis presents the same conclusions as the core analysis; the ZEV mandate delivers significant carbon savings over all carbon budget periods, regardless of the geographic coverage of the regulations.

	Policy carbon savings
CB4	0
CB5	29
CB6	79
2024 – 2050	420

Table 51 Total non-traded carbon savings from cars and vans for the future UK wide scheme

3.132 Table 52 shows the direct monetised impacts for the UK-wide policy when excluding the rebound effect. The regulations deliver significant net benefits from a social cost benefit analysis perspective. The combined benefits for cars and vans deliver a Net Present Value (NPV) of £119 billion. This includes Present Value Benefits (PVB) of £170 billion and Present Value Costs (PVC) of £51 billion. Both the cars and van markets deliver positive Net Present Value over the appraisal period.

	Impact (present value, discounted; 2021 prices)	Policy impact
Car	Benefits	131,554
Car	Costs	-42,379
Car	Net present value	89,175
Van	Benefits	38,573
Van	Costs	-9,149
Van	Net present value	29,424
Both	Benefits	170,127
Both	Costs	-51,528
Both	Net present value	118,599

Table 52 Expected present value direct monetised impacts for the future UK wide scheme, excluding the rebound effect (£m, 2021 prices)

3.133 Table 53 presents the same impacts but includes the indirect impacts associated with induced demand – the most important of which is increased congestion. Again, the analysis estimates significant positive impacts on society represent by the large Net Present Values. The regulations deliver a social NPV of £40 billion over the lifetime of the appraisal. The NPV is lower than that achieved when only considering direct impacts due to a number of factors including, most importantly, increased congestion.

	Impact (present value, discounted; 2021 prices)	Policy Impact
Car	Benefits	131,554
Car	Costs	-97,627
Car	Net present value	33,927
Van	Benefits	38,573
Van	Costs	-32,412
Van	Net present value	6,161
Both	Benefits	170,127
Both	Costs	-130,040
Both	Net present value	40,088

Table 53 Expected present value direct monetised impacts for the future UK wide scheme, including the rebound effect (£m, 2021 prices)

3.134 As shown in Table 52 and Table 53, the policy is expected to achieve a positive Net Present Value (NPV), with significantly greater positive impacts when the rebound effect is excluded.

3.135 As with the core GB analysis, this analysis of the future UK policy position accounts for refinements and improvements to the analysis as well as amendments to the policy following the consultation stage. For this reason, carbon savings and NPV estimates presented in the consultation analysis for a proposed UK wide scheme should not be directly compared to the new analysis presented here. All refinements are listed in Annex B.

Cost sensitivities

3.136 Several assumptions are made with regard to the costs of the ZEV mandate regulations. This sensitivity varies these input assumptions to ascertain the social cost-effectiveness of these regulations, 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 54 sets out the input scenarios for each over-arching cost sensitivity; Table 55 sets out the monetised impacts including the rebound effect; Table 57 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.

3.137 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.

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 54 Input assumptions for cost sensitivities

Vehicle type	Impact	Low NPV	Central	High NPV	Highest NPV
Car	PVB	75,465	128,652	210,844	216,863
Car	PVC	-49,724	-41,444	-15,004	-15,004
Car	NPV	25,741	87,208	195,839	201,859
Van	PVB	22,139	37,833	64,156	64,802
Van	PVC	-10,946	-8,974	-7,587	-7,587
Van	NPV	11,193	28,859	56,569	57,214
Both	PVB	97,604	166,485	275,000	281,664
Both	PVC	-60,671	-50,418	-22,591	-22,591
Both	NPV	36,933	116,067	252,408	259,073

Table 55 Monetised impacts for GB cost sensitivities, excluding the rebound effect (present value; 2021 prices; £m)

Vehicle type	Impact	Low NPV	Central	High NPV	Highest NPV
Car	PVB	75,465	128,652	210,844	216,863
Car	PVC	-103,888	-95,474	-68,884	-68,884
Car	NPV	-28,423	33,178	141,960	147,979
Van	PVB	22,139	37,833	64,156	64,802
Van	PVC	-33,874	-31,790	-30,279	-30,279
Van	NPV	-11,735	6,043	33,877	34,522
Both	PVB	97,604	166,485	275,000	281,664
Both	PVC	-137,763	-127,264	-99,163	-99,163
Both	NPV	-40,158	39,221	175,836	182,501

Table 56 Monetised impacts for GB cost sensitivities, including the rebound effect (present value; 2021 prices; £m)

3.138 As shown in Tables 55 and 56, 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 -£40bn - +£37bn 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), but this will ultimately depend on the true magnitude of the rebound effect.

3.139 However, there are several important caveats to this result. Firstly, the NPV in the central scenario (the scenario deemed most likely to occur) is significantly positive, and the upside scenario NPV (optimistic, but roughly as likely as the downside scenario) is extremely positive with an estimated NPV exceeding £39bn including the rebound effect. When the rebound effect is excluded, this rises to more than £116bn. Furthermore, the downside scenario should be considered as a worst-case scenario where the downside in each cost element occurs simultaneously, which is an unlikely scenario. On the balance of probability, then, it is deemed very likely that the outcome NPV exceeds £0 and will increase social welfare.

3.140 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 57, 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.

3.141 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 probability of a negative social NPV.

3.142 Another indicator of cost-effectiveness of emissions reduction policies is whether the policy abates carbon at a cost below the Non-traded Cost Comparator (NTCC[35]), 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 value scenario are presented in Table 57, alongside an indication of whether the policy is 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.

3.143 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, but, van abatement is expected to remain cost-effective in this scenario.

3.144 When the rebound effect is excluded, the policy is expected to beat the NTCC benchmark in all combinations of sensitivities and carbon values. 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 would abate carbon in a cost-effective way. Overall, this suggests that the policy will provide the opportunity for cost-effective carbon abatement.

3.145 Carbon values are determined by the marginal cost of abating carbon; therefore, in scenarios which assume high costs, implicitly it is more likely that carbon values 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 does the expected cost of abatement exceed the NTCC benchmark.

				NTCC under different carbon value sensitivities		
Carbon price				Low	Central	High
Car	Cost to offset a tonne of carbon (£/tCO_2e)			86	172	258
	Abatement Cost under difference cost/benefit sensitivities	Downside	148 (30)	No (Yes)	Yes	Yes
		Central	100 (-18)	No (Yes)	Yes	Yes
		Upside	-33 (-150)	Yes	Yes	Yes
Van	Cost to offset a tonne of carbon (£/tCO_2e)			92	185	268
	Abatement Cost under difference cost/benefit sensitivities	Downside	177 (6)	No (Yes)	Yes	Yes
		Central	133 (-37)	Yes	Yes	Yes
		Upside	38 (-131)	Yes	Yes	Yes
Combined	Cost to offset a tonne of carbon (£/tCO_2e)			87	175	260
	Abatement Cost under difference cost/benefit sensitivities	Downside	154 (25)	No (Yes)	Yes	Yes
		Central	107 (-22)	No (Yes)	Yes	Yes
		Upside	-17 (-146)	Yes	Yes	Yes

Table 57 Policy carbon abatement cost-effectiveness versus the non-traded sector under different cost sensitivities (abatement costs excluding rebound effect shown in parentheses)

[35] See Annex F for more detail.

3.146 Taken together, this suggests that the policy 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.

Energy system impacts

3.147 Energy systems modelling has been undertaken to provide additional assurance on the changes to the energy system of the ZEV mandate. This regulation is expected to lead to a significant increase in electricity demand, relative to the baseline, reflecting the gradual increase in ZEV uptake and their share of the overall fleet. DfT's projections estimate an increase of approximately 25 TWh of electricity demand by 2050.

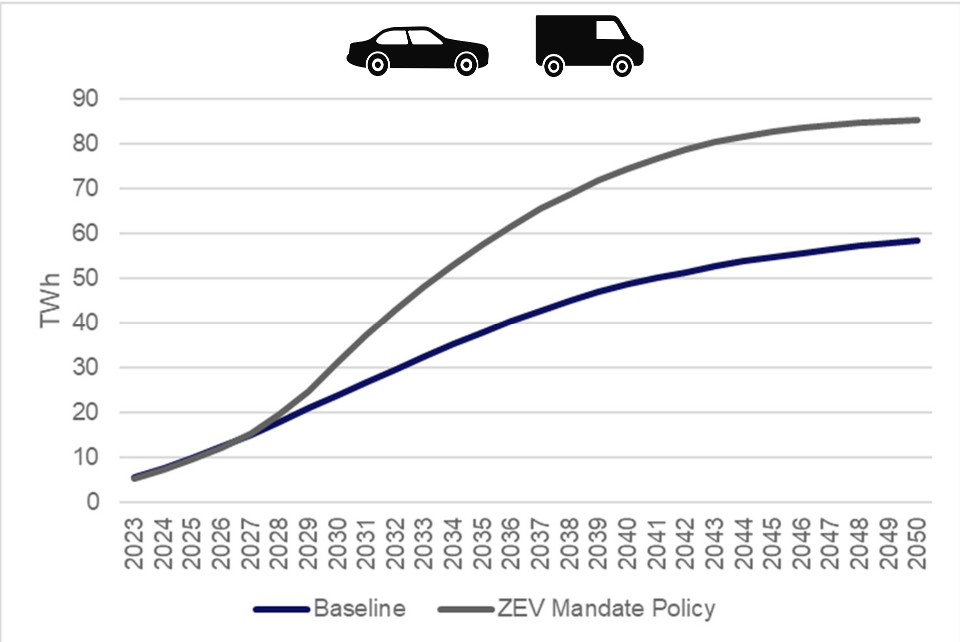


Figure 58 Electricity Demand (TWh) from cars and vans in GB for the baseline and the policy scenario

3.148 With greater levels of electricity demand, the energy system will need to adapt, changing the composition of generation sources by technology, and the capacity it is drawn from, as well as increasing the resilience of the high and low voltage distribution networks. These necessary changes to a net-zero compatible energy system will result in costs to society. However, while energy system impacts can be directly attributed to the regulations, broader net-zero planning already accounts for the full electrification of zero emission car and vans. Consequently the long run variable costs of energy supply used in this analysis already take into account these costs.

3.149 The core assessment uses Green Book values for energy resource and retail costs, which capture the marginal social costs of increased electricity consumption. These Green Book values account for the decarbonisation of road transportation and the electricity system. However, due to the scale of the non-marginal impacts of the ZEV Mandate, it was deemed proportionate to model system-wide impacts of this policy in isolation. More information on the methodology underpinning these impacts can be found in Annex L. This analysis has been undertaken in collaboration with the Department for Energy Security and Net Zero (DESNZ) using DESNZ's Dynamic Dispatch Model (DDM) and the Distribution Network Model (DNM).

3.150 It should be noted that neither “vehicle to grid” technologies nor smart charging have been accounted for in the modelling. "Vehicle to grid" could help to balance the system by enabling charge points to discharge electricity to the network during peak times, thereby reducing system costs. Smart charging is already regularly used to ensure that vehicles are only charged away from peak electricity demand. Therefore, the cost estimates produced should be considered conservative.

Value	Net Present Value (£m)
Including the rebound effect	32,786 (25,917)
Excluding the rebound effect	109,632 (102,763)

Table 59 Net present value when adjusted energy system impacts are included (present value; 2021 prices; £bn)

3.151 Table 59 presents the policy net present value when these impacts are included. From this, it can be concluded that the policy still achieves value for money when accounting for upstream system-wide impacts.

4. Policy risks

Risks to carbon savings

4.1 The primary objective of these regulations 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.

4.2 Several 'flexibilities' are proposed to allow manufacturers to meet their obligations at the lowest possible risk and cost, but 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 discusses uncertainty and risks associated with the policy design and the uncertainty inherent in key assumptions.

Potential impact of trading and manufacturer strategies

4.3 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', but 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.

4.4 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.

4.5 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.

4.6 To mitigate this risk, 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

4.7 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 to ensure that the costs of non-compliance exceed compliance costs, meaning that rational firms have a greater incentive to meet their targets.

4.8 However, this policy 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.

4.9 The final policy introduces a small change to the borrowing flexibility for vans; an increase in the borrowing cap in 2024 to 90% (from 75%), then returning to 50% and 25% in 2025 and 2026 respectively in line with cars.

4.10 To assess the impact of this change on ZEV delivery and carbon savings, a ‘late delivery’ sensitivity is presented. In this scenario, each manufacturer is assumed to maximise their borrowing from subsequent years, with full repayment in 2027 subject to a 3.5% compounding interest rate. This scenario considers maximum borrowing levels for both cars and vans.

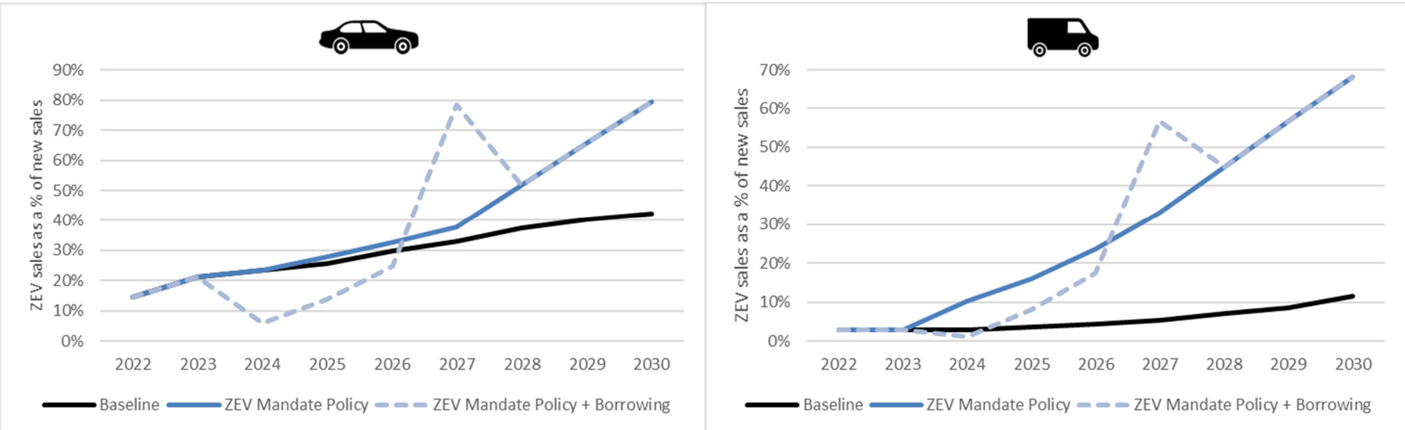


Figure 60 ZEV annual sales shares for the maximum borrowing/late delivery scenario, versus the central scenario

4.11 Despite increasing the total number of ZEVs delivered over the period, this flexibility poses some risk to the policy’s expected contribution to interim carbon budget targets. Table 61 shows the expected carbon savings under the central and late delivery scenarios; as shown, the flexibilities could lead to significant lost carbon savings in Carbon Budget 4, but the increase in required ZEV sales in 2027 offsets this and leads to marginally higher carbon savings over the rest of the appraisal period.

		ZEV mandate carbon savings risked $MtCO_2e$			
		CB4	CB5	CB6	2024-2050
Cars	Net total	-5	2	1	1
Vans	Net total	-1	0	0	0
Net	Net lost carbon savings	-6	2	2	1

Table 61 Net difference in non-traded carbon impacts of central versus late-delivery scenario

4.12 However, it should be noted that this sensitivity presents a 'worst-case' where all manufacturers maximise their borrowing, resulting in significantly lower ZEV sales from 2024-2026; not all manufacturers will utilise borrowing to achieve compliance and 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.

Transfers from non-ZEV allowances to ZEV credits

4.13 The flexibilities 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 allow manufacturers to use their more efficient non-ZEVs already baked into current production plans to assist with delivering ZEV targets.

4.14 The final policy introduces a small change to the transfer cap on annual ZEV targets for both cars and vans – an increase to 65% in 2024, 45% in 2025 and 25% in 2026. This flexibility poses a risk to carbon savings due to uncertainty in non-ZEV real-world emissions and the degree to which allowances can be converted from non-ZEV CO_2 allowances to ZEV credits.

4.15 The proposed rates of transfer set out at the consultation-stage remain. Transfer rates of non-ZEV CO_2 allowances to the ZEV mandate are estimated based on the rationale that a ZEV saves approximately 167 gCO_2/km and 216 gCO_2/km for cars and vans respectively, relative to the average non-ZEV (ZEVs have zero exhaust emissions, so their emissions savings equal the emissions of the non-ZEV they replace).

4.16 To fully illustrate the potential scale of carbon savings risked by this flexibility, this scenario analysis assumes a certain level of over delivery in non-ZEV CO_2 efficiencies. This results in fewer ZEVs sold into the fleet and reduced carbon savings. Table 62 shows the expected carbon savings lost under 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.

4.17 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).

4.18 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.

4.19 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.

4.20 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.

	ZEV mandate carbon savings risked $MtCO_2e$			
	CB4	CB5	CB6	2024-2050
Low	-0.3	-0.4	-0.3	-1.3
Central	-0.9	-1.2	-0.9	-3.8
High	-3.1	-4.1	-3.2	-12.7
Maximum (worst-case)	-4.2	-5.6	-4.4	-17.4

Table 62 Net difference in non-traded carbon impacts of central versus two-way transfer scenarios

4.21 The analysis infers that this flexibility could have a significant impact on carbon savings, particularly under the high and maximum scenarios. However, for those scenarios, it is assumed that the market would need to significantly increase average non-ZEV CO_2 efficiencies through increasing PHEV sales. For the worst-case, all manufacturers would need to reach the transfer limit in every year. Figure 63 demonstrates the effect on ZEV sales.

