Written evidence submitted by the Climate Change Committee (EVP0118)

I am pleased to submit written evidence from the Climate Change Committee to your inquiry on zero-emission vehicles.

Surface transport is the UK's highest emitting sector, accounting for 22% of UK greenhouse gas emissions, with little progress in reducing emissions made over the past decade. This must change if the UK is to meet Net Zero by 2050, its NDC pledge to the Paris Agreement and our recommended Sixth Carbon Budget.

The transition to zero-emission vehicles will play a crucial role in decarbonising surface transport, with rapid take-up of electric cars and vans needed in the next decade. The analysis presented in the Committee's recent Sixth Carbon Budget report considered a wide range of evidence for how this could be achieved and set out several pathways for this transition. We have picked out four key messages from this work relevant to your inquiry:

1. **We welcome the Government's decision to phase-out new petrol and diesel vehicles by 2030. This needs to ensure the vast majority of cars sold in the early 2030s are fully electric (i.e. without a petrol or diesel engine).**

If petrol and diesel vehicles continue to be sold during the early 2030s, that would lock-in high levels of emissions well into the 2040s and miss out on cost savings for motorists. By ensuring that the vast majority of sales are fully electric, we can avoid this and deliver a fleet that is fully electrified by 2050. While hybrids are often advertised as low-emission vehicles, their real-world emissions are often more comparable with conventional vehicles than with zero-emission vehicles. Our analysis indicates that hybrids must play at most a minor role, with limited sales beyond 2030 (e.g. they make up less than 5% of sales by 2030 in the Balanced Pathway we presented in December).

Accelerating the phase-out to 2030 is likely to reduce cost to society and enable more consumers to make cost-saving purchasing choices. This is because a new battery-electric car will be cost-saving over its lifetime compared to a petrol or diesel car by the mid-2020s, while we expect upfront cost-parity by 2030.

Delivering this earlier transition will require production and supply of EVs to scale up rapidly throughout the 2020s. Evidence suggests that there are plentiful global supplies of the raw materials needed to supply the growing global battery market, although there could be challenges around scaling up supply chains, particularly around 2025-30, that must be monitored and mitigated. It may be helpful for Government to consider a certification scheme for ethical sourcing.

2. **A strong package of support covering purchase incentives, charging infrastructure and incentives on car manufacturers is still required from Government to deliver the 2030 commitment.**

Strong consumer incentives to purchase zero-emission vehicles should continue for as long as EVs remain more expensive to purchase, providing certainty and clarity to consumers. These should also aim to reverse recent trends towards SUVs (e.g. through higher rates of Vehicle Excise Duty). In addition, car manufacturers should be required to sell an increasing proportion of zero-emission vehicles, increasing to reach 100% by 2030 – mimicking the 'ZEV mandate' schemes introduced in California and China.

Substantial roll-out of charging infrastructure across the UK is necessary to give consumers confidence that they will be able to reliably charge an EV whenever they need to. Particular focus needs to be on providing access to on-street charge points for the 30% of households who do not have off-street parking. Investment will need to continue throughout the 2020s and beyond. Extra grid capacity will be needed to cope with increased demand.

3. **Government should plan for ending sales of diesel buses and coaches by 2040 at the latest, but most operators should be encouraged to switch over much sooner. Local Authorities should be empowered to continue driving take-up of zero-emission vehicles and to improve bus services.**

Bus usage and service provision have both declined in recent years. Buses offer an important low-carbon alternative to car travel, so this trend needs to be reversed and decarbonisation must not be achieved at the expense of service improvement. This will help support a just transition.

The bus sector is very heterogeneous, with different routes having very different characteristics. However, zero-emission buses are already being deployed on many urban routes around the UK, often as a result of Local Authority efforts to reduce air pollution. As a result, costs are falling, with cost-parity over the vehicle lifetime expected in the early-2020s. The transition is more challenging for longer-distance buses and coaches, but hydrogen could be attractive for these routes.

4. **The sale of new diesel heavy goods vehicles (HGVs) should be phased out by 2040 and Government should publish a plan for how to achieve this.**

Despite making up just 5% of road vehicles, HGVs account for 17% of surface transport emissions. Unlike for cars and vans, zero-carbon HGV technologies are currently at an early stage and it is too soon to say which will emerge as market-leaders. However, manufacturers are beginning to offer commercial battery-electric, pantograph-electric and hydrogen fuel-cell products.

Our assessment is that sales of new diesel HGVs should be phased-out by 2040, and that Government should publish a comprehensive plan for how this will be delivered (including infrastructure deployment and purchase incentives) in the early-2020s. We welcome Government's announcement of £20 million in 2021 to fund zero-emission trials for HGVs. Funding will need to continue to enable these trials to evaluate commercial operations at a large scale for up to five years. The trials should demonstrate the feasibility of zero-carbon HGV technologies and establish which is the most suitable and cost-effective technology mix for the UK.

Our evidence on each of these topics, which is taken from our Sixth Carbon Budget publication, is set out in detail in the accompanying evidence annex.

Evidence annex: accelerating the shift to zero-emission vehicles

The Climate Change Committee (CCC) is an independent, statutory body established under the Climate Change Act 2008. Our purpose is to advise the UK and devolved governments on emissions targets and to report to Parliament on progress made in reducing greenhouse gas emissions and preparing for and adapting to the impacts of climate change.

The evidence that is set out within this annex will focus on the inquiry's first topic: "Accelerating the shift to zero-emission vehicles".

This evidence is based on the detailed analysis and modelling that we produced in support of our advice to Government on the level of the Sixth Carbon Budget. This analysis was published in December 2020, in the form of three reports, an accompanying dataset and a range of supporting evidence. These are available through the CCC's website.

We set out our evidence in four sections, mirroring the four key criteria stated within the Call for Evidence:

1. The feasibility, opportunities and challenges presented by the acceleration of the ban on the sale of new petrol and diesel vehicles to 2030;
2. The actions required by Government and private operators to encourage greater uptake of electric vehicles and the infrastructure required to support them;
3. The particular challenges around decarbonising buses and how these should be addressed; and
4. The Government's ambition to phase out the sale of new diesel heavy goods vehicles, including the scope to use hydrogen as an alternative fuel.

1. The feasibility, opportunities and challenges presented by the acceleration of the ban on the sale of new petrol and diesel vehicles to 2030

The CCC welcomes the Government's recent decision to bring the phase-out date for new sales of petrol and diesel vehicles forward to 2030. Compared to the previous date of 2035, this will accelerate the UK's transition to a zero-carbon transport system, delivering substantial emissions reductions and helping consumers to realise cost savings. Our assessment is that this earlier phase-out date is feasible, but that Government will need to ensure that industry is on-track to deliver it throughout the 2020s.

In what follows, we set out our evidence concerning the emissions impacts, the cost impacts and the feasibility of this accelerated phase-out.

a) Emissions impacts of accelerating the phase-out

CCC pathways

Our analysis for the Sixth Carbon Budget considered the emissions reductions that could be delivered under four exploratory scenarios, involving varying levels of technological innovation and public engagement, and a Balanced Net Zero Pathway, which represented the most balanced approach to delivering emissions reduction towards Net Zero by 2050.

These scenarios considered the impact of various phase-out dates for new petrol and diesel cars and vans:

- The Balanced Pathway assumed that all new sales would be fully battery-electric from 2032.
- By contrast, the Headwinds scenario reflected the previous Government position of a 2035 phase-out.
- Finally, the Widespread Engagement, Widespread Innovation and Tailwinds scenarios considered a petrol and diesel phase-out taking place in 2030.

Our analysis found that earlier phase-out dates would lead to earlier widespread adoption of battery-electric vehicles (BEVs), reducing the number of high-carbon petrol and diesel vehicles entering circulation.

- Since cars typically stay in operation for an average of 14 years, any new high-carbon vehicles sold during the early 2030s are likely to continue generating emissions considerably into the 2040s.
- A 2032 phase-out could deliver cumulative emissions reductions of almost 90 $MtCO_2e$ over the period out to 2050[1] compared to a 2035 phase-out.

[1] These emissions assessments are based on tailpipe emissions. However, BEVs deliver considerable emissions savings even when accounting for their full

  - This is primarily due to an earlier phase-out incentivising manufacturers to switchover to production of BEVs for the UK market sooner, leading to quicker BEV uptake during the 2020s.
  - As a result, there could be around 3.8 million fewer petrol and diesel cars and vans on UK roads by 2035 than under a 2035 phase-out.
  - In their place, there would be 3.5 million additional BEVs in operation (along with 0.3 million additional plug-in hybrid electric vehicles (PHEVs)).
- Our modelling of a 2030 phase-out shows this to deliver a further reduction in emissions of around 20 $MtCO_2e$ out to 2050.
  - This is due to a further 0.7 million sales of petrol and diesel vehicles and 0.3 million PHEV sales being displaced to BEVs by 2035.