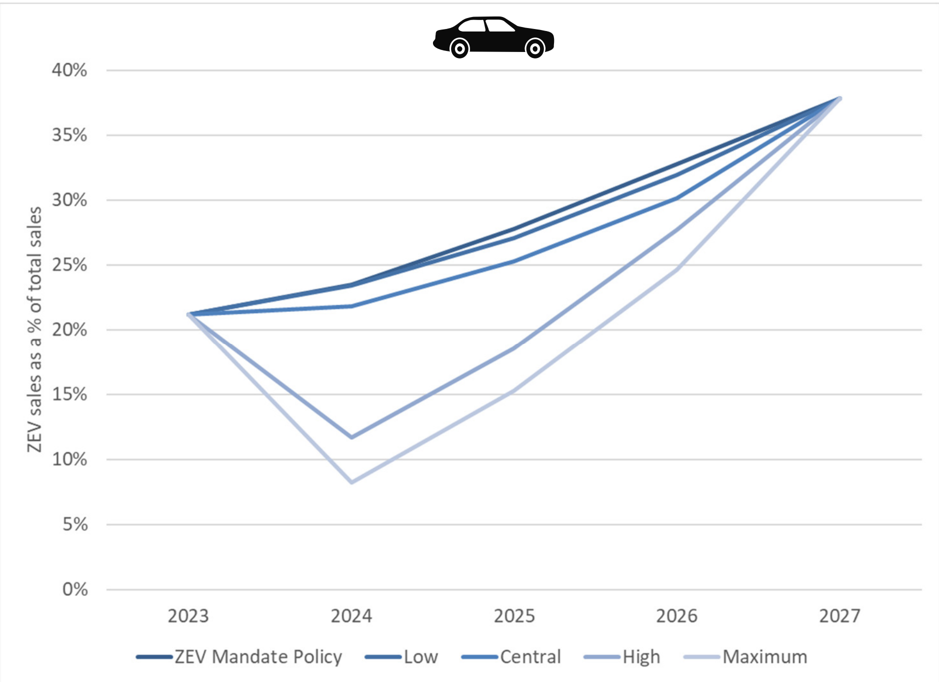


Figure 63 ZEV annual sales shares for the two-way transfer scenarios, versus the central scenario

4.22 These maximum and high scenarios are considered highly unlikely, given there a limited number of manufacturers who can achieve the necessary level of CO_2 efficiency

improvements needed to capitalise on transfers up to the cap. This is compounded by only a small proportion of the market currently offering PHEVs, and even those manufacturers who produce PHEVs would need to ramp up production, before ramping back down by 2027. Therefore, it is likely the true level of transfers is closer to those underpinning the central or low scenarios.

Bonus credits

4.23 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 the normal allowance that accrues from selling a ZEV, 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.

4.24 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 wider 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.

4.25 Since the final consultation, we have chosen to amend the 2-year car club ownership requirement from 2 years to 18 months. Consequently, manufacturers will need to wait 18 months, rather than 2 years before they can claim the 0.5 credit bonus for each ZEV sold to a car club. We do not expect this to have any carbon saving implications.

Final Compliance payments

4.26 The final feature of the policy which may present a risk to carbon savings are the payments participants will be obliged to make if they are not compliant through other mechanisms 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 Greenbook 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.

4.27 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, 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 businesses or 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.

4.28 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.

4.29 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.

4.30 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 H.

4.31 Since the final consultation, we have chosen to reduce the compliance payment for vans in 2024 from £18,000 to £9,000. Reducing the non-compliance payment would reduce potential costs incurred by manufacturers facing multiple challenges. The Government acknowledges that the zero-emission van market is at a much earlier stage of development than that for cars. For example, there are a smaller number of zero emission van models, lower ranges, and higher upfront vehicle costs.

4.32 Given the availability of other flexibility measures, offering multiple routes to compliance and therefore allowing manufacturers to avoid the £9,000 cost, we do not expect a significant increase in the use of compliance payments. From 2025, compliance payments will return to £18,000.

Consumer behaviour

4.33 Separate from policy details, carbon savings will vary if the way in which consumers use vehicles varies from the central assumptions. As set out previously, 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.

4.34 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.

4.35 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.

4.36 It is also 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.

4.37 As set out in the consultation stage cost benefit analysis report, we previously conducted sensitivity analysis considering an outcome where new car sales are constrained either due to supply side issues, or due to a decrease in demand. This analysis found that a conservative assumption of a 10% suppression in ZEV sales between 2027 and 2029 (inclusive), with the same mileage delivered by the fleet, the impact on carbon saving is relatively small; approximately 2MTCO_2e from 2024-2050. Given that there have only been minor amendments to the policy from since the consultation we expect a similar sensitivity impact to apply to this analysis.

4.38 However, 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. This change in public attitudes indicates that the chance of this 'worst-case' scenario occurring is low.

Real-world emissions

4.39 There is significant evidence to suggest that historically, real-world emissions have exceeded those measured at the test cycles, such as the New European Driving Cycle (NEDC) and Worldwide Harmonised Light Vehicle Test Procedure (WLTP); it is estimated that the NEDC test cycles is downwardly biased by 33%-45% of real-world emissions. This gap has also grown over time from an estimated ~8% in 2000 to 39% in 2018 (to the NEDC test cycle). This has reduced the carbon savings achieved by historic policies based around delivering carbon savings measured through a test cycle. The move to WLTP should mitigate some of this measurement error. However, ICCT research suggests there is still the potential for the gap between measured and real-world performance to grow.

4.40 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%, primarily as PHEVs are driven in petrol or diesel mode more often than previously assumed. 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.

4.41 In the consultation analysis, we considered alternative high and low sensitivities, using the ICCT research. 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.

4.42 Following the consultation, we have decided to amend the CO_2 baseline target for manufacturers to be the higher of non-ZEV average performance in 2021, or the fleet wide target; this has resulted in marginally lower carbon savings. Given this, the implications of the high and low real-world emissions will be greater, so it is considered proportional to return to this test to revalidate our previous conclusions. Figure 67 and Figure 68 demonstrate the alternative vehicle efficiency inputs.

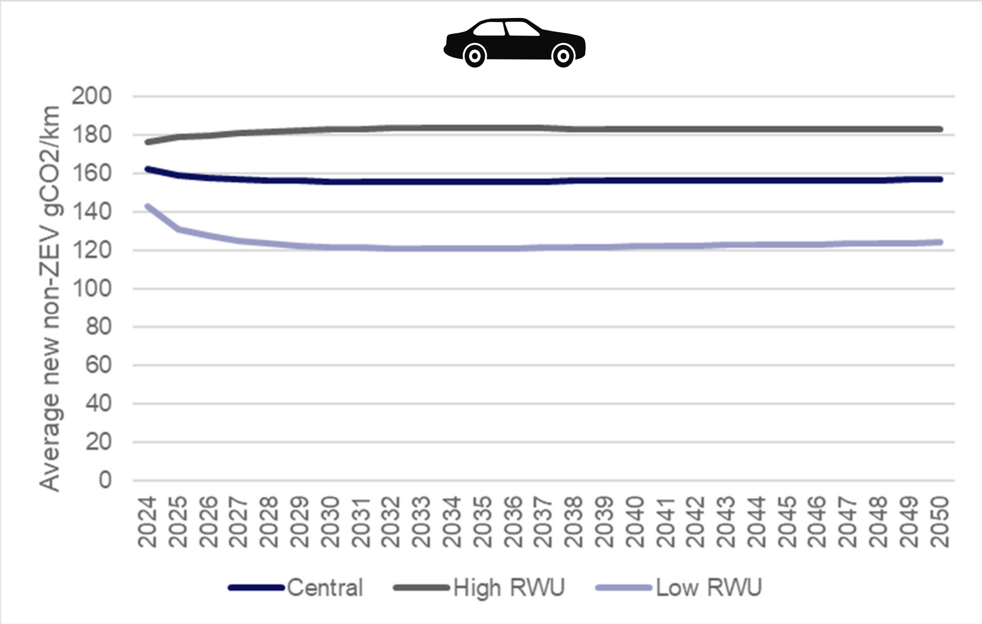


Figure 64 Real-world emissions sensitivities (gCO_2/km) for the average new non-ZEV car

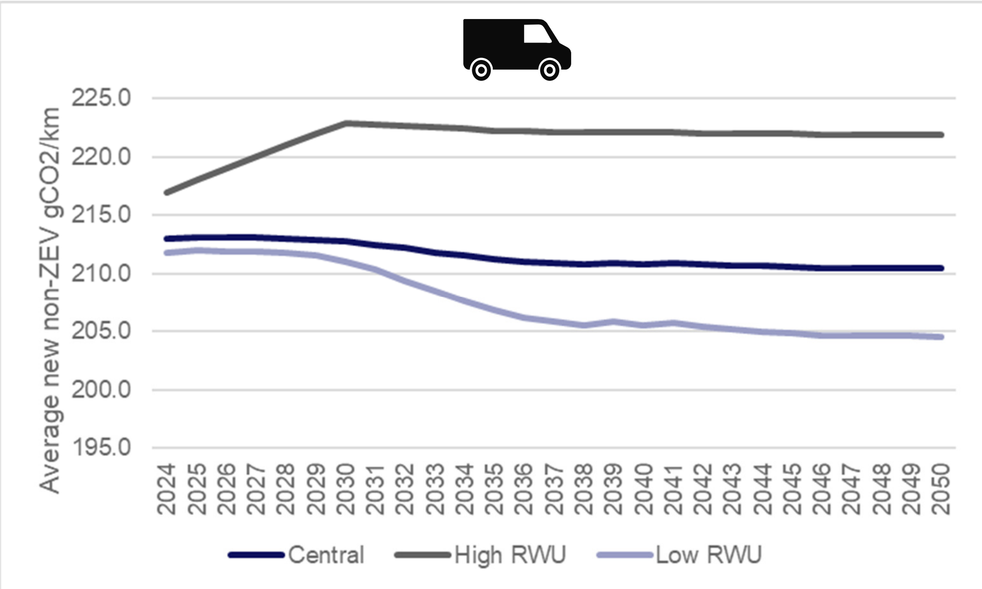


Figure 65 Real-world emissions sensitivities (gCO_2/km) for the average new non-ZEV car

4.43 In this analysis, non-ZEVs are still permitted to be sold post-2035, and so the implications for carbon savings are likely to be biased upwards. Table 69 presents the outcomes of these sensitivities. Real-world uplifts are applied in both the baseline and the policy scenario.

	CB5	CB6	2024-2050
Low RWU	12	49	255
Central	28	77	411
High RWU	40	95	493

Figure 66 Carbon saving estimates under alternative real world uplift scenarios for cars and vans

4.44 These results confirm that the carbon savings are sensitive to changes in the real-world uplift assumptions for non-ZEVs. Overtime, the effect of real-world emission uplifts diminish, as non-ZEVs are phased out of the fleet. 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.

4.45 Nonetheless, differences in all periods are very large and indicate that there may be market failures associated with the non-ZEV portion of the 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.

Supply constraints

4.46 The ZEV mandate is expected to lead to an increase in the supply of EVs to the GB 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. For this reason, it is exposed to global shifts in supply and demand.

4.47 Demand for several key minerals such as lithium, nickel, cobalt, as well as other inputs like microchips/semiconductors is projected to increase significantly over the next decade. Supply of 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.

4.48 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, shortages of other inputs, such as semiconductors, are expected to alleviate by the beginning of the ZEV mandate trajectory, as investments expand productive capacity. In these cases, the likelihood of shortages and supply chain issues is likely to be fairly limited.

4.49 However, there are 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.

4.50 However, there are market developments that will help mitigate supply side risks. 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.

4.51 Furthermore, widespread investment in battery recycling technology is expected in the medium to long-term, and the diversification of resource extraction will expand as the demand for earth minerals continues to rise. 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.

4.52 With regard to timing, the ZEV mandate will 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.

4.53 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.

4.54 While we think it is unlikely that supply constraints will be binding, given the considerations set out above, there remains a risk of unforeseen circumstances impacting upon supply. As such, as presented in *Section 4: Policy risks - Consumer behaviour*, we have considered sensitivity analysis of constrained car sales. This found that even if ZEV sales are depressed by 10% between 2027 and 2029 (inclusive) this would only result in a relatively small impact of 2MTCO_2e in lost carbon savings from 2024-2050.

4.55 These regulations also 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.

The market and competition

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

4.57 Due to differences in manufacturers' product cycles and decarbonisation strategies, the regulations may affect different manufacturers in different ways. Some manufacturers have already committed to phase-out dates (see Figure 5) 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.

4.58 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.

4.59 Several policy features are proposed 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.

4.60 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.

4.61 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 5: Wider impacts - Small and micro businesses assessment.*

5. Wider Impacts

Competition assessment

5.1 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.

5.2 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.

5.3 For non-exempt manufacturers (around 99.5% and 97.5% of sales, for cars and vans, respectively), these regulations 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.

5.4 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. We expect these costs to be relatively small, given any new business functions will replace those that monitor and ensure compliance under existing EU regulations. Nevertheless, 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.

5.5 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. The effect on competition of these fixed costs is likely to be negligible.

5.6 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 regulations will 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.

5.7 Smaller manufacturers above the SVM threshold could be perceived to be placed at a disadvantage compared to SVMs based on the proposed thresholds, but these regulations 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.

5.8 If these thresholds were to be applied proportionally to manufacturers' domestic 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.

5.9 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.

5.10 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.

5.11 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.

5.12 Thirdly, the compliance payment 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.

5.13 Similarly, 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.

5.14 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 regulations on administrative costs is expected to be very small, therefore these costs are not expected to be disproportionate.

5.15 Since the final consultation, we have chosen to reduce minimum range requirements on ZEVs from 120 miles to 100 miles for all new ZEVs. Furthermore, any ZEVs with a range lower than 100 miles are already approved for sale in the UK in 2023 will be applicable as

a ZEV sale. This will assist in ensuring SVMs with more limited production capacity to produce ZEVs will see even lower barriers to entry, given battery supply costs are a significant component of production cost.

Innovation test

5.16 These regulations 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.

5.17 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.

5.18 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.

5.19 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.

5.20 Finally, as noted previously, 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.

5.21 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 regulations drive additional demand for ZEVs, they are expected to support greater investment in innovation.

Cost of living

5.22 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. Today, a new ZEV costs more to buy outright than its petrol equivalent, but this is counteracted by lower running costs such as fuel savings, lower maintenance costs and

beneficial tax rates. 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 costs) 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.

5.23 Internal DfT analysis undertaken in early summer 2023 compared the TCO cost of an average new ZEV car to a petrol car over a three-year lease period. The analysis considered the cost over a three-year lease for a car with average mileage, charged at home[36] at the 30p/kWh domestic energy price cap in place in June 2023. The analysis covered a basket of different car types with basic trim. This analysis found that it currently costs £60 more per month to lease and operate a battery electric car than a petrol car, if it isn't leased using a salary sacrifice or company car tax scheme. However, if a salary sacrifice or company car tax scheme does apply, it is already cheaper by £110 to £160 per month to lease and operate a ZEV than a petrol equivalent. Analysis of DfT and HMRC data suggests that electric vehicles receiving company car benefit (including those using a company car for personal use and those under salary sacrifice schemes) represented just under 30% of all licensed battery electric vehicles at the end of March 2022.

5.24 This TCO calculation will move in BEVs' favour for higher mileage drivers, those who charge using an overnight off peak tariff and drivers who benefit from avoided congestion charge. However, relative BEV costs will increase for those who rely on public charging or drive less mileage.

5.25 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 buying a car upfront 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.

5.26 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 over their lifetime medium sized zero emission cars already have a lower total cost of ownership than ICE cars.

5.27 Furthermore, it forecasts that ZEVs may become more cost-effective than ICEVs for the first owner by 2025 or 2026 (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 £98 per 1,000 miles in 2021, on average (the figure rises to nearly £120 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

[36] Research in 2022 found that over 94% of current battery electric car and plug in hybrid owners have off street parking typically meaning they will be able to do the majority of their charging at home (BEIS, EV smart-chargepoint survey 2022). However analysis of the DfT technology tracker survey indicates that 73% of adults in England with cars/vans in their household report typically parking their vehicle in a private driveway / garage (DfT technology tracker wave 8) so the proportion of drivers with access to home charging is expected to trend to 73% as EV uptake increases over time.

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.

5.28 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.

5.29 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, 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.

5.30 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. Fuel prices, reflecting 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.

5.31 In each comparison, BEVs are assumed to achieve the same annual mileage as their ICEV counterpart, to compare the cost of achieving the same level of output.[37] Finally, cash flows are adjusted for resale and depreciation using depreciation data provided by AutoTrader.

5.32 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.[38]

5.33 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.

5.34 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.

5.35 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. Sensitivities

[37] 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.

[38] https://www.geotab.com/uk/blog/ev-battery-health/

are presented in Annex E to illustrate how private cost-effectiveness might change under different depreciation scenarios.

5.36 As shown in Figure 67, a BEV bought in 2025 is 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.

5.37 Figure 68 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 if they switch to a BEV. 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.

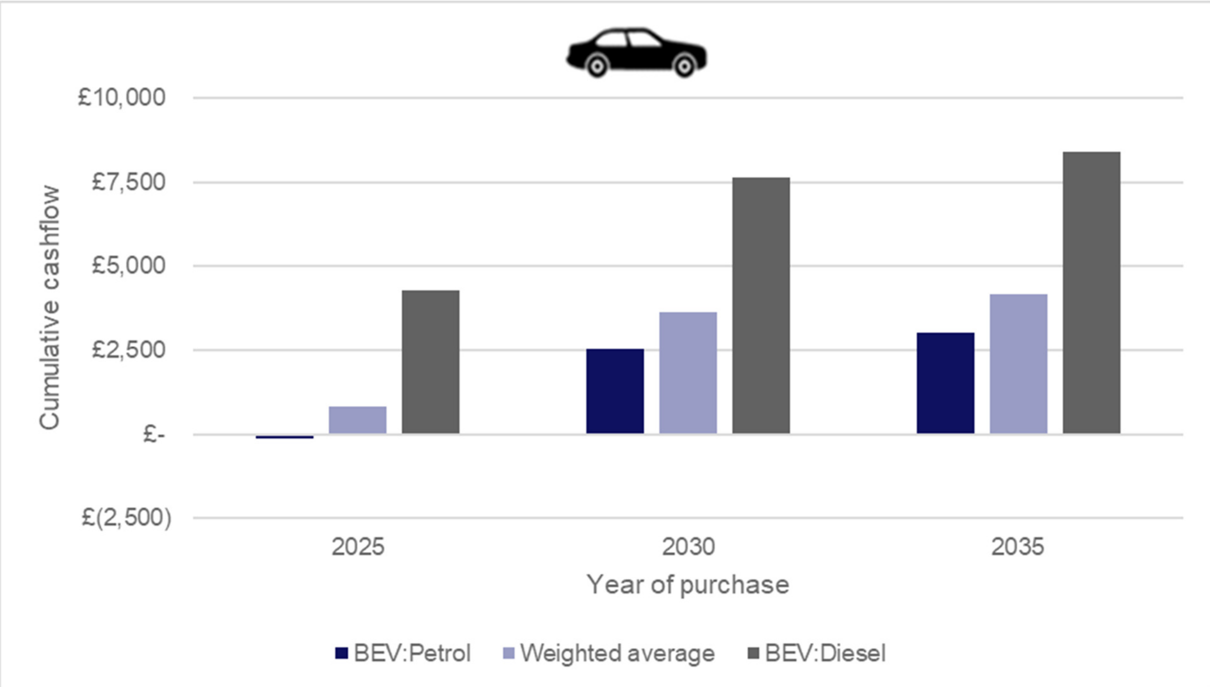


Figure 67 Cumulative cash flow for 1st hand owners of car BEVs versus petrol/diesel ICEVs after 5 years

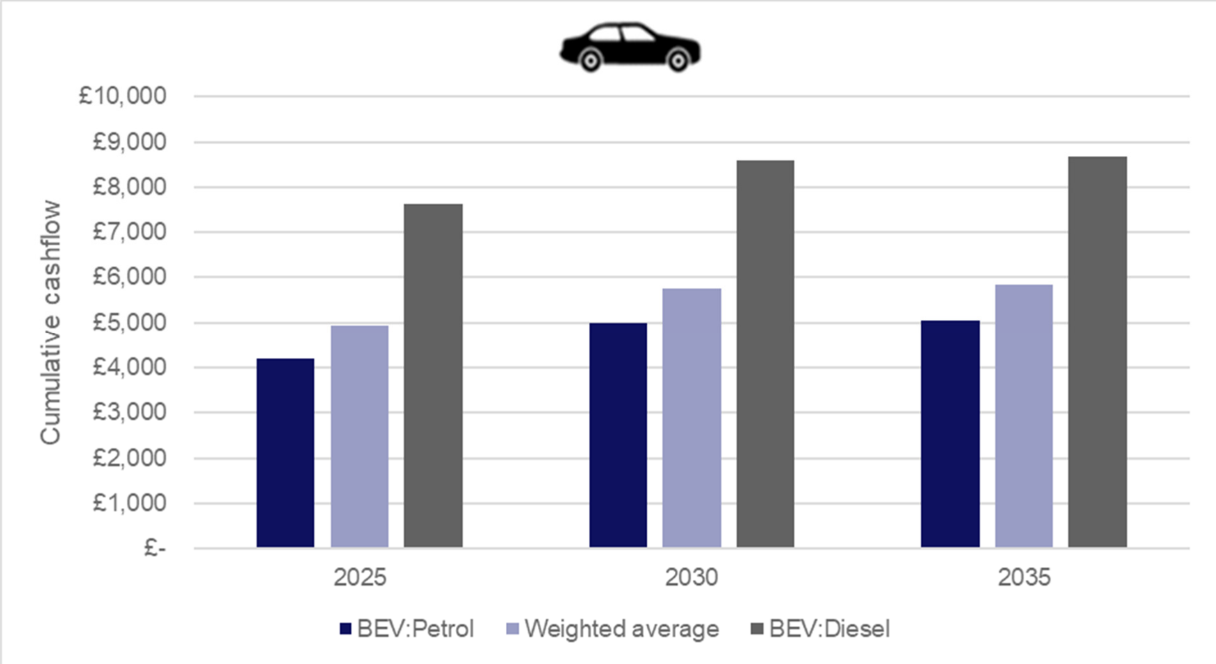


Figure 68 Cumulative cash flow for 2nd hand owners of car BEVs versus petrol/diesel ICEVs after 5 years

5.38 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 69 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.