The role of hybrid vehicles

In all of our scenarios, we assume that sales of all new cars and vans that contain a fossil fuel internal combustion engine are ended at the stated phase-out date.

- PHEVs and other hybrids burn fossil fuels and are not zero-emission vehicles. Therefore, our scenarios include their phase-out.
  - While PHEVs are often advertised as low-emission vehicles, recent studies[1,2] have shown that PHEVs can emit two- to four-times more during real-world driving than test values. This makes their real-world emissions more comparable with conventional vehicles than with zero-emission vehicles.
  - PHEVs typically have a very low electric-only range (around 40 km), which means that they require very frequent charging to avoid driving in fossil fuel mode.

By contrast, Government is proposing to continue to allow sales of hybrids with a minimum emissions-free range between 2030-35. This risks allowing high-emitting vehicles to continue to be sold beyond the stated phase-out date.

- Separate modelling that we conducted suggests that this could allow almost 5.0 million additional PHEVs to be sold out to 2035, as compared to sales under our Balanced Pathway.
  - While 1.6 million of these PHEVs are bought in place of petrol or diesel sales that would happen in our Balanced Pathway, 3.3 million are PHEVs being bought instead of BEVs.
  - This is due to the risk that allowing an additional five years for sales of PHEVs or other hybrids could lead to manufacturers continuing investment in their development and pushing their sales in order to maximise their existing investments in internal combustion engine technology.
  - The emissions impact of such additional volumes of PHEV sales could total an increase of 35 $MtCO_2e$ out to 2050 relative to our Balanced Pathway, which would offset more than one-third of the savings calculated for a 2030 phase-out date above.

lifecycle emissions. Our analysis shows that BEVs, powered with today's average UK electricity, repay the 'carbon debt' from the production of their battery within slightly more than a year and save more than 35 tonnes of CO_2 over their lifecycle versus a conventional equivalent. These savings will increase as the UK electricity grid decarbonises. See Box 2.2 in our Sixth Carbon Budget Methodology Report.

We therefore recommend that, in developing the precise details of its proposal, Government should ensure that the resulting emissions and miles driven using each powertrain type are consistent with our Balanced Pathway.

- Policies must ensure that hybrids play a declining role relative to pure electric vehicles, and minimal beyond 2030.
- Policy should be designed to ensure clear consumer benefit to buying full electric over hybrid models (including through provision of effective charging solutions) and to encourage manufacturers to supply them (e.g. by setting stringent CO_2 emissions targets for new vehicles or requiring a high minimum electric mileage for hybrid vehicles).

b) Cost impacts of accelerating the phase-out

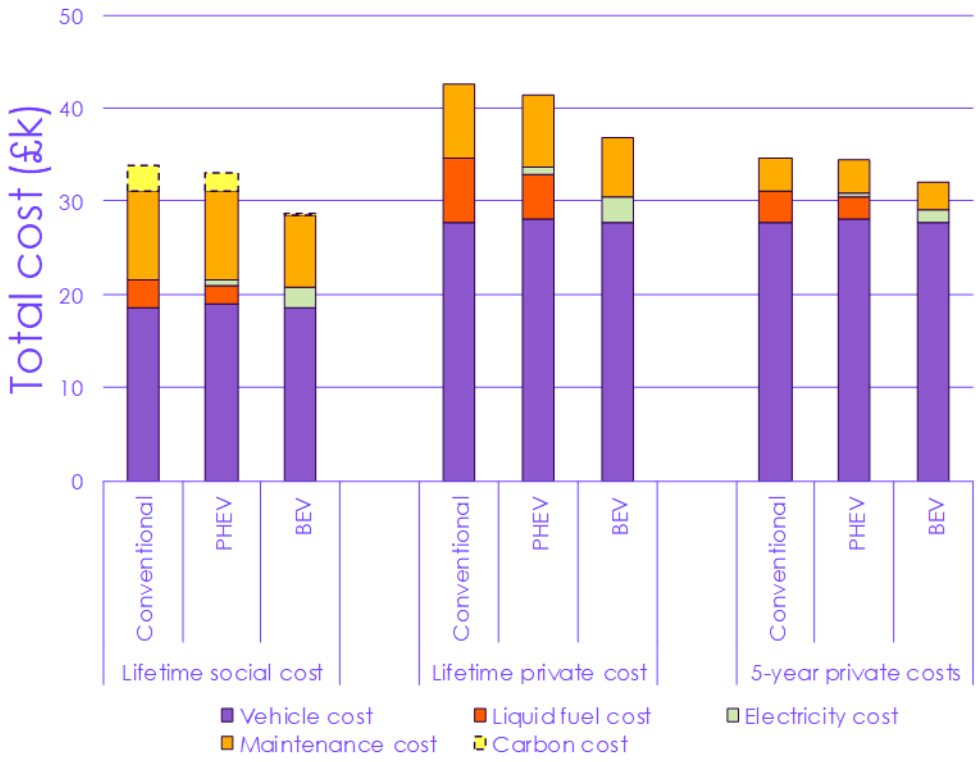
The cost of buying an electric vehicle (EV) is rapidly falling, while their ongoing running costs are substantially lower than for a petrol or diesel vehicle. Therefore, we expect that bringing forward the EV transition will be cost-saving for society.

- Significant investment in vehicles and charging infrastructure starting from now and rising to £12 billion per year in 2035 will be required. Investment costs continue to rise to 2050 as zero-emission technology and infrastructure is rolled out. This includes both public investment (including on deployment of public charging infrastructure) and private expenditure (such as for purchase of vehicles).
- As EVs are much more efficient than conventional vehicles, these will be offset by lower operational expenditure from around 2030, with annual operating cost savings of around £20 billion in 2035.

By the mid-2020s, we estimate that a new battery-electric car will be cost-saving compared with a petrol or diesel car over the lifetime of the vehicle, even when including costs of developing charging infrastructure and upgrading power networks to deal with increased demand for electricity and taking account of the need to replace exchequer revenue from fuel duty (Figure 1).

- A typical BEV car today is around 35% more expensive to purchase than a comparable conventional car. By 2030, we expect these upfront costs to reach parity, and by 2035 a typical BEV would offer a small upfront cost saving.
  - Battery costs currently make up at least 30% of the upfront cost of a BEV.
  - Battery costs have fallen by around two-thirds over the past five years, and will continue to reduce quickly during the 2020s.[3]
- EVs already offer substantial operating cost savings compared to petrol and diesel vehicles.
  - Over the lifetime of the vehicle, the total societal cost of fuel for a typical conventional car is around £2,900. By comparison, the cost of electricity is lower at around £2,200. If fuel duty is included, the cost saving to a private owner is around £6,700 (around £500 per annum) in cash terms.
  - BEVs have fewer moving parts, so also typically have lower maintenance costs than conventional vehicles. This can save the owner up to £170 per year.
- The cost of installing a home charger is expected to fall by around 25% by 2035.

Figure 1 Cost comparison for new BEV, PHEV and conventional vehicles in 2030



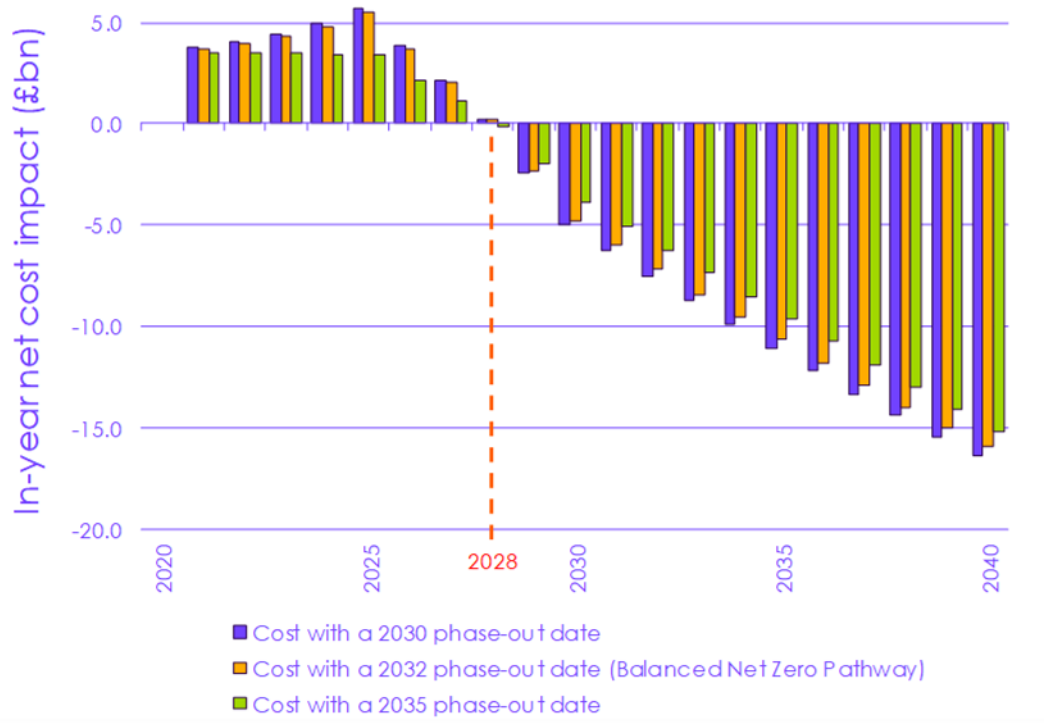
Source: CCC analysis.