5.39 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.

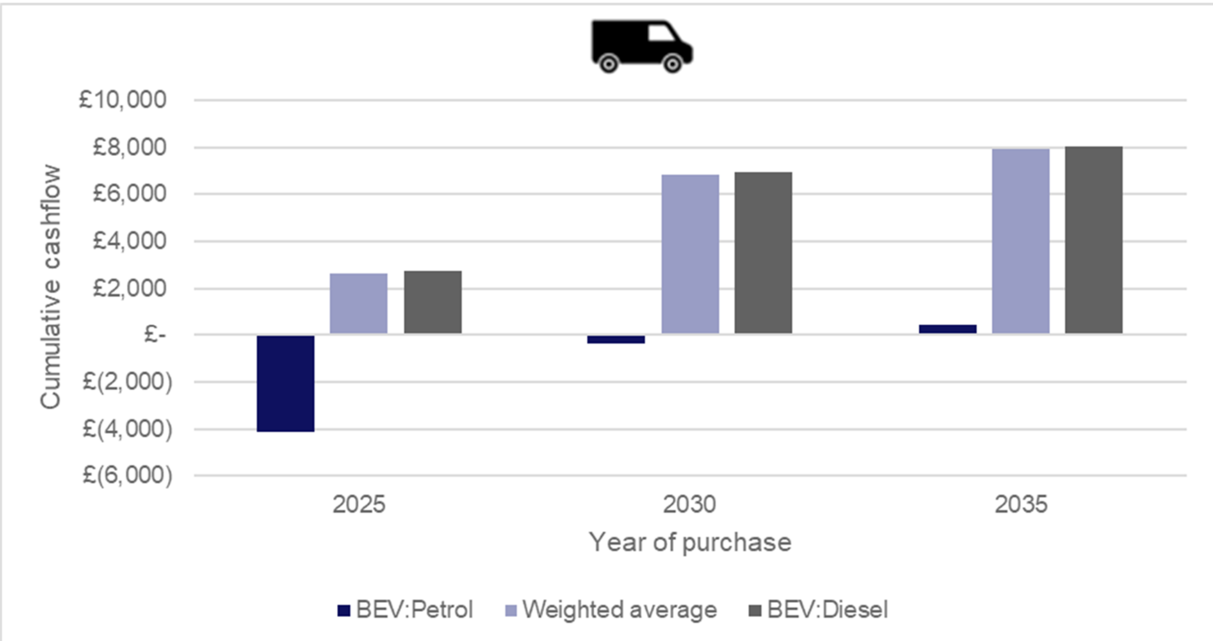


Figure 69 Cumulative cash flow for 1st hand owners of van BEVs versus petrol/diesel ICEVs after 5 years

5.40 When considering the second-hand van market, the conclusions are similar to that for cars. BEVs are cost-effective versus petrol or diesel alternatives and the savings are greater than those of a first-hand owner. 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.

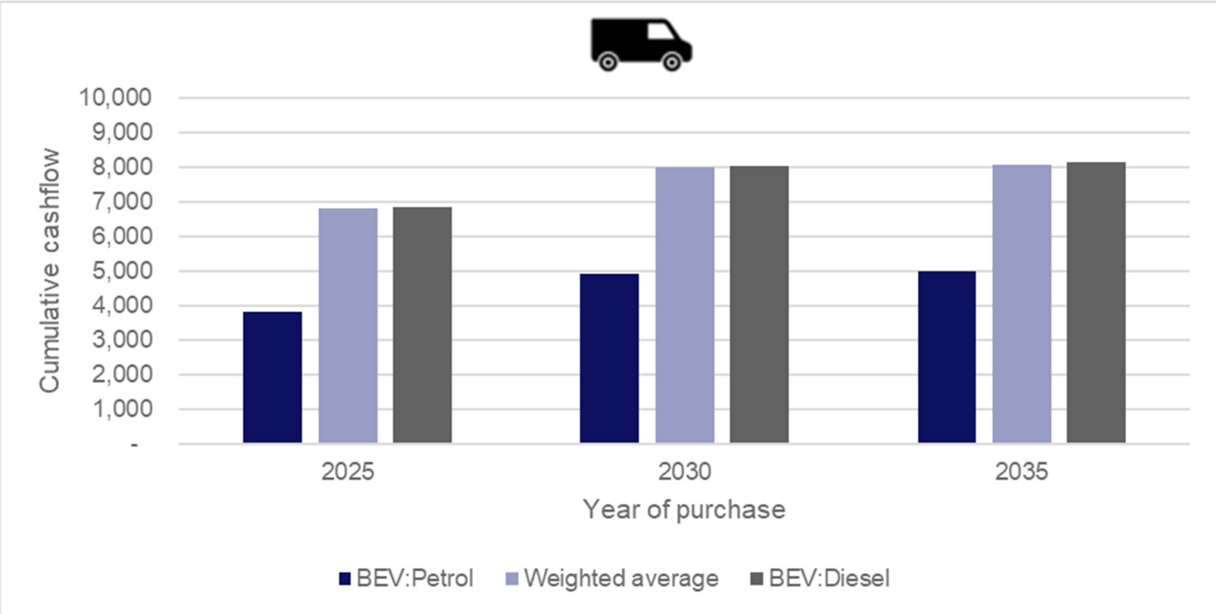


Figure 70 Cumulative cash flow for 2nd hand owners of van BEVs versus petrol/diesel ICEVs after 5 years

5.41 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.

5.42 However, it should be noted 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. Relative changes in energy costs will also impact upon the relative costs.

Small and micro businesses assessment

5.43 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).[39]

[39] Conversions will vary continuously with currency valuations.

5.44 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 the regulations.

5.45 The small and micro volume manufacturer exemption thresholds match those applied through the existing regulatory framework, which applies to all registrations made in the EU area. This threshold was set 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.

5.46 In the interests of proportionality, the headcount and turnover data for each manufacturer in the domestic 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.

5.47 They are, however, 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.

5.48 Taken as a whole, the regulations 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 the policy 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, as they may take part and sell earnt allowances if they choose to do so.

Equality impact assessment

5.49 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.

5.50 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

5.51 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[40]

[40] 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.

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 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.

Analysis of ZEV mandate and CO_2 framework

5.52 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 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.

5.53 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.

5.54 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.[41] 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.

5.55 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.

5.56 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.

5.57 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

[41] 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

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 71 summarises the expected impacts and sets out mitigating actions; these impacts are discussed in greater detail in Annex J.

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 additional credits will be on offer 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 policy will affect the large majority of households in materially different ways, but 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 policy.	
Sex and sexual orientation and gender reassignment	No negative impact.	LGB&T groups are not likely to face specific barriers to engagement with the policy based on their financial status.	

Table 71 Summary of expected impacts for groups with protected characteristics

5.58 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.

5.59 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 72.

5.60 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 72 Household savings by gross weekly income

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

Trade impact

5.62 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.

5.63 The regulations will apply equally to imports, exports, and domestic trade as they apply to GB 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 imposed through the ZEV mandate 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.

5.64 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 is not likely to have a differential effect on domestic versus foreign producers or trading partners in a way which may lead to trade issues.

5.65 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 non-tariff measures in general; and broader challenges regarding modelling the effect of quantity-based non-tariff measures (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.

5.66 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. However, this period is 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.

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

6. Monitoring and evaluation

6.1 Monitoring and evaluation activities will be conducted to ensure that the regulation is fit for purpose and delivers intended policy outcomes of increases zero emission vehicles as a proportion of new car and vans sales. This section outlines the Government's plans for monitoring and evaluation of the ZEV mandate and CO_2 regulations.

Evaluation planning

6.2 The Government has the statutory requirement for a Post Implementation Review (PIR), due in 2029. However, following on from the final consultation, the Government is also committing to an additional mid-point review to be published in Q1 of 2027. This date has been chosen as respondents favour a review around this time and some flexibilities will have expired at the end of 2026.

6.3 Separately, the trading schemes administrator will publish an annual report, in each year, summarising the scheme year following the close of the trading window for that year.

6.4 These activities will also be utilised to evaluate elements of scheme design and operations, with the view to improving it for the second phase of the policy, which will run from 2031 – 2035.

Theory of change

6.5 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 sets out the impacts of interest, key actors involved, and a number of the assumptions underpinning the policy. It will be used to finalise the policy’s Key Performance Indicators (KPIs).

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:

This section sets out a PIR potential approach. This will be refined following the implementation of the policy.

Potential evaluation approaches

Given the complex nature of these regulations, the potential for unintended consequences, and potential interactions between policy features, a comprehensive approach to evaluation may be suitable. This may cover impact, process, and value-for-money evaluation.

Impact

Impact evaluation will help us to understand if the policy has had the intended impacts and to determine progress against objectives. This will be used to estimate the impact of the policy on ZEV and non-ZEV sales, new non-ZEV sales' efficiency, fleet make-up and emissions, etc. The impact evaluation will also consider whether the observed changes are attributable to the policy, and to what extent contextual factors may have influenced outcomes. In addition, impact evaluation could help illustrate the policy's effects on vehicle prices, access to wheelchair-accessible vehicles, and infrastructure investment.

Process

Process evaluation will aim to help us understand the implementation of the regulations, and whether they are functioning 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.

Value for money

Value-for-money evaluation will seek to complement the impact and process evaluation by assessing the real-world social cost-effectiveness of these regulations.

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 regulations impact on access to wheelchair-accessible vehicles and competition in the automotive sector. A number of methods may be required to collect this additional information, such as surveys and stakeholder feedback sessions[42]. However, this data collection is deemed to be proportionate due to the importance of monitoring and evaluation in identifying unintended outcomes.

Figure 73 Post Implementation Review (PIR) approach

[42] The methods applied in the PIR are subject to change as the evaluation plan develops.

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	Have ZEV sales exceeded the expected baseline, and have they matched targets? Have sales of petrol and diesel cars in the second-hand market increased?	DVLA statistics on new vehicle registrations by drivetrain type	Primary data will be provided by car and van 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 the car and van fleet	Does increased uptake of ZEVs lead to a reduction of the required scale in total transport and 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 domestic 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? Are ZEV costs of ownership affordable for consumers? How do costs of ownership change over this period?	ONS manufacturer producer price inflation for the automotive industry 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.	Primary data collection on the outturn of vehicle purchase prices, fuel prices, and maintenance costs can 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.
Social impacts on individuals with protected characteristics	Have there been any unforeseen impacts on individuals with protected characteristics? If so, how?		Primary data to be collected through engagement with consumer groups and surveys.
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 final 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.

Table 74 PIR evidence collection plans

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

1. To what extent have the policy aims been achieved?

2. How is the policy being implemented in practice?

3. What (intended and unintended) impact has the policy had on relevant stakeholders and markets? Including additional burdens and benefits to manufacturers and consumers

6.7 The Government will continue to develop its monitoring and evaluation approach following the implementation of regulations.

Annex A - modelling methodology

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

Baseline modelling

6.9 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 75.

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[43] Vans: WhatVan[44] 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.

[43] FleetNews, 21st July 2020

[44] WhatVan, October 2020

Steps	Details
	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.
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.

Table 75 Baseline calculations

Fleet modelling

Model system overview

6.10 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.

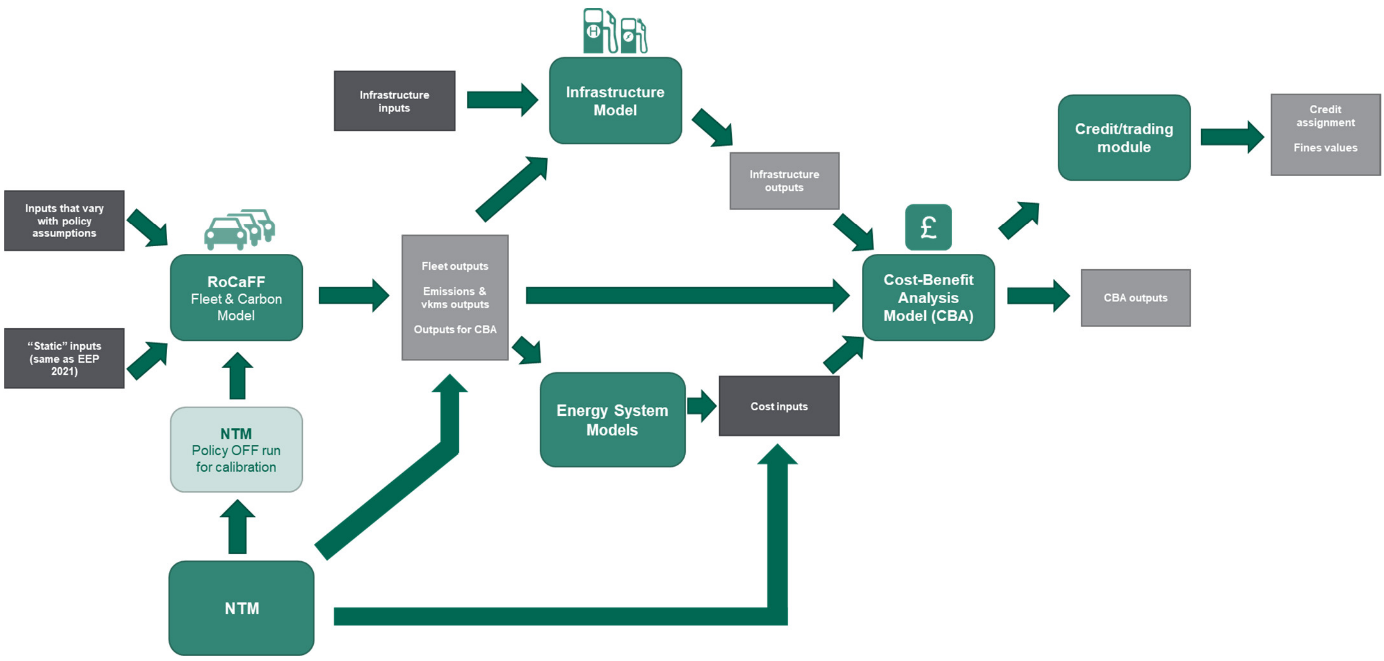


Figure 76 Analysis model pipeline

Fleet model schematic

6.11 Figure 76 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.

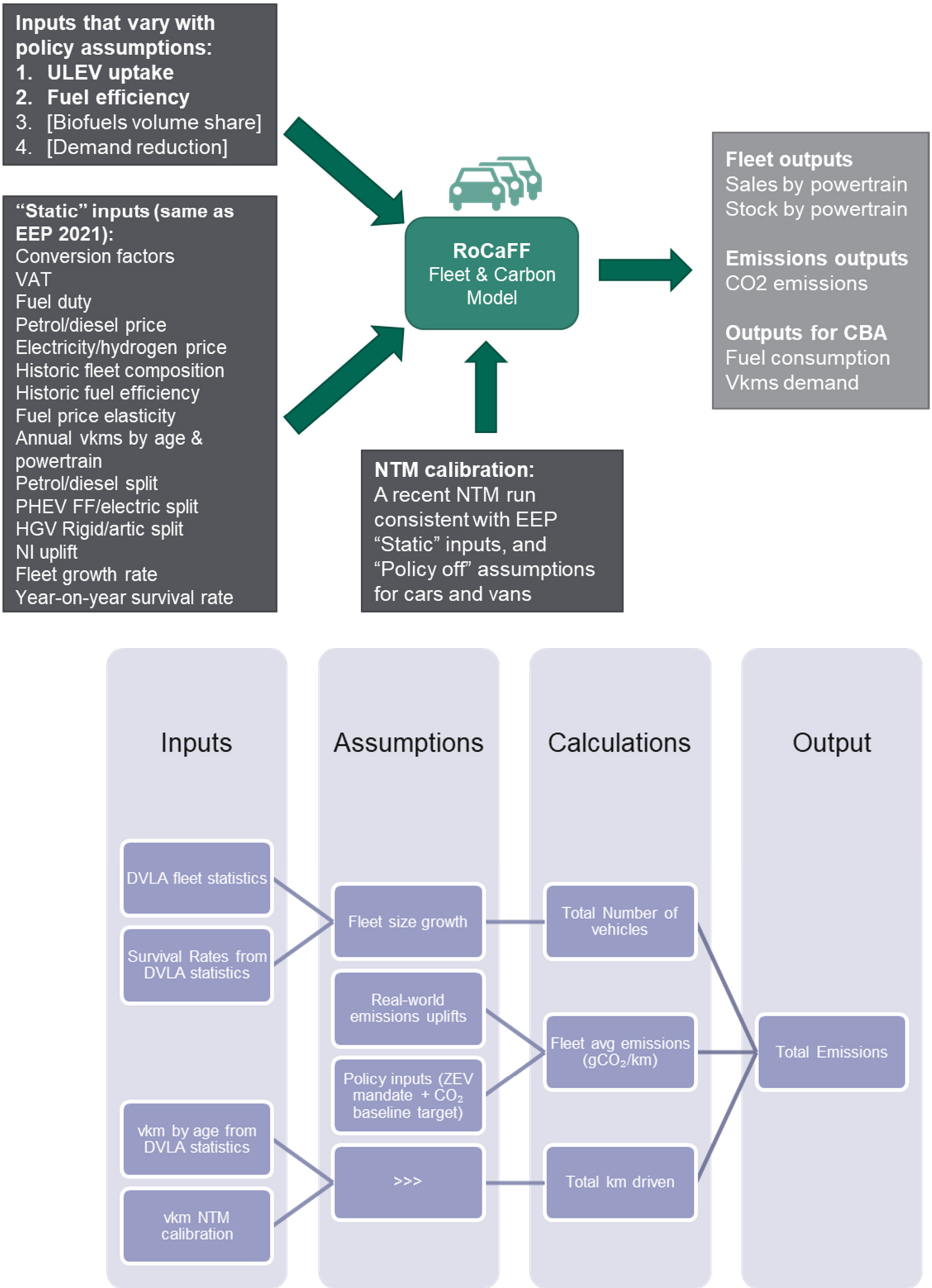


Figure 77 Fleet model (RoCaFF) overview

6.12 Table 78 below sets out the detail underpinning the above schematic.

Group variable	Index range
Vehicle ∈	{Car, Van}
Powertrain ∈	{Petrol ICE/HEV, Diesel ICE/HEV, Petrol PHEV, Diesel PHEV, BEV}
Year ∈	{2024, 2025, …, 2071}

Group variable	Index range
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

Step	Method	Output
Future Uptake and emissions policy assumptions		
1	Assumptions are input for sales and gCO_2/km by vehicles, powertrain, and year. This reflects our policy scenarios.	% sales gCO_2 /km l/km kWh/km

Step	Method	Output
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

Step	Method	Output
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. 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 km (calibrated) Total litres petrol/diesel (calibrated) Total kWh electricity (calibrated) For GB

Step	Method	Output
Mileage and Calibration to NTM		
1	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

Step	Method	Output
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

Step	Method	Output
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)

Table 78 Detailed fleet modelling methodology steps

Cost benefit analysis model method

6.13 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 79 below.