Notes: Societal costs are discounted at the social discount rate of 3.5% and represent net costs to society over the lifetime of the vehicle (i.e. excluding taxes and duties). Private costs are discounted at a private discount rate of 7.5% and include all taxes and duties.

Therefore, accelerating the phase-out to 2030 will enable more consumers to make cost-saving choices in their purchase of new vehicles. Furthermore, earlier scale-up of manufacturer EV capacity would be expected to increase economies-of-scale in the production process, thereby enhancing these cost-savings.

- Our analysis found that a 2032 phase-out date would deliver £6 billion in additional cost-savings over the period out to 2050, compared to continuing to allow petrol and diesel vehicles to be sold until 2035 (Figure 2).

Figure 2 Impacts of alternative phase-out dates for new petrol and diesel cars and vans



Source: CCC analysis.
Notes: Comparison between the annual cost to society (cost of vehicles, infrastructure, fuel and maintenance) of the EV transition under three phase-out dates for new petrol and diesel car and van sales (including PHEVs): i) 2030; ii) 2032 (as in our Balanced Net Zero Pathway); and iii) 2035.

c) Feasibility of a 2030 phase-out

We believe that phasing out new petrol and diesel car and van sales by 2030 is feasible, and our Sixth Carbon Budget scenarios illustrate a range of pathways by which this can happen.

- BEVs entered the UK market in the early 2010s, and have now begun to reach mass-market appeal, making up around 5% of new sales during 2020.[4]
- To be on track to deliver Net Zero and the Sixth Carbon Budget, it is important that sales of BEVs ramp up through the 2020s at rates consistent with our Balanced Pathway (Table 1). This demonstrates a steady ramp-up that can deliver an accelerated phase-out.

Table 1
Proportion of car and van mileage driven by each powertrain among all new vehicles sold in each year, in our Balanced Net Zero Pathway

	2020	2022	2024	2026	2028	2030	2032 (and beyond)
Fossil fuel vehicles (including mild and full	92%	77%	52%	27%	18%	2%	0%

hybrids)							
Plug-in hybrid electric vehicles	3%	10%	17%	17%	8%	<1%	0%
Battery-electric vehicles	5%	12%	31%	56%	74%	97%	100%

The supply of different EV models is increasing, widening consumer choice. Evidence suggests that raw materials and supply chains will be able to scale up quickly enough to enable this to continue.

- EV models are now becoming widely available across all sizes and car types.
  - Worldwide, 105 new BEV models and 38 new PHEVs were launched in 2019. A further 293 BEVs and 137 PHEVs are planned by 2022.
  - In the UK, there were 14 BEV car models from 14 manufacturers and 8 BEV van models from 2 manufacturers available in 2015. By 2020, these increased to 37 BEV cars from 20 manufacturers and 18 BEV vans from 14 manufacturers. There are at least 8 upcoming BEV car models, from 5 different manufacturers, in the next year.
  - Delivery times for EVs have fallen rapidly over the past year, with waiting times for all models now within 12 weeks, compared with over a year for some models in 2019. This is comparable to waiting times for new conventional vehicles.
  - However, only 175,000 EVs were sold in the UK in 2020, compared with 1.5 million petrol and diesel vehicles, and there still needs to be a significant switch in investment from petrol and diesel vehicles to high-volume EV production.
  - While EVs are less complex to produce and assemble, new supply chains, skills and production methods will need to be developed and original equipment manufacturers (OEMs) will need time to adjust. Re-training and re-skilling across the sector could be needed.
- In March 2020, we sent a questionnaire to a range of academics, industry experts and research bodies asking for views and evidence around the challenges and opportunities for future raw materials supply globally and for the UK. The key findings were:
  - Global battery capacity will need to accelerate to meet demand. There are plentiful global supplies of raw materials to supply the growing market for current-generation batteries (e.g. lithium, graphite, cobalt, nickel and manganese), but supplies will need to scale up significantly, especially from the mid-2020s. There could be challenges around scaling up, particularly around 2025-30, which will need to be monitored and mitigated.
  - New mining facilities, appropriate battery-sizing and re-use and recycling will be fundamental to meeting demand cost-effectively. While new battery chemistries are being developed, these will take time and it is uncertain when or if they will come to market.

– A certification scheme for ethical sourcing of raw materials would help to address issues around working conditions, low pay and use of child labour in mines.

2. The actions required by Government and private operators to encourage greater uptake of electric vehicles and the infrastructure required to support them

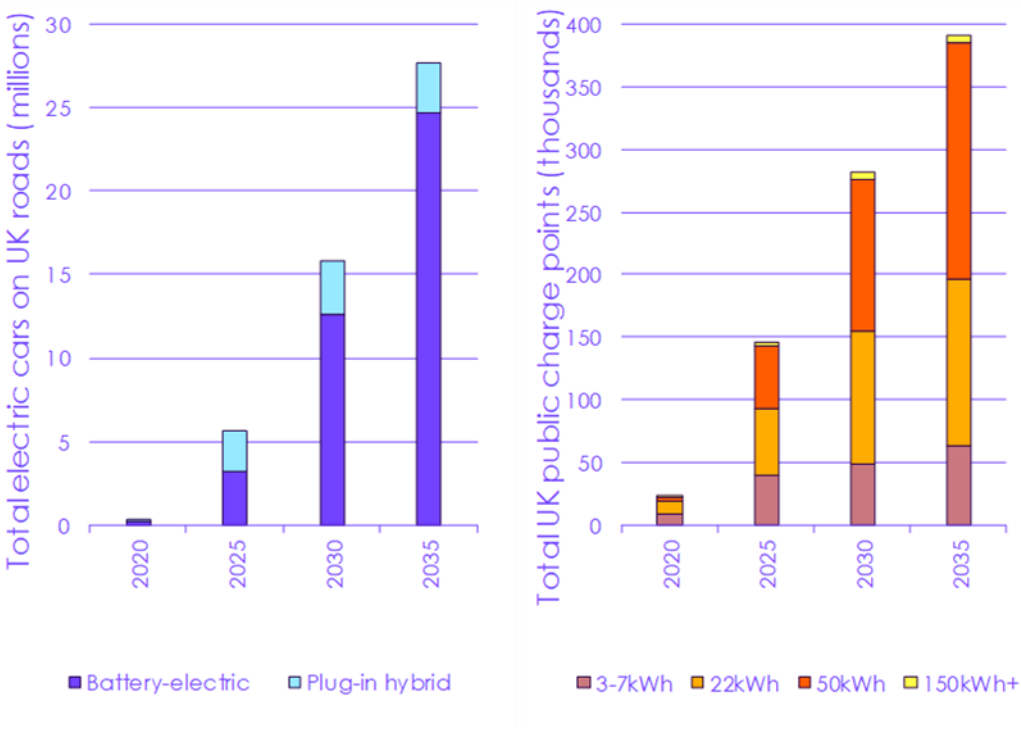
Government and industry need to ensure that EVs are affordable options for all consumers, that supply ramps up sufficiently quickly and that the necessary infrastructure is in place to support an accelerated transition. The wider EV ecosystem also needs to ensure that EVs provide an appealing consumer experience, so as to ensure that they are desirable to the mass market.

a) EV charging infrastructure

Numerous studies have shown that the biggest concern about the transition to EVs is vehicle range and the ability to reliably and quickly recharge. While EV driving range is expected to continue increasing over the coming decade, charge points will also need to scale up to support the phase-out of new petrol and diesel cars.