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 78
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.

Calculate Capital Costs		
1	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 Analysis 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	$kgCO_2e$/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.

Figure 79 CBA calculations

Air quality impacts methodology

6.14 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

6.15 As noted in *Section 3: Policy analysis - 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.

6.16 To quantify the emissions of ICEVs, the average vehicle speed on English roads in 2021[45] is weighted by traffic statistics of travel on different types of roads[46] 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).

6.17 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

6.18 In contrast because ZEVs still emit non-exhaust emissions ZEVs can still contribute to air quality damage. 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 consider these equal per km for both a combustion engine vehicle and an electric vehicle. Note that PM2.5 is a subset of PM10, but there is significant uncertainty around by how much.[47]

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

Table 80 Non-exhaust emissions of vehicles

6.19 Non-exhaust emissions can increase if ZEVs drive more miles than conventional vehicles, and due to their heavier weight, but some non-exhaust emissions of ZEVs could also decrease due to technologies such as regenerative braking. The potential increase in non-exhaust emissions due to additional mileage has been included in this analysis. However, any differential impact of ZEVs on non-exhaust emissions is not quantified within this

[45] Table CGN0503d & Table CGN0404a

[46] Table TRA0102

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

assessment due to uncertainty around the relative impact of ZEVs and potential future technology development and adoption to reduce these emissions.

Monetisation

6.20 The quality of the air can have an impact on human health, productivity, wellbeing, and the environment.[48] To quantify this impact, air quality damage costs are taken from Defra's air quality appraisal guidance, adjusted to a 2021 price year using HMT Green Book guidance for economic appraisal. In line with air quality appraisal guidance, a 2% annual uplift is applied from 2017, reflecting the assumption that willingness to pay for health outcomes will rise in line with real GDP growth.

6.21 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).

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%

Table 81 Air quality damage costs from Defra's appraisal guidance

6.22 Air quality impacts are discounted in line with Health discount factors, following the Department for Transport's Transport Analysis Guidance and as a result, we estimate net air quality benefits to society, despite potential increases in non-exhaust emissions from additional milage driving some social costs. These impacts are presented above in *Section 3: Policy analysis - Benefits.*

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

Annex B - assumptions log

1.113 This annex sets out the underlying assumptions which underpin this analysis.

Base assumptions

6.23 The table below presents the underlying assumptions used in this analysis. It is not always possible to present values in this tabular format, as some assumptions relate to many unique values. These assumptions have not changed since the consultation analysis.

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
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 Analysis 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

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<tr><td>8</td><td>Greenbook values</td><td>Discount Rate</td><td><30 years
Standard: 3.5%
Intergenerational: 3%
Health: 1.5%

>30 years
Standard: 3%
Intergenerational: 2.6%
Health: 1.3%</td><td>https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685912/Discount_Factors.xlsx</td></tr>
<tr><td>9</td><td></td><td>Air Quality:
Average speed</td><td>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</td><td>Road Congestion Statistics
Table CGN0503d
Table CGN0404a

Traffic (www.gov.uk/government/organisations/department-for-transport/series/road-traffic-statistics)

Table TRA0102</td></tr>
<tr><td>10</td><td>Greenbook values</td><td>Air Quality Damage Costs</td><td>PM2.5 Road Transport £/tonne 203,331
NOx Road Transport £/tonne 10,699
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>
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<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</td><td>Medium</td><td>GDI</td><td>0.0008</td></tr>
</table></td><td>Exhaust: DEFRA NAEI 2020 October

Non-exhaust: TAG databook, A3.5</td></tr>
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<table>
<tr><th>No</th><th>Category</th><th>Assumption</th><th>Value/Description</th><th>Source:</th></tr>
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<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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Table 3, Rows 29:46</td></tr>
<tr><td>13</td><td>Greenbook values</td><td>Carbon values</td><td></td><td>Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal
Table 3</td></tr>
<tr><td>14</td><td>Greenbook values</td><td>Electricity emissions factors ($kgCO_2e/kWh$)</td><td></td><td>Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal
Table 1: Grid Average: Consumption-based: Domestic</td></tr>
<tr><td>15</td><td>Greenbook values</td><td>Fuel cost impacts: Long-run Variable costs of energy supply</td><td>Note: LRVC are used to represent factor costs rather than market prices in line with Greenbook Guidance.</td><td>Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal
Table 9-13</td></tr>
<tr><td>16</td><td>Cost</td><td>Vehicle maintenance</td><td>Costs of upkeep of ZEV versus ICEV cars and vans.</td><td>Regression analysis of 2020 Fleet data.</td></tr>
<tr><td>17</td><td>Cost</td><td>Manufacturer administrative costs</td><td>Bottom-up estimate of familiarisation costs per obligated manufacturer.</td><td>Annual Survey of Hours and Earnings</td></tr>
<tr><td>18</td><td>Cost</td><td>Government administrative costs</td><td>£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.</td><td>https://www.legislation.gov.uk/uksi/2007/3072/pdfs/uksiem_20073072_en.pdf</td></tr>
<tr><td>19</td><td>Cost</td><td>Energy Systems impacts: Long-run Variable costs of energy supply</td><td>LRVCs</td><td>Green Book supplementary guidance: valuation of energy use</td></tr>
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No	Category	Assumption	Value/Description	Source:
				and greenhouse gas emissions for appraisal Table 9-13
20	Cost	Car/Van capital costs sensitivity	High and low cost values for cars and vans.	Several – see Annex C.
21	Cost	Infrastructure capital	Up-front costs from internal chargepoint demand modelling and market cost data.	Several: CCC; BEISDESNZ; EESI
22	Cost	Infrastructure reinstallation	Costs of replacing infrastructure after functional lifetime	Several: CCC; BEISDESNZ; EESI
23	Cost	Infrastructure maintenance	Cost of upkeep of chargepoints required by ZEVM	Consumer experience IA
24	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_CO_2_en.pdf PHEV: https://theicct.org/wp-content/uploads/2022/06/real-world-phev-use-jun22-1.pdf

Table 82 Base assumptions log

Refinements since the consultation analysis

6.24 There have been a small number of refinements to the core analysis since the consultation stage. These changes have been made to improve the veracity of the results without compromising on proportionality. Table 83 below presents these new assumptions.

No	Category	Assumption	Description
1	Fleet Assumptions	Fleet composition	Projections of petrol/diesel splits have been updated in the policy line to be consistent with Energy and Emissions Projections (EEP) 2021
2	Battery Assumptions	Electric efficiencies in policy line	Analysis assumes electric efficiencies will improve in line with efficiencies in the baseline. No additional economies of scale effects are assumed due to increased GB ZEV uptake, given most GB vehicles are imported and are a small component of global demand.
3	Real-world Assumptions	Real-world electric downlift on ZEVs	Assumes a reduction in electricity per km from PHEVs to account for less driving in electric mode in real-world conditions.
4	Fleet Assumptions	Historical fleet data	Updated 2022 sales splits

Table 83 List of refinements to the analysis

Annex C - cost assumptions

Battery prices

6.25 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 to decline significantly as battery technology improves with learning and as sales grow, increasing economies of scale. Figure 84 shows that the assumptions used in this analysis on the cost per kilowatt hour align closely with forecasts from Transport and Environment/Bloomberg New Energy Finance (BNEF) and the International Council on Clean Transportation (ICCT), all of which expect battery costs to decline significantly over this decade.

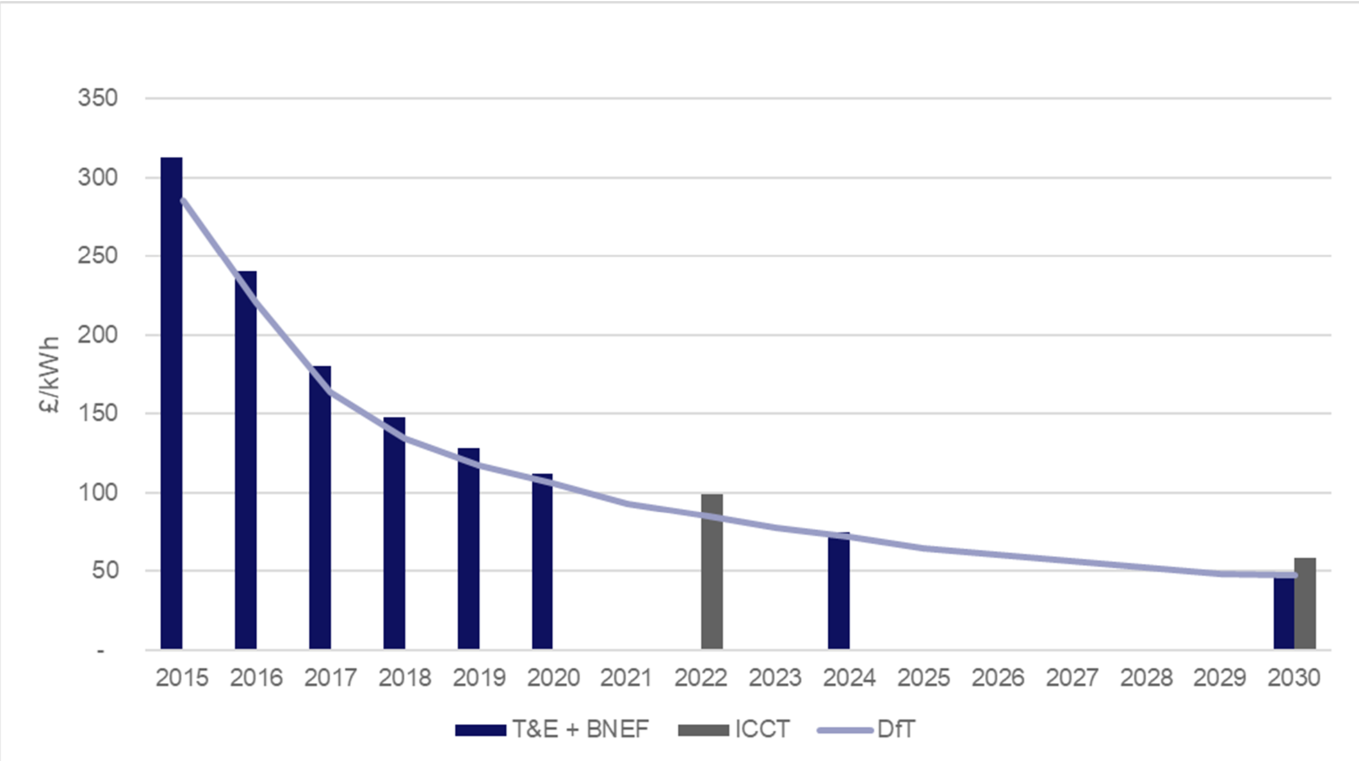


Figure 84 Forecast battery cost estimates (DfT 2022, BNEF 2021, ICCT 2022)

Capital cost methodology

6.26 This section briefly sets out the high-level methodology used to estimate capital costs in *Section 3: Policy analysis - 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.

6.27 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 efficiency improvement projections to provide the total cost of the electric vehicle (as above). For cars and vans, the modelling assumes the battery efficiency gains are attributed to increasing vehicle range, rather than reducing battery sizes.

6.28 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 Transport and the Environment, Bloomberg and the Climate Change Committee (CCC).

6.29 As noted above the assumptions in this analysis result in a lower rate of relative ZEV cost decrease than that forecast by many external commentators. This is due to a number of factors including our assumptions on ICE emission improvements and ZEV range changes. For DfT's central assessment, we do not include the potential cost of Euro 7 requirements for two key reasons. (1) 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). (2) Because this is not a 'firm and funded' policy and is still subject to agreement, 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. In the central case it is also assumed that improvements in battery technology are deployed to improve vehicle range as well as to lower vehicle costs, reducing the extent to which ZEV costs are assumed to fall.

6.30 As a result, DfT's central case reflects a conservative estimate of the relative cost of electric vehicles. 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 Section 3: Policy analysis - 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. A comparison of the resulting relative price changes is set out in the table below.

Organisation	Scope	Publication year	Price parity in	
			Car	Van
DfT downside (slow cost convergence)	GB	2023	N/A	N/A
DfT Central	GB and UK	2023	N/A	N/A
DfT upside (fast cost convergence)	GB	2023	2049	2027
DfT most optimistic case	GB	2023	2027	2026

Organisation	Scope	Publication year	Price parity in	
Fleet Europe	EU	02/2022	2030s	2030s
T&E + BNEF[49,50]	EU	05/2021	2026-27	2025-26
CCC[51,52]	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	

Organisation	Scope	Publication year	Total cost of ownership parity in	
			Car	Van
DfT Central	GB and UK	2023	2025	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

Table 85 Stakeholder capital cost scenarios

Cost sensitivity scenarios

6.31 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 86.

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

Table 86 Sensitivities and input values

6.32 For some cost 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.

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

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

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

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

6.33 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 sensitivities

6.34 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).

6.35 As set out above for DfT's central assessment, we do not include the potential cost of Euro 7. Instead, additional Euro 7 costs are included in the upside cost sensitivity, making the cost of EVs more attractive relative to ICEVs. The underlying assumption is in this scenario is that manufacturers decide to follow the Euro 7 regulations in the UK market to avoid the need for multiple product lines.

6.36 We recognise our ZEV cost 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. This is an equally plausible cost scenario depending on the roll-out of Euro 7 compliant vehicles in the GB market, vehicle characteristics and speed of cost reductions. The input parameters and resultant costs are set out in the tables and figures below.

	Parameter	Upside (High NPV value)	Downside (Low NPV value)
DfT Assumptions	Platform	Dedicated platform efficiency -£1500 for BEVs	-
	Battery Price	-	+30% in 2030 vs BNEF central battery price forecast
	Driving range	-	-
	Vehicle efficiency	-	-
	Euro 7 costs on ICEs	+£1000 for ICEs[53],[54],[55],[56]	-
High optimism cost scenario (informed by T&E and Bloomberg assumptions)[57]	Platform	Dedicated platform efficiency -1500 euros in 2030 for BEVs vs central	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	-

Table 87 Battery electric vehicle price sensitivity parameters

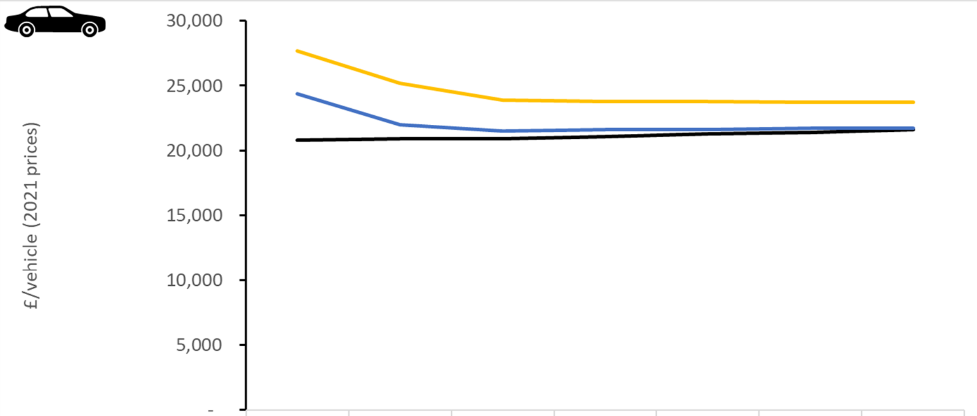
[53] Sources show this cost can be around 150 for petrol and more like 1500 euros above a euro 6d diesel vehicle.

[54] https://mobilitynotes.com/wp-content/uploads/2021/04/WCX-2021-Emission-Regulations-and-Technologies-AmeyaJoshi-Final.pdf

[55] https://www.automotiveworld.com/news-releases/the-ongoing-battle-for-stricter-vehicle-emission-limits-in-europe/

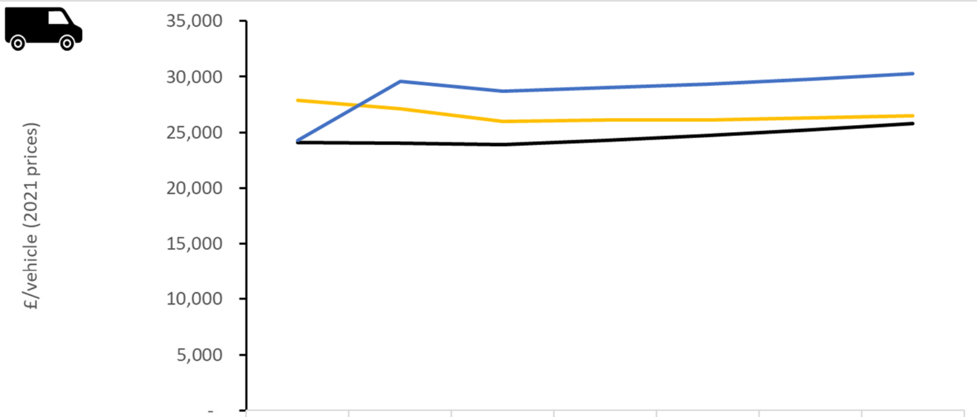
[56] The ICCT also estimate an incremental cost of ~1600 euros in their lowest cost configuration in 2021.
Source: Table 15, https://theicct.org/wp-content/uploads/2021/06/tech-cost-euro-vii-210428.pdf

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



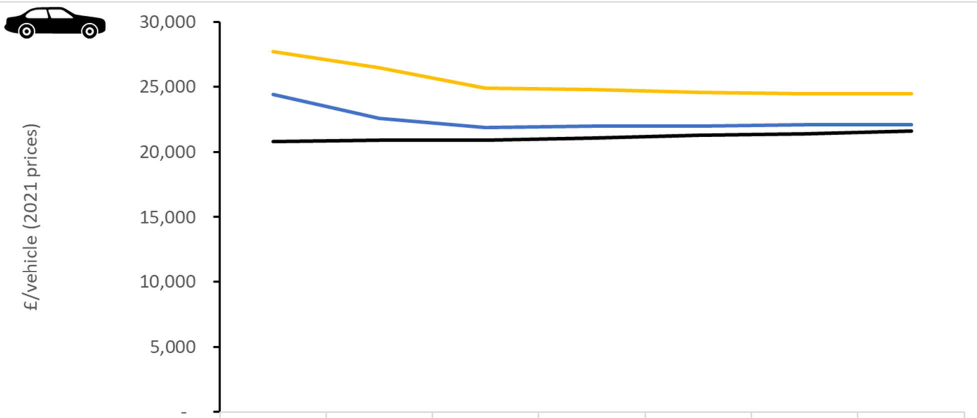
	2020	2025	2030	2035	2040	2045	2050
Central BEV	27,700	25,200	23,900	23,800	23,800	23,700	23,700
Central Average ICEV	20,800	20,900	20,900	21,100	21,300	21,400	21,600
Central Average PHEV	24,400	22,000	21,500	21,600	21,600	21,700	21,700

Figure 88 Central capital cost assumptions for cars



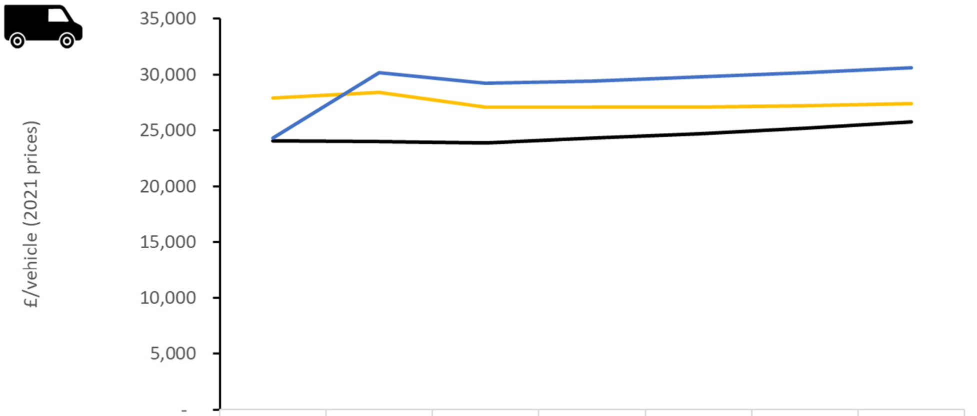
	2020	2025	2030	2035	2040	2045	2050
Central BEV	27,900	27,100	26,000	26,100	26,100	26,300	26,500
Central Average ICEV	24,100	24,000	23,900	24,300	24,700	25,200	25,800
Central Average PHEV	24,300	29,600	28,700	29,000	29,300	29,800	30,300

Figure 89 Central capital cost assumptions for vans



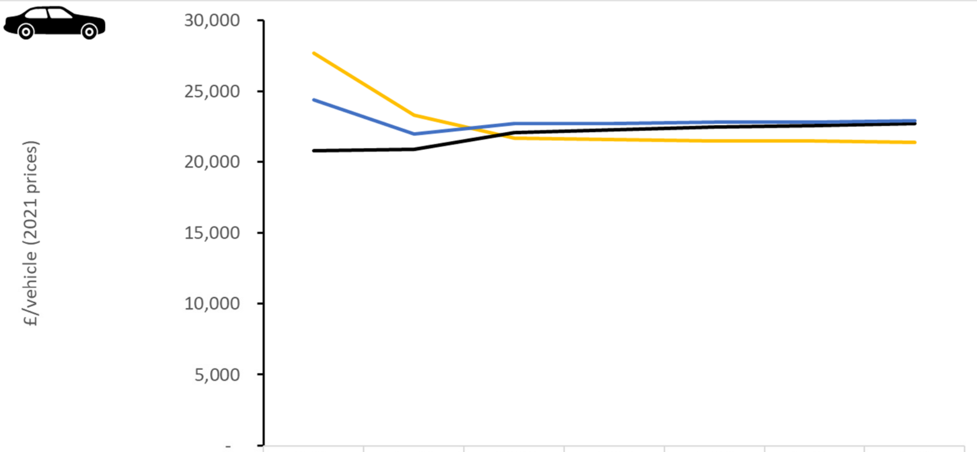
	2020	2025	2030	2035	2040	2045	2050
Low BEV	27,700	26,500	24,900	24,800	24,600	24,500	24,500
Low Average ICEV	20,800	20,900	20,900	21,100	21,300	21,400	21,600
Low Average PHEV	24,400	22,600	21,900	22,000	22,000	22,100	22,100

Figure 90 Low NPV (High capital cost) assumptions for cars



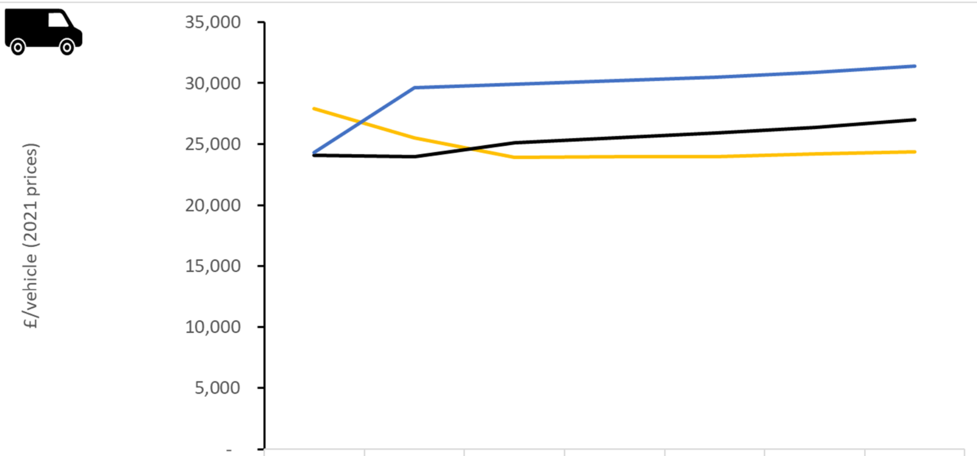
	2020	2025	2030	2035	2040	2045	2050
Low BEV	27,900	28,400	27,100	27,100	27,100	27,200	27,400
Low Average ICEV	24,100	24,000	23,900	24,300	24,700	25,200	25,800
Low Average PHEV	24,300	30,200	29,200	29,400	29,800	30,200	30,600

Figure 91 Low NPV (High capital cost) assumptions for vans



	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 92 Very High NPV (Very Low capital cost) assumptions for cars



	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

Figure 93 Very High NPV (Very Low capital cost) assumptions for vans

Marginal external costs

6.37 As set out in *Section 3: Policy analysis*, this analysis applies the 'high' marginal external costs (MECs), published in the latest version of Transport Analysis Guidance data tables[58]. These MEC estimates have been calculated using the 'shift to zero emission vehicles scenario' 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.

6.38 While new MECs have been estimated as part of the latest Road Traffic Projections published in 2022, these MECs have not yet been included in the latest version of Transport Analysis Guidance. Based on an assessment of proportionality, it was considered appropriate to use the existing values in the absence of newer values.

6.39 However, based on an assessment of proportionality, these values are considered reasonable to use in the absence of more up-to-date MEC projections.

6.40 Figures 94 and 95 show the MECs of accident and congestion.

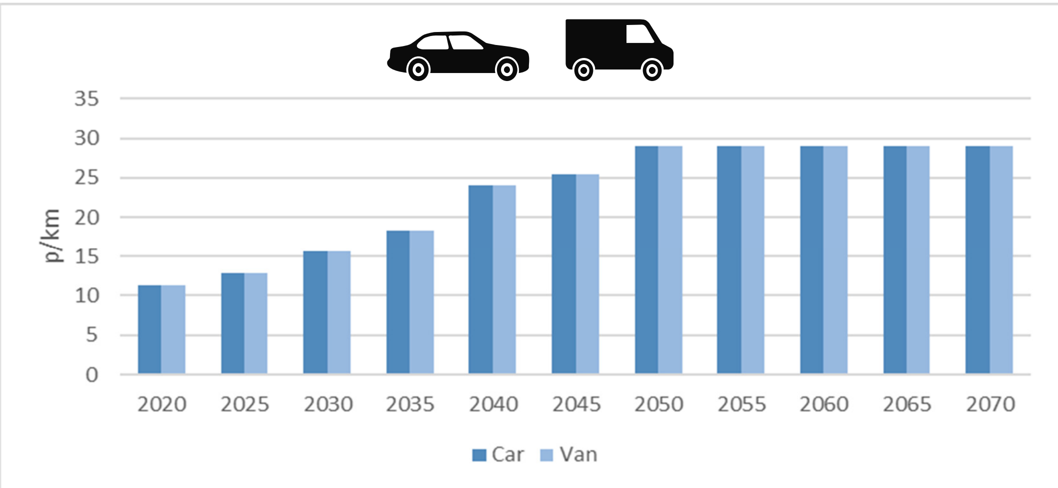


Figure 94 Transport Analytical Guidance 'High' Congestion Marginal External Costs

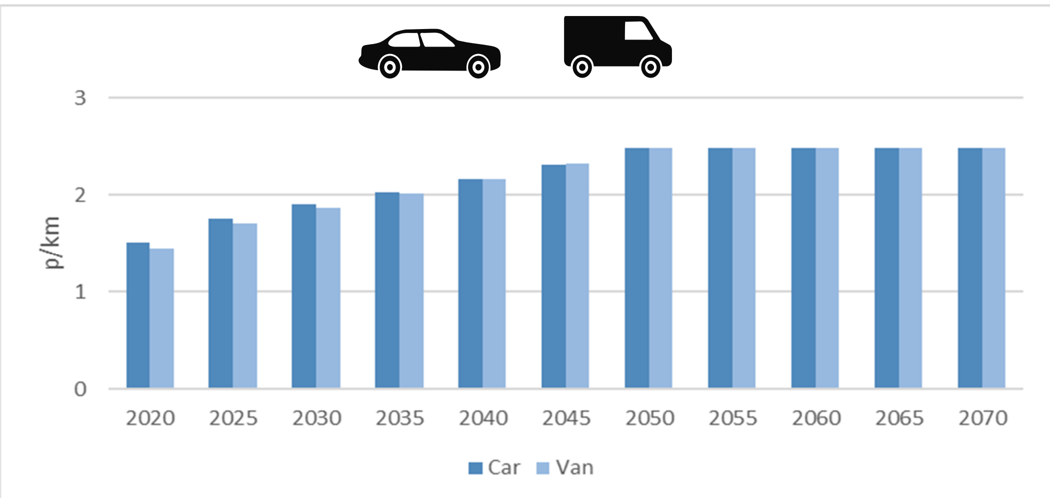


Figure 95 Transport Analytical Guidance 'High' Accident Marginal External Costs

[58] TAG databook table 5.4.2.2

Annex D - detailed model output tables

6.41 The following table presents the disaggregated model outputs for the cost sensitivities presented in *Section 3: Policy analysis - Sensitivity analysis*. Negative numbers are either costs or disbenefits, while positive numbers are either benefits or cost savings.

Vehicle type	Impact	Low	Central	High	Very high
Car	Capital cost PV (Discounted)	-31778	-25294	9730	15750
Car	Operating cost PV (Discounted)	9370	9370	9370	9370
Car	Fuel cost PV (Discounted)	21731	34583	50834	50834
Car	Infrastructure CAPEX PV (Discounted)	-10584	-8467	-6350	-6350
Car	Infrastructure OPEX PV (Discounted)	-2152	-1722	-1291	-1291
Car	Traded CO_2 cost PV (Discounted)	-364	-727	-1212	-1212
Car	Non-Traded CO_2 cost PV (Discounted)	39541	79083	132745	132745
Car	NOx cost PV (Discounted)	65	724	3123	3123
Car	PM cost PV (Discounted)	-67	-312	-1072	-1072
Car	Accident cost PV (Discounted)	-5046	-5046	-5046	-5046
Car	Congestion cost PV (Discounted)	-53876	-53876	-53876	-53876
Car	Administrative cost PV (Discounted)	-22	-29	-36	-36
Car	Indirect tax PV (Discounted)	3088	3222	3372	3372
Car	Consumer surplus PV (Discounted)	1670	1670	1670	1670
Car	PVB (Discounted)	75465	128652	210844	216863
Car	PVC (Discounted) (excl. rebound)	-49724	-41444	-15004	-15004
Car	PVC (Discounted)	-103888	-95474	-68884	-68884
Car	NPV (Discounted) (excl. rebound)	25741	87208	195839	201859
Car	NPV (Discounted)	-28423	33178	141960	147979
Car	Abatement cost (excl. rebound)	30	-18	-137	-150
Car	Abatement cost	148	100	-20	-33
Van	Capital cost PV (Discounted)	-3771	-1827	3381	4026
Van	Operating cost PV (Discounted)	5974	5974	5974	5974
Van	Fuel cost PV (Discounted)	1208	4151	8687	8687
Van	Infrastructure CAPEX PV (Discounted)	-3043	-2434	-1826	-1826
Van	Infrastructure OPEX PV (Discounted)	-693	-554	-416	-416
Van	Traded CO_2 cost PV (Discounted)	-431	-862	-1385	-1385
Van	Non-Traded CO_2 cost PV (Discounted)	11929	23859	39669	39669

Vehicle type	Impact	Low	Central	High	Very high
Van	NOx cost PV (Discounted)	70	781	3252	3252
Van	PM cost PV (Discounted)	-48	-223	-762	-762
Van	Accident cost PV (Discounted)	-2210	-2210	-2210	-2210
Van	Congestion cost PV (Discounted)	-23676	-23676	-23676	-23676
Van	Administrative cost PV (Discounted)	-3	-4	-6	-6
Van	Indirect tax PV (Discounted)	2418	2529	2653	2653
Van	Consumer surplus PV (Discounted)	540	540	540	540
Van	PVB (Discounted)	22139	37833	64156	64802
Van	PVC (Discounted) (excl. rebound)	-10946	-8974	-7587	-7587
Van	PVC (Discounted)	-33874	-31790	-30279	-30279
Van	NPV (Discounted) (excl. rebound)	11193	28859	56569	57214
Van	NPV (Discounted)	-11735	6043	33877	34522
Van	Abatement cost (excl. rebound)	6	-37	-126	-131
Van	Abatement cost	177	133	43	38
Both	Capital cost PV (Discounted)	-35548	-27121	13111	19776
Both	Operating cost PV (Discounted)	15344	15344	15344	15344
Both	Fuel cost PV (Discounted)	22939	38734	59520	59520
Both	Infrastructure CAPEX PV (Discounted)	-13627	-10901	-8176	-8176
Both	Infrastructure OPEX PV (Discounted)	-2845	-2276	-1707	-1707
Both	Traded CO_2 cost PV (Discounted)	-795	-1590	-2597	-2597
Both	Non-Traded CO_2 cost PV (Discounted)	51471	102941	172414	172414
Both	NOx cost PV (Discounted)	136	1505	6375	6375
Both	PM cost PV (Discounted)	-115	-535	-1834	-1834
Both	Accident cost PV (Discounted)	-7255	-7255	-7255	-7255
Both	Congestion cost PV (Discounted)	-77552	-77552	-77552	-77552
Both	Indirect tax PV (Discounted)	5505	5751	6025	6025
Both	Administrative cost PV (Discounted)	-25	-33	-42	-42
Both	Consumer surplus PV (Discounted)	2210	2210	2210	2210
Both	PVB (Discounted)	97604	166485	275000	281664
Both	PVC (Discounted) (excl. rebound)	-60671	-50418	-22591	-22591
Both	PVC (Discounted)	-137763	-127264	-99163	-99163
Both	NPV (Discounted) (excl. rebound)	36933	116067	252408	259073
Both	NPV (Discounted)	-40158	39221	175836	182501
Both	Abatement cost (excl. rebound)	25	-22	-135	-146
Both	Abatement cost	154	107	-6	-17

Table 96 Detailed cost benefit analysis of cost sensitivities (present value; 2021 prices; £m)

Annex E - depreciation sensitivities

6.42 The relative cost of ownership between ZEVs and non-ZEVs presented in *Section 5: 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. The central assumption is that ZEVs depreciate at the same rate as the ICEV they replace.

6.43 However, while evidence suggests that the rate of depreciation has been higher for BEVs than ICEVs previously, there are three reasons to assume that this higher rate of depreciation is a temporary effect, all due to the nascent stage of the electric vehicle market. Firstly, significant improvements in battery technology have been made in recent years and many second hand BEVs would have been manufactured before these improvements were made. Secondly, as battery powered vehicles are a relatively new product for the mass market there is likely to some degree of conservatism in the second-hand market. And thirdly, new BEV prices have fallen over recent years; if the price of a new vehicle falls, then the price of a second hand equivalent of the same vehicle is also likely to decrease (as the potential purchaser of a one or two year old vehicle will choose a new vehicle if it is cheaper). In addition, new BEVs are more likely to be purchased by those who undertake greater than average mileage, as the running cost savings will accrue more quickly, and as such, an average three year old BEV is likely to have a greater mileage than a three year old ICEV. This assumption is supported by prices in the new car lease market, where a significantly greater depreciation for BEVs does not seem to be priced into the relative costs.

6.44 However given the inherent uncertainty 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 97 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 5: 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 have depreciated at a greater rate, on average, than their ICEV counterparts.