- These will comprise a mix of private chargers at homes and workplaces and public on-street charge points for those without off-street parking, around towns and cities for top-up charging and on the strategic road network for longer-distance inter-urban charging.
- We expect around 280,000 public chargers to be required by 2030 (Figure 3). This is a considerable increase from the 18,000 available today.

Figure 3 Total electric cars and charging infrastructure in the Balanced Net Zero Pathway



Source: CCC analysis. 2020 figures based on DfT, OLEV, SMMT and Zap-Map statistics.
Notes: Includes all small, medium and large cars and all publicly accessible charge points in the Balanced Net Zero Pathway.

The need to provide access to on-street charge points for households without off-street parking is essential to enable the roll-out of EVs across society. This will give confidence that people will be able to charge when they need to. Technology is developing and options include lamp-post charging which could offer a convenient, low-cost solution.

- Around 30% of households in the UK do not have off-street parking. These households are underrepresented among early adopters of EVs, but will need to be able to participate in the EV transition.
  - Government has committed to investing £1.3 billion to accelerate the roll-out of charging infrastructure, including on major roads and on-street near homes and workplaces. This is around the right level of investment at present, and investment, including through facilitation of private-sector investment, will need to continue throughout the 2020s and beyond to support widespread EV roll-out.
  - OZEV has allocated £20m of funding for Local Authorities to install on-street charging bays during 2020-21. This should continue and be extended to provide access to on-street charging for all those without off-street parking as well as around towns and cities for top-up charging.

Networks and the wider energy system will require investment to support increased demand from EV charging.

- By 2050, we estimate that electricity demand among road vehicles will increase from below 1 TWh today to over 100 TWh.
  - This increased demand will require reinforcement of the distribution network. It is expected to be more cost-effective to proactively ensure that networks are able to cope with increased demand, rather than to wait until demand outstrips capacity. Thus, our scenarios assume that these upgrades begin in the 2020s and do not constrain EV uptake.
  - Government should deliver plans to ensure investment in networks can accommodate future demand levels in coordination with Ofgem.
  - Government must continue to work with industry and network operators to ensure there is a fair funding model to enable maximum charging infrastructure installation, without placing undue cost burdens on Network Operators or the first-mover company or Local Authority in a particular region.
- The scale of upgrades required can be reduced (but not eliminated altogether) through effective use of smart charging. This can smooth the new peaks in residential demand resulting from home charging and shift charging demand into off-peak periods.
  - Government and the industry should look into how to enable as many EV owners as possible to realise the benefits of smart charging (e.g. charging their EV when electricity prices are low), to ensure EVs provide a flexible resource to the power sector and consumers can realise maximum benefit.
  - Further, innovations such as vehicle-to-grid schemes should be supported.

- There also need to be common standards for interoperability and data sharing, to ensure a positive consumer experience for EV users.
  - Agreeing common standards will allow more effective data sharing between the EV and electricity sectors, enabling them to work together to deliver the transition.
  - There are currently 16 major public charging networks across the UK. Roaming agreements will be important to enable easy interoperability between these networks, so that EVs can be plugged in anywhere and paid for in a simple, transparent way for the consumer. Consumers will also need to be able to rely on each network's charge points to deliver high levels of reliability and availability.

b) Cost subsidies and incentives

Strong consumer incentives to purchase zero-emission vehicles in the form of purchase subsidies, preferential company car tax, fuel duty exemption and lower vehicle excise duty should continue. These can be scaled back as costs of EVs fall.

- Our pathways assume that during the 2020s, a differential between conventional vehicles and EVs from subsidies, benefits-in-kind and taxes remains.
  - Consumers currently benefit from a grant of up to £3,000 towards the purchase of a new vehicle. However, this is significantly less than the price difference between at typical EV and a comparable petrol or diesel vehicle.
  - Purchase subsidies should remain as long as EVs remain more expensive to purchase.
- Over time, we would expect this gradient to shift from EV subsidy to taxation of petrol and diesel vehicles.
  - Since 2017, new car emissions have actually increased, driven by the rapid increase in purchases of higher-emitting vehicles, particularly sports utility vehicles (SUVs). Stronger disincentives for purchasing more polluting vehicles are needed to help reverse this trend.
  - Potential distributional impacts of any increased taxation of petrol and diesel vehicles will need to be carefully considered.
- The development of a robust second-hand EV market, which could be facilitated through early adoption of EVs particularly by fleet operators, will be crucial