6.45 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.

6.46 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.

6.47 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 km. 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).

6.48 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.

		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

Table 97 Cumulative cashflow after 5 years of ownership for cars, for 1st and 2nd owners

6.49 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.

		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

Table 98 Cumulative cashflow after 5 years of ownership for vans, for 1st and 2nd owners

6.50 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)

6.51 To ascertain whether decarbonisation policies represent good value-for-money, it is important to understand how their costs compare against the marginal cost of taking alternative action to decarbonise 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.

6.52 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 99.

Vehicle type	Scenario	Low	Central	High
Car	Central	86	172	258
Van	Central	89	178	268
Both	Central	87	174	260

Table 99 Non-traded cost-effectiveness comparator (NTCC) to other climate policies, under different carbon prices

Vehicle type	Including rebound effect	Excluding rebound effect
Car	£100	-£18
Van	£133	-£37
Both	£107	-£22

Table 100 Abatement costs of the ZEV mandate, with and without the rebound effect

6.53 A comparison of the values in Table 99 and Table 100, indicates that the final policy is 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.

6.54 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 in *Section 3: Policy analysis - Indirect costs and benefits* is expected to be more likely).

6.55 More detail on the NTCC and the underlying methodology can be found on gov.uk.

Annex G - real world emissions evidence

6.56 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 the policy. This section summarises some of the recent evidence on this performance gap and details the approach taken in this analysis.

PHEVs

6.57 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. In its 2022 analysis the ICCT considered a large range of international evidence accrued across multiple EU countries including the UK. The results are also supported by the findings of the ICCTs 2020 research across a further number of large countries with significant PHEV penetration such as the US, Canada and China. The ICCT utilises a range of primary data gathering methods, illustrating consistent results.

6.58 The PHEV real-world uplift applied in this analysis 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).[59],[60] 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 102, below.

ICEVs and HEVs

6.59 ICEV and HEV real-world emissions are estimated using assumptions taken from Ricardo & JRC research (2018).[61] 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,

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

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

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

somewhat less recent than the PHEV performance data being based on analysis of the 2014 real-world emissions gap.

6.60 The ICCT also publishes the observed real-world emission gaps of ICEVs. These estimates 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.[62],[63] Overall, this suggests ICEV real-world performance estimates from Ricardo & JRC remain relatively robust.

6.61 Table 101 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 102 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 is also slightly higher.

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

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%[64]	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%*

[62] From laboratory to road: A 2018 update of official and "real-world" fuel consumption and CO_2 values for passenger cars in Europe (theicct.org)

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

[64] 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.

* 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%.

Table 102 PHEV Central real-world emissions gaps and uplift factors with uncertainty bounds

Annex H - final compliance payments

Stakeholder Views

6.62 The flexibilities in the mandate design are expected to de-risk and mitigate the challenge of the targets for manufacturers, providing manufacturers with alternative routes to compliance. However, to incentivise compliance and ultimately increase ZEV sales, some level of financial payment is required under the scheme. This ensures that manufacturers will exhaust all possible cost-effective options before conceding a compliance payment.

6.63 In setting this payment, it is important to avoid setting a payment which is too low, which would be expected to lead to some manufactures finding it more cost-effective to make a payment rather than selling ZEVs, which could undermine carbon savings; 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).

6.64 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 would also be worse off as the financial penalty (cost to society) would exceed the benefit to society.

6.65 Through the lens of guaranteeing manufacturers' delivery of ZEV compliance, 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.

6.66 Finally, in an open economy, it is important to consider the interaction between connected markets. Vehicle emissions regulations and compliance penalty frameworks in other connected markets could jeopardise the delivery of the policy; this may occur 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.

6.67 From the final consultation, stakeholder responses provided a mixed view of the proposed payment levels; some respondents felt the payment levels for the ZEV mandate were too low, others felt they were too high, and some supported the proposal. A substantial minority, mainly vehicle manufacturers, specifically referred to the comparison of payment levels in the Californian Zero-Emission Vehicle Program, arguing ZEV mandate payments should be lower as the California scheme allows a broader range of drivetrain technologies to contribute towards compliance. No specific alternative payment levels had widespread support.

6.68 However, Government also recognises that the new zero emission van market is at a much earlier stage than that of cars, due to a smaller number of zero emission van models, technical challenges with range, and higher upfront vehicle costs that challenges the total cost of ownership benefits of zero emission vans compared to non-ZEVs. This provided sufficient justification for a reduction in the ZEV mandate scheme payment level for 2024 only.

Treatment Under Existing UK Regulations

6.69 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.[65] 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

6.70 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 GB ZEV mandate).

[65] https://www.vehicle-certification-agency.gov.uk/download-publication/3899/New-Car-and-Van-CO₂-Regulations-Guidance-2022

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[66].
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[67].

Figure 103 Summary of penalties under existing ZEV regulations worldwide[68]

6.71 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 ZEV mandate in Great Britain, 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.

Considerations For Setting Payment Price

Test 1: Cost Premium Of Producing A ZEV

6.72 To incentivise compliance with the mandate, the minimum bound on payments should ensure that 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

6.73 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 drives more miles, this value is higher at £6,850 – £20,500, rising to £22,200 by 2029.

6.74 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-

[66] Tom Kang, "China's 'dual Credit' Policy, What You Need to Know," CnEVPost (blog), July 25, 2021, https://cnevpost.com/2021/07/25/chinasdual-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/.

[67] 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.

[68] Currency equivalents using exchange rates from 23 August 2022.

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

6.75 The ZEV mandate has been 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.

6.76 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.

6.77 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.

6.78 Current UK vehicle CO_2 regulations also implicitly place the same value on each ZEV sold as the current EU regulations, 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

6.79 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 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.

6.80 Although the trading price of credits is difficult to predict, it will not exceed the stated non-compliance payment price. This is because a manufacturer will seek to use the lowest cost compliance route. If the trading price of credits were hypothetically greater than the compliance payment, manufactures would simply choose to make the compliance payment. Therefore, setting a higher 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 domestic 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 - additional flexibilities analysis

Banking and borrowing

6.81 As proposed at the final consultation, one way in which Government can provide additional 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), but there are also potential risks.

6.82 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.

6.83 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.

6.84 Nevertheless, there are several facets of policy design which will 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.

6.85 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.

6.86 The 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.

6.87 The vast majority of stakeholder feedback from the final consultation agreed with the proposal to allow banking of allowances, while views were mixed for borrowing. Based on the range of feedback, the banking and borrowing flexibility remains largely unchanged from final consultation proposal, with a small change that sees the borrowing cap for vans increase from 75% to 90% in 2024 only. As with the change to the compliance payment for vans in 2024, this change is designed to help manufacturers with the challenges associated to the infancy of the ZEV van market.

6.88 Figure 104 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.

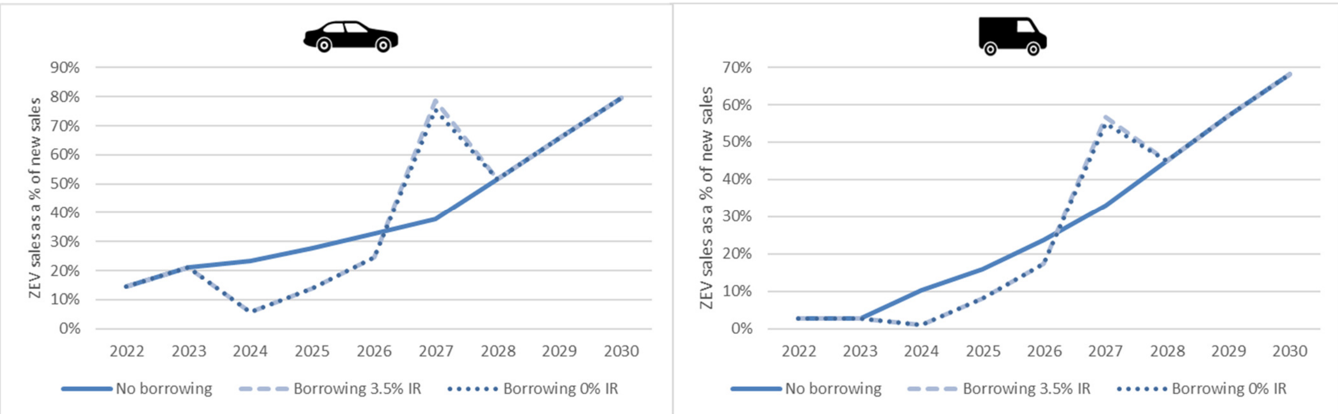


Figure 104 New car and van uptake trajectories under alternative borrowing scenarios (with and without a 3.5% IR)

6.89 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 is less than presented here.

6.90 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 delivery 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.

6.91 Manufacturers will also 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.

6.92 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.

2-way allowance transfers

6.93 The final consultation also proposed the additional flexibility of 2-way allowance transfers. In summary, this allows for a transfer of allowances from either scheme, subject to a transfer rate.

6.94 Given that the shift to ZEVs is the core priority of this framework, 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. For this reason, the carbon saving risk is small, as there are limited real-world emission implications.

6.95 Equally, manufacturers that over-perform against their non-ZEV CO_2 targets may count this excess performance against their ZEV allowances, for the years 2024-2026.

6.96 In order to count non-ZEV over-performance against ZEV delivery targets, a conversion rate is required. This rate is 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]. A conversion rate based on real-world emissions has been chosen to mitigate carbon risks associated with the real-world performance difference to the WLTP test cycle.

6.97 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, this transfer is capped at 65%, 45% and 25% in 2024, 2025 and 2026 respectively.

6.98 As the transfer of non-ZEV allowances to ZEV credits carries a risk of lost carbon savings, sensitivity analysis to assess the potential impact on carbon savings is

proportionate. The analysis is summarised in *Section 4: Policy risks - Transfers from non-ZEV allowances to ZEV credits.*

6.99 Due to the uncertainty associated to the degree to which manufacturers will incorporate allowance transfers within their compliance strategy, multiple scenarios have been considered. Each scenario assumes manufacturers use excess PHEV deployment to accrue excess non-ZEV allowances to trade into ZEVs allowances (although in reality, it may be a combination of efficient ICEVs and PHEVs). As a result, fewer ZEVs are sold into the fleet and carbon savings are reduced. This analysis is only tested for cars, as van PHEVs are currently, and are expected to still be far less prevalent, which will limit their ability to risk carbon savings.

6.100 Alternative pathways of PHEV deployment are based on SMMT's car outlook forecasts; these have been chosen to present alternative levels of feasible PHEV deployment 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. Figure 105 presents these alternative PHEV deployments.

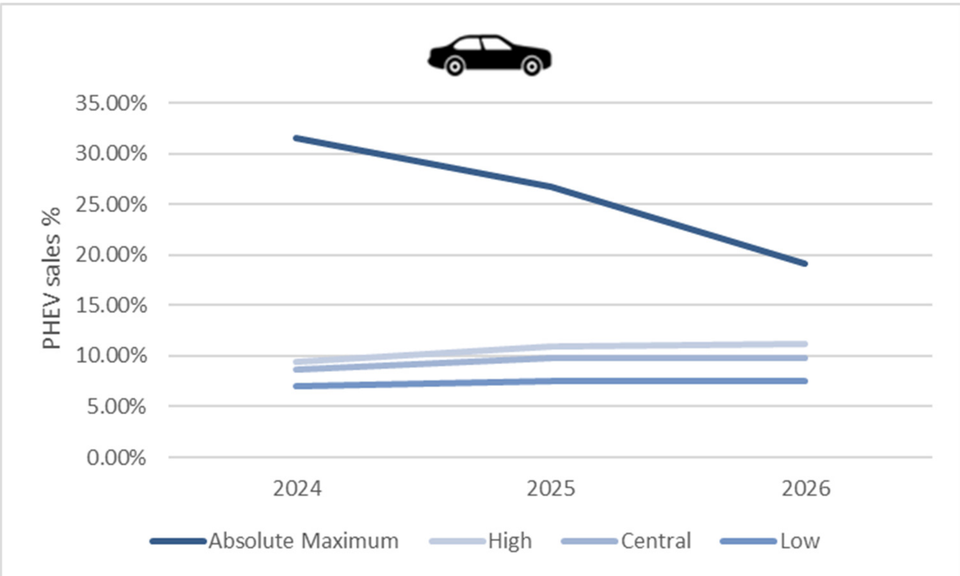


Figure 105 Alternative PHEV deployment scenarios from the SMMT car outlook forecasts

Annex J - detailed distributional analysis

6.101 This section follows on from *Section 5: Wider Impacts*. It sets out in greater detail the expected impact of these regulations 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.

6.102 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.

6.103 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 in the sections below.

6.104 All evidence is sourced from the 2020-2021 English Housing Survey (EHS), unless stated otherwise.

Age

6.105 Detailed data on the relationship between age and household income is not readily available, but the differential effect of these regulations on households of different ages can be proxied using the state pension age. Figure 106 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.

6.106 However, evidence 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.

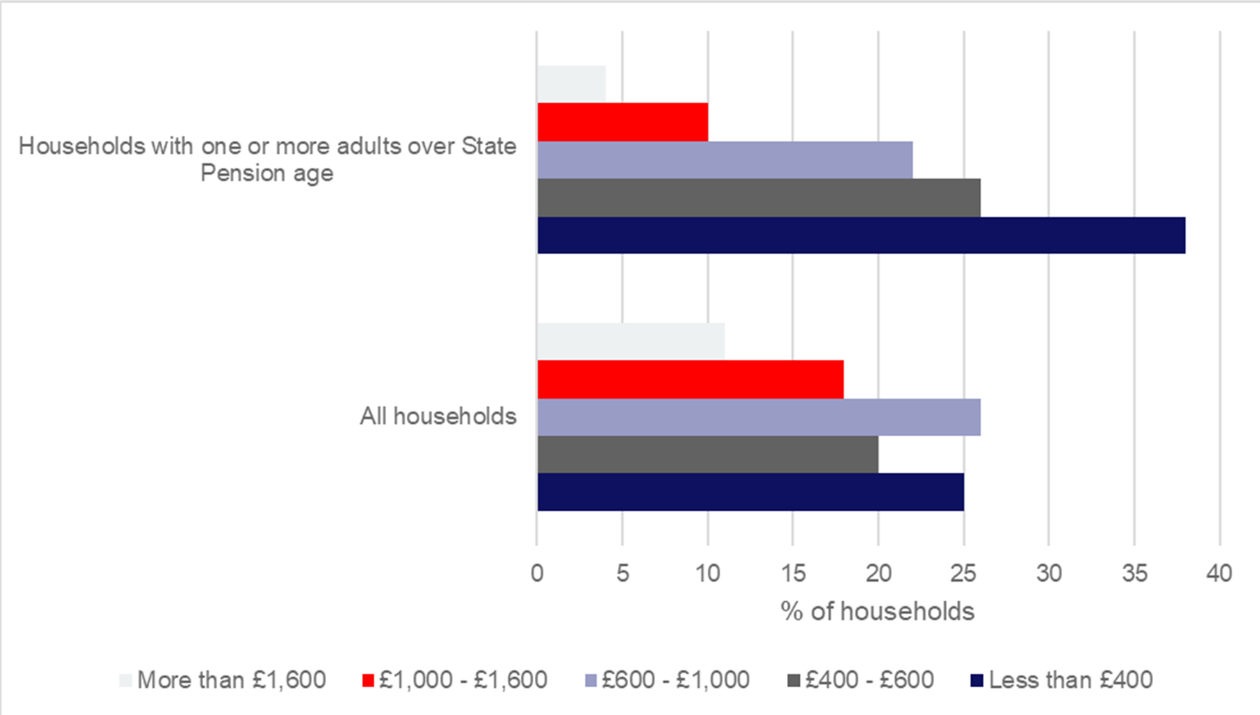


Figure 106 Gross weekly household income for all households versus those with at least one adult over state pension age

6.107 Furthermore, Figure 107 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.

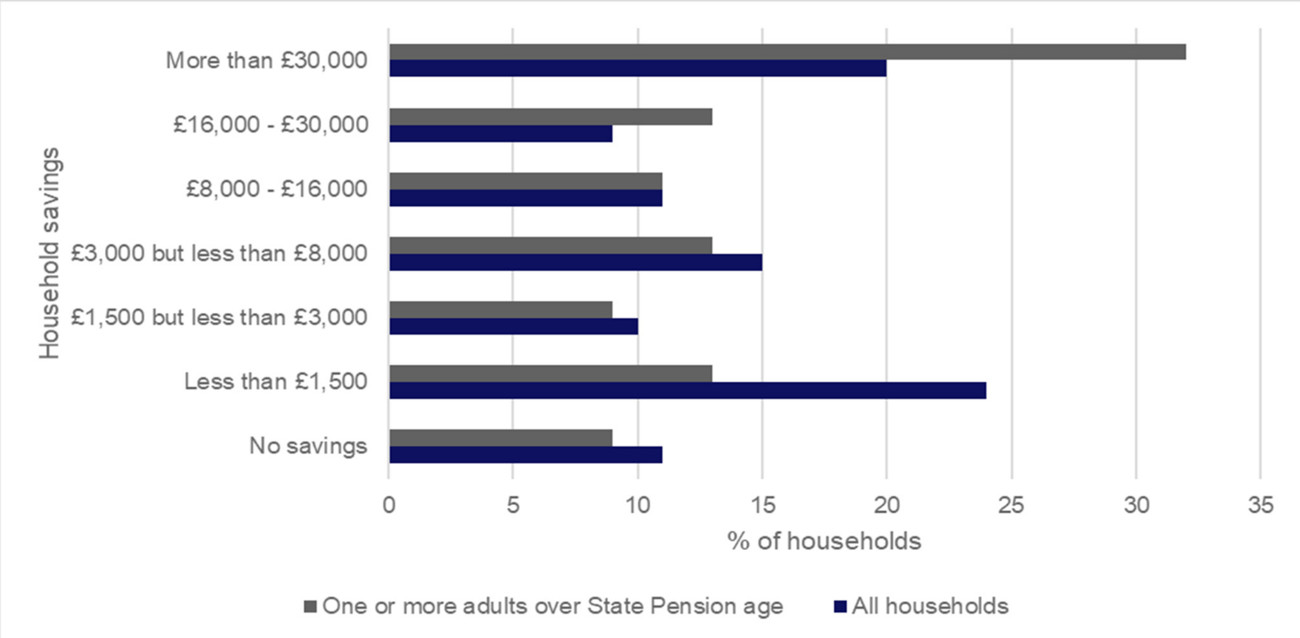


Figure 107 Household savings for all households versus those with at least one adult over state pension age

6.108 On balance, it seems unlikely that older households would face significant barriers to car ownership as a result of these regulations, compared to the general population.

Disability

6.109 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.

6.110 As shown in Figure 108 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 109 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.

6.111 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.

6.112 The most direct way in which these regulations 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 provided. These incentives aim to increase the relative benefit of the production of wheelchair-accessible ZEVs to reduce the likelihood of insufficient supply.

6.113 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 regulations.

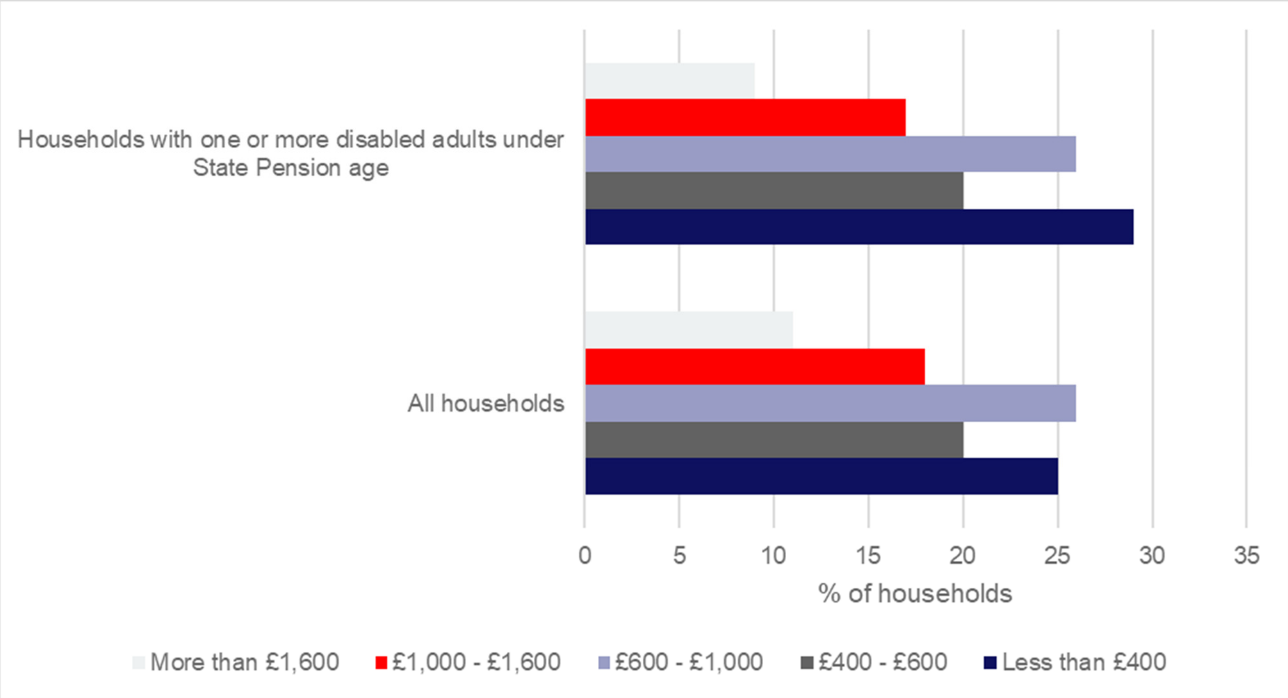


Figure 108 Gross weekly household income for all households versus those with at least one disabled adult under state pension age

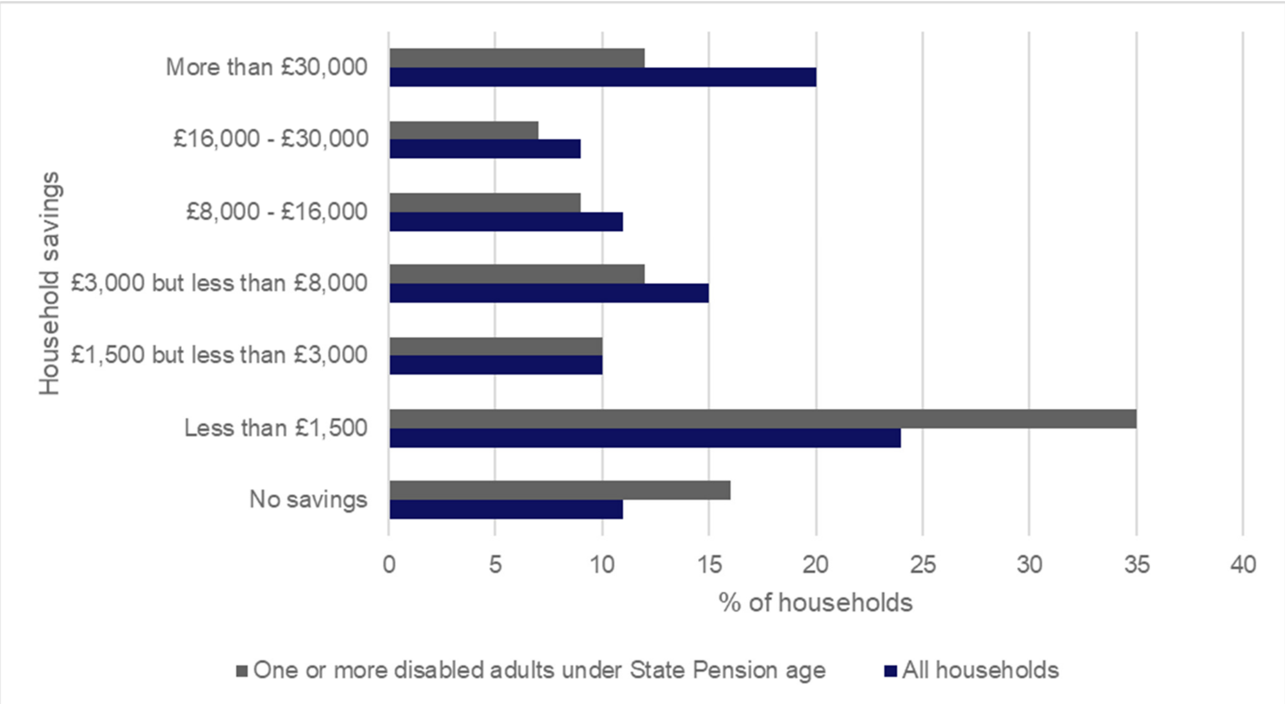


Figure 109 **Household savings for all households versus those with at least one disabled adult under state pension age**

Race and ethnicity

6.114 Figure 110 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.

6.115 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.

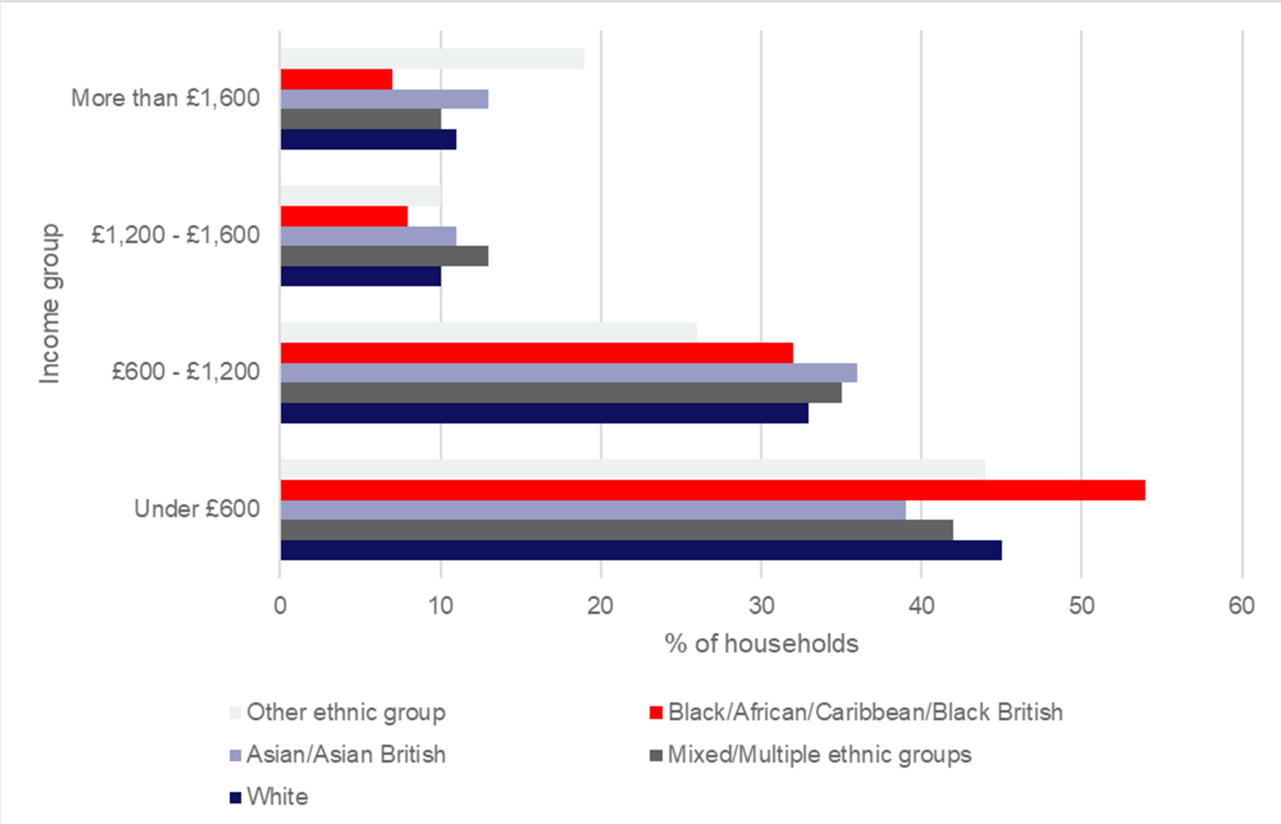


Figure 110 Gross weekly household income by ethnicity

6.116 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 5.60, it seems reasonable to expect that Black/African/Caribbean/Black British households also hold relatively lower values of savings and investments, and may face barriers to taking up BEVs, especially first-hand.

6.117 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 regulations on disadvantaged groups may not be negative.

Pregnancy and maternity

6.118 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.

6.119 As shown in Figure 111, 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.

6.120 On average, two- and three or more- adult households with children 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.

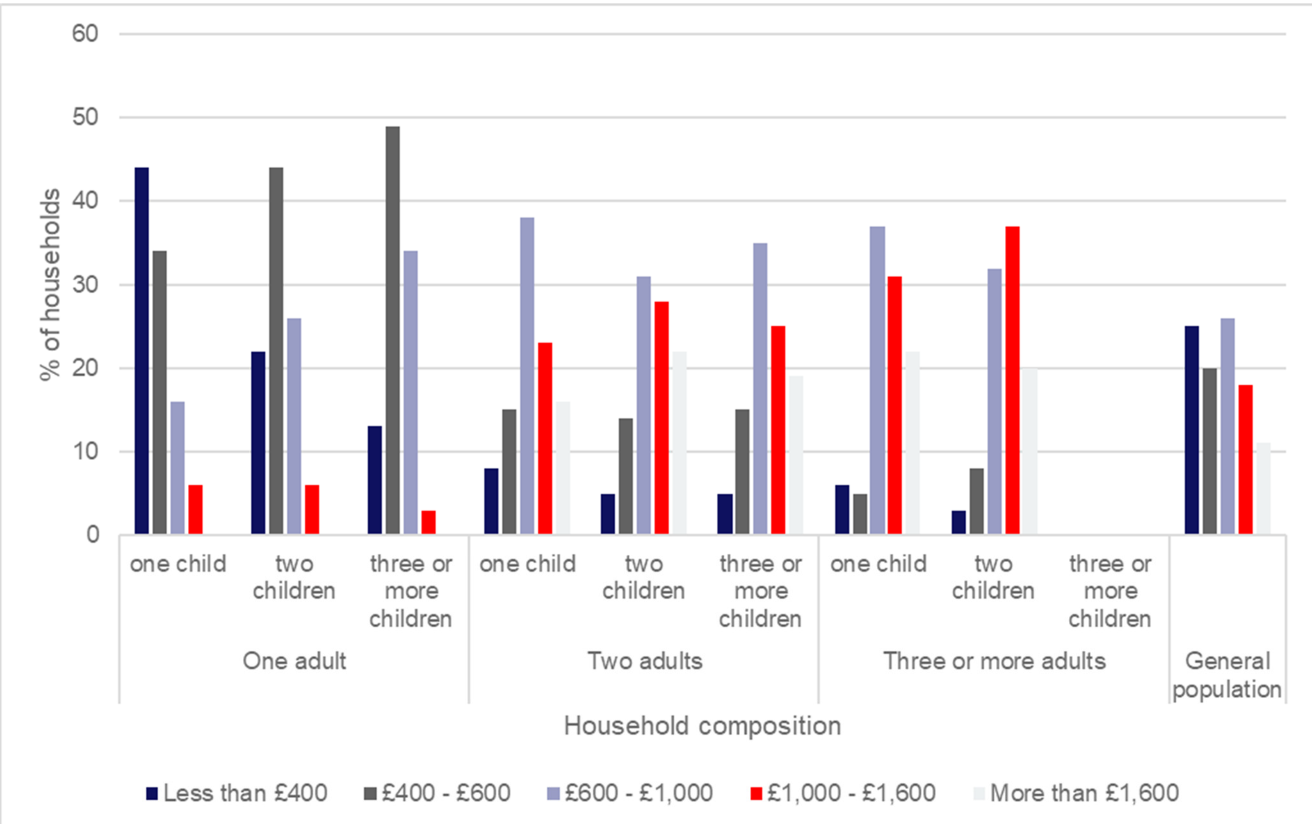


Figure 111 Gross weekly household income by household composition

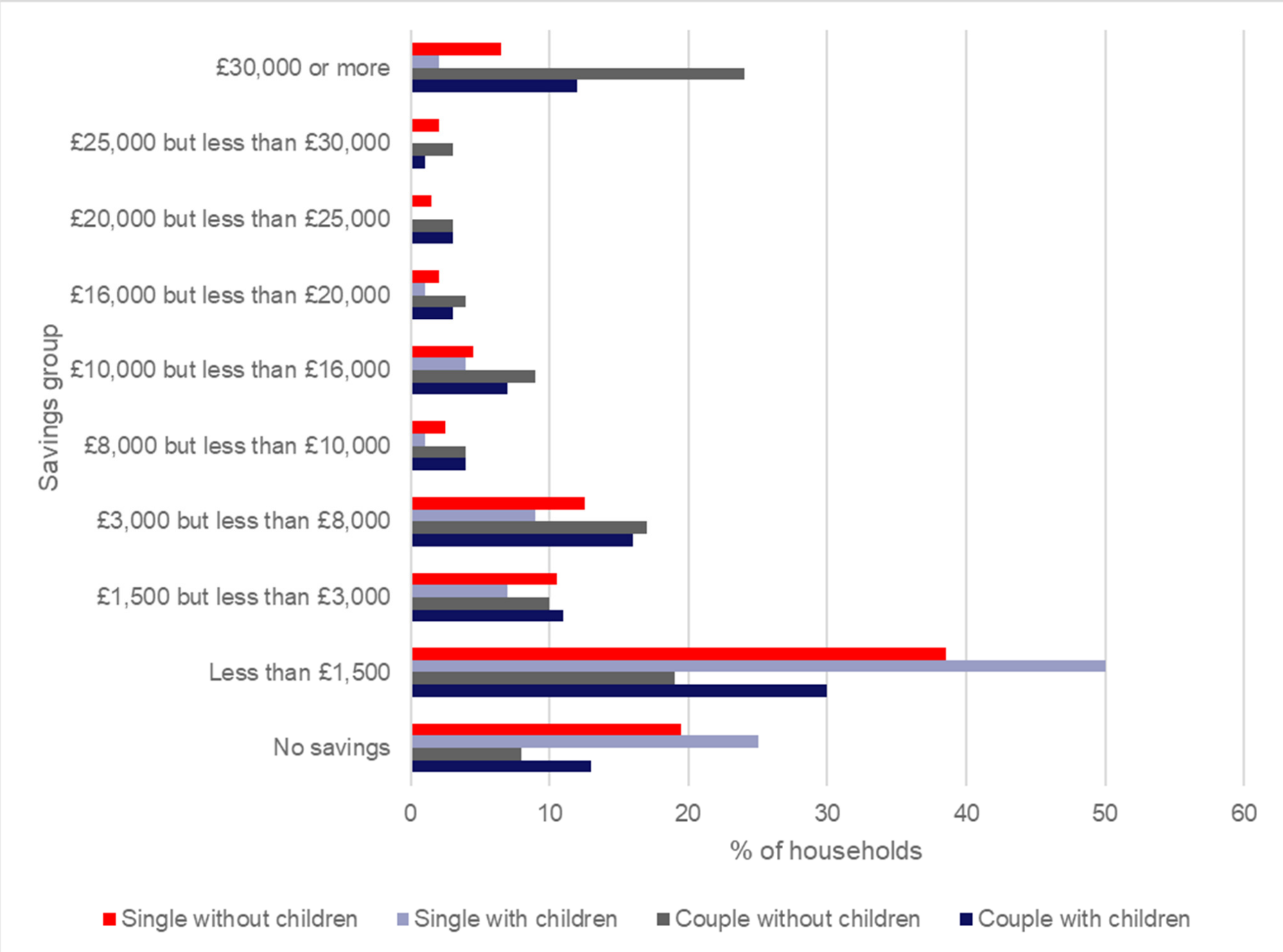


Figure 112 Household savings by household composition

6.121 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.

6.122 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

6.123 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.

6.124 Figure 113 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.

6.125 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.

6.126 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.

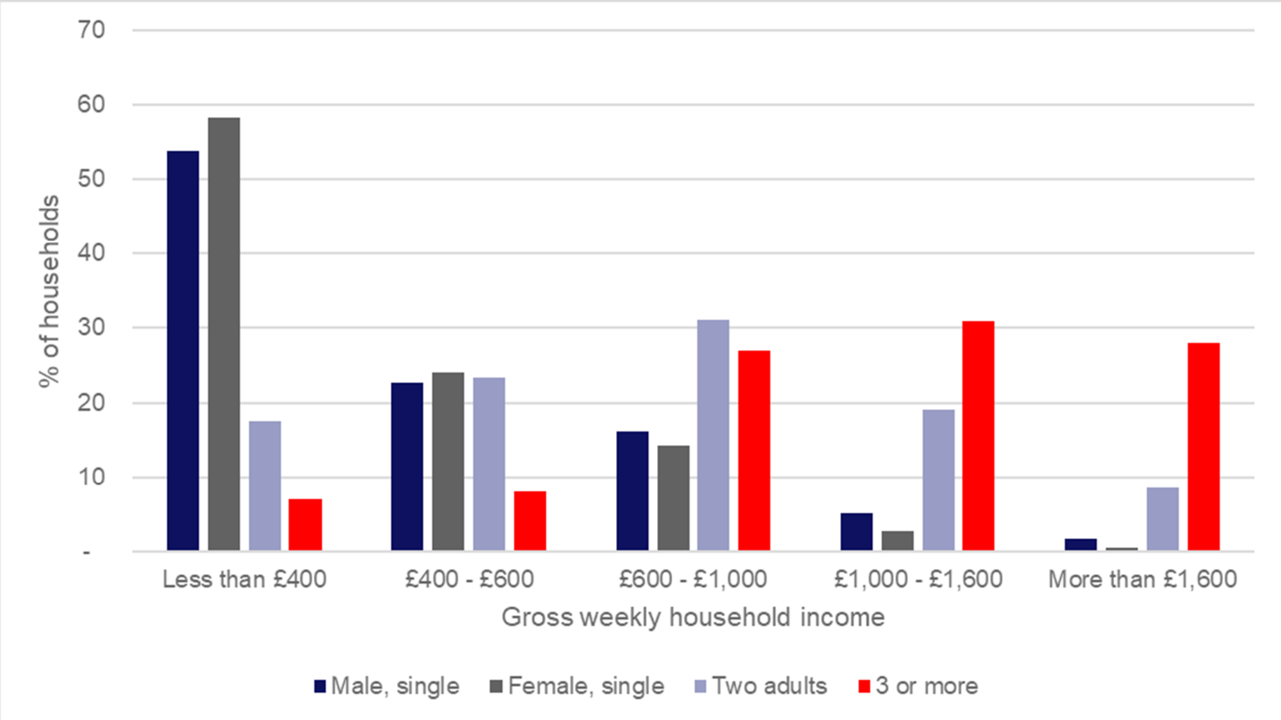


Figure 113 Gross household weekly income by household type and gender for single-person households

6.127 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.

6.128 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 114, 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.

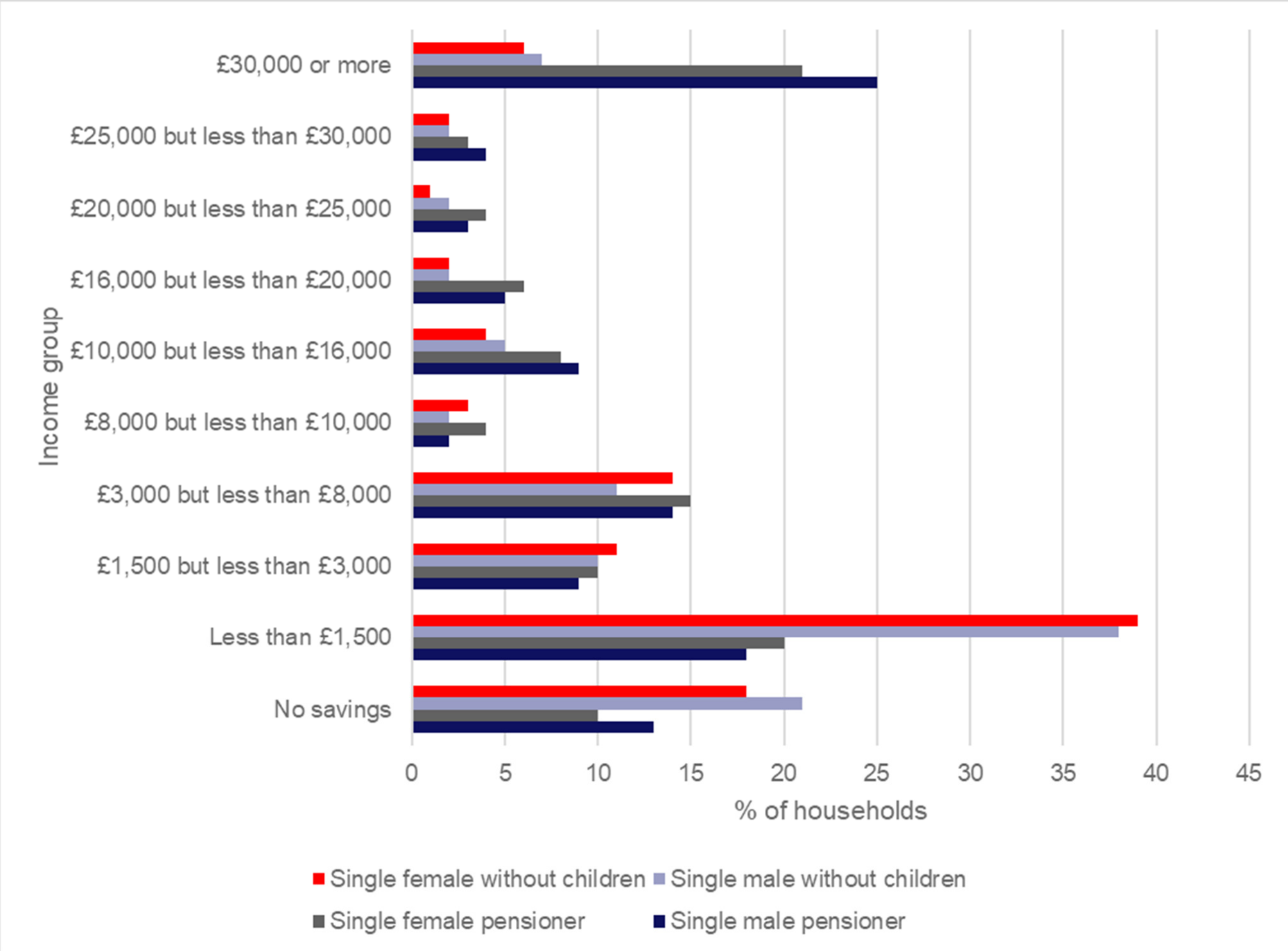


Figure 114 Savings by gender and age

6.129 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.

6.130 With regard to the ZEV mandate, the similarities in the income distributions of these two groups suggest it is unlikely the regulations 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

6.131 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.

6.132 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.

6.133 The report mentioned in paragraph 6.132 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.

6.134 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.

6.135 Nonetheless, the overall finding is that on average LGB&T groups are unlikely to face barriers to engagement with these regulations, based on their financial status.

Religion or belief

6.136 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 regulations in different ways.

Rural communities

6.137 While rural communities are not a protected characteristic under the Public Sector Equality duty, some stakeholders provided feedback through the final consultation around potential impacts on rural communities. There is evidence to suggest that individuals living in rural communities could be impacted more significantly by the regulations than those living in suburban or urban locations.

6.138 Notably, individuals living in rural communities have a greater reliance on car availability for transport to access key services. Evidence from the National Travel Survey shows that in 2020, only 8% of households in rural towns have no car or van; significantly lower than in suburban and urban areas, as shown in Figure 115.

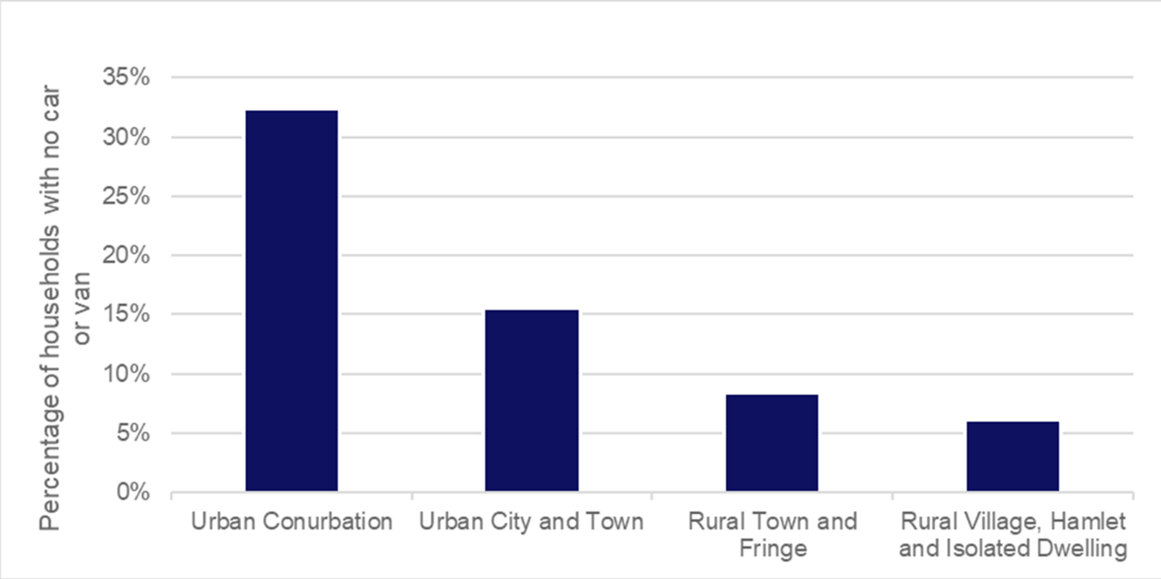


Figure 115 Proportion of households by residency area with no car or van

6.139 Evidence on earnings shows that on average in 2020, rural communities earn marginally less than those living in predominantly urban areas (excluding London); approximately £100 less a year.

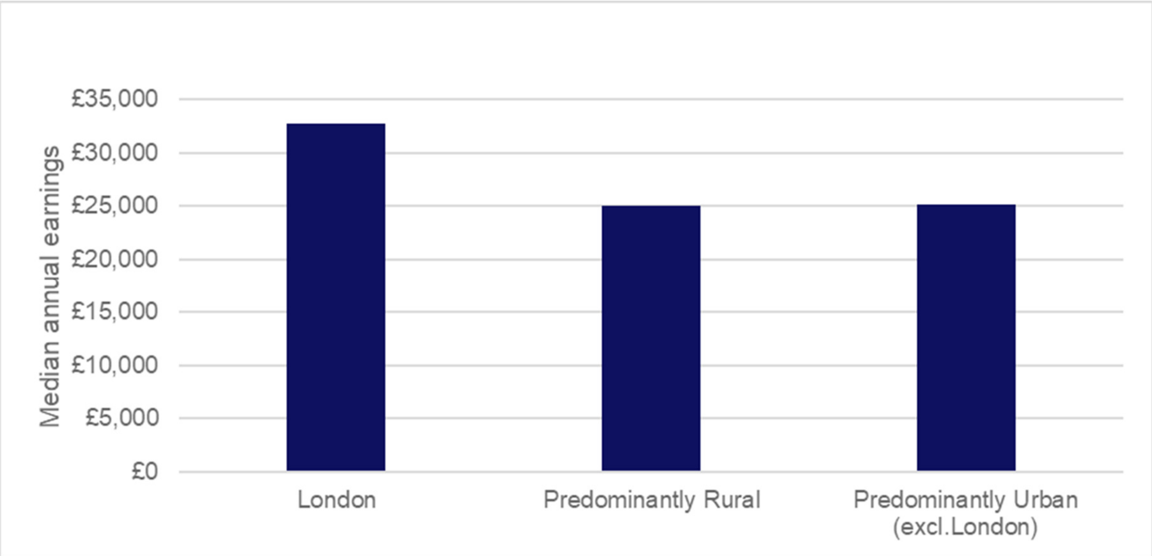


Figure 116 Gross median annual earnings by residency area type

6.140 This could suggest that the higher upfront capital cost of ZEVs will not have a disproportionate impact on rural communities due to income inequalities alone. However, typically rural communities require or have preference for larger vehicles, with greater mileage to service rural trips. As a consequence, these communities may face a higher upfront cost of vehicle purchase. However, those undertaking more mileage will also generate running cost savings at a faster rate. The availability of vehicle charging points may also be a concern for rural communities. The lower population density in rural areas can lead to a lower provision of public chargepoints, but equally, those in rural areas are more likely to have access off street parking, which will mean they can undertake the vast majority of their charging at home.

There will still be a need for sufficient charging infrastructure to support long journeys and households without access to off street parking. To address this issue Government is providing support to chargepoint deployment through the Rapid Charging Fund and the Local Electric Vehicle Infrastructure fund.

Island communities impacts

6.141 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.

6.142 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.

6.143 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.[69] 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[70] 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 5 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.

6.144 Finally, drivers on several Scottish islands are exempt from requiring an MOT on their vehicles, subject to certain conditions.[71] 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 expected to be greater, thereby potentially offering greater net social benefits to island communities.

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[69] Road fuel review - GOV.UK (www.gov.uk)

[70] Rural Fuel Duty Relief Scheme (Notice 2001) - GOV.UK (www.gov.uk)

[71] The Motor Vehicles (Driving Licences) Regulations 1999 (legislation.gov.uk)

6.145 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[72], 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 increasingly become available at lower cost on the second-hand market over time; as set out in Section 5, 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.

6.146 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 regulations. 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.

[72] 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)

Annex K - analysis comparison with the CBDP

6.147 In March 2023, the Department for Energy Security and Net Zero published the Carbon Budget Delivery Plan (CBDP); which set out Government's plans to meet the delivery of Carbon Budgets 4, 5 and 6. As part of the plans to decarbonise domestic transport, the ZEV mandate and related CO_2 regulations were included for both cars and vans.

6.148 The detailed breakdown of projected emissions savings by policy included within the CBDP included lines related to the accelerated transition to zero emission cars and vans. However these numbers are not comparable to the analysis set out in *Section 3: Policy analysis - Summary assessment of impacts*.

6.149 As mentioned in *Section 3: Policy and analysis overview*, this CBA solely considers this first phase of legislation, whereby ZEV uptake trajectories are assumed flat after 2030. However, the Government intends to introduce further legislation covering the period post-2030, taking ZEV targets up to 100% by 2035.

6.150 The approach of the CBDP is to account for all planned policies and proposals. Hence the impact of the second phase of ZEV mandate legislation, and the phasing out of new petrol and diesel cars and vans by 2035 are included within the CBDP analysis but not in the analysis of this specific regulation.

6.151 Furthermore, there are some methodological differences across the models, as for instance the CBDP accounts for interactions with other policies, which the ZEV Mandate does not. In addition, carbon savings within the CBDP have been calculated using an adjusted version of the government Energy and Emissions Projections (EEP 2021-2040) as a “baseline” for future emissions. This baseline is not fully aligned to the baseline assumed within this CBA.

6.152 There have also been minor policy amendments since the publication of the CBDP, as set out in *Section 3: Policy and analysis overview* although the impact of these changes is not significant.

6.153 Therefore, both the baseline and the policy scenarios are different between the two sets of analysis. For these reasons, the carbon savings will differ.

Annex L - energy systems analysis methodology

6.154 Energy systems modelling has been undertaken to provide additional assurance on the changes to the energy system. This regulation is expected to lead to a significant increase in electricity demand, relative to the baseline, reflecting the gradual increase in ZEV uptake and their share of the overall fleet. DfT's projections estimate an increase of approximately 25 TWh of electricity demand by 2050.

6.155 This analysis has been undertaken in collaboration with the Department for Energy Security and Net Zero (DESNZ) using DESNZ's Dynamic Dispatch Model (DDM) and the Distribution Network Model (DNM).

6.156 The DDM is an electricity supply model of the GB electricity generation market. It is a bottom-up agent-based simulation model which dispatches generation and makes investment decisions based on the generator's projected profits. This model simulates a wide range of granular impacts, including investment in new generation sources and grid-balancing technologies to meet demand, and carbon intensity of the electricity generated.

6.157 The DNM is an investment model of the GB electricity distribution network. It quantifies the costs of reinforcing and maintaining the electricity network for both load and non-load related distribution, as well as the disruption costs from underground and overground investment.

6.158 The impacts of the policy are compared against a baseline through both models, whereby the baseline accounts for Net Zero policies in other sectors. This is intended to provide a detailed assessment of the net impact of the regulations on the electricity system that coincide with greater electricity demand from other decarbonising sectors, such as Clean Heating.

6.159 It should be noted that the potential for "vehicle to grid" technologies and smart charging, which have not been accounted for in the modelling, are expected to help to balance the system by enabling charge points to discharge electricity to the network away from peak times, thereby reducing system costs. Therefore, the costs estimated below are conservative.

6.160 Both the DDM and DNM calculate costs up to and including 2050. To resolve this within the appraisal, DDM costs from 2050 onwards have been assumed to flatline at the 2050 level, simulating ongoing generation, dispatch and transmission costs for a net zero grid. For the DNM, it is assumed that the distribution network requires no new reinforcements to facilitate net zero requirements in 2050; therefore, any new costs incurred post 2050 will be largely derived from maintenance of the network, which is a small proportion of overall network costs. Based on this, costs are assumed to flatline at zero. Based on these modelling limitations, these approaches are considered proportional.

6.161 Due to significant uncertainty in the estimations of spare capacity on the low voltage distribution network, two sensitivities are presented, showing costs associated with a higher (60%) and lower (30%) amount of spare capacity. Current estimates suggest that the true value lies closer to the 60% spare capacity scenario, although there is considerable uncertainty around this. While the 60% sensitivity is assumed within our central scenario, it is important to acknowledge the potential for significantly higher costs from the 30% sensitivity scenario.

6.162 Table 117 presents the direct outputs from both models.

Value	Costs (£m)
Generation, dispatch and transmission costs calculated using the DDM	26,147
Distribution network reinforcement, maintenance and disruption costs calculated using the DNM	11,549 (18,417)

Table 117 DDM and DNM outputs, with DNM outputs from the 60% capacity scenario (30% capacity) (present value; 2021 prices; £bn)

6.163 As the core analysis set out in *Section 3: Policy analysis - Detailed analysis of the policy* includes the total costs associated to electricity usage and associated emissions, these must be subtracted from DDM impacts. Firstly, the DDM calculates a bespoke estimate of carbon emissions from generation, dispatch and transmission. Consequently, model outputs account for the traded carbon costs paid by generators through the Emissions Trading Scheme and Carbon Price Support, as well as the unpriced carbon emissions which are not captured. Secondly, the calculation of electricity fuel costs, a component of the estimates in Table 42, have been calculated using LRVCs, which implicitly account for the variable costs associated with generation, dispatch and transmission.[73] Therefore, this sensitivity test should be included as an alternative to the inclusion of those impacts. Table 118 shows the adjustment calculation for the adjusted DDM outputs.

Value	Costs (£m)
Electricity fuel costs calculated using LRVCs	29,671
Traded emission costs calculated using grid intensity factors	1,590
Total costs associated to electricity	29,671 + 1,590 = 31,261
Generation, dispatch and transmission costs calculated using the DDM	26,147
Adjusted generation, dispatch and transmission costs	26,147 - 31,261 = - 5,113

Table 118 Calculation of adjusted present value generation, dispatch and transmission costs (present value; 2021 prices; £bn)

[73] Valuation of energy use and greenhouse gas: Background documentation

6.164 This result shows that when calculating energy systems costs associated to electric cars and vans use using the LRVC costs are greater than those that are estimated using the DDM. Valuing the cost of electricity using LRVC is a simplified approach, which in particular does not take account of the specific time of charging for electric vehicles, but assumes a typical charging profile. Modelling using the DDM reflects the fact that electric vehicles predominantly charge away from peak demand, even when smart charging or vehicle-to-grid are not included, which means the additional costs of supplying electricity are also lower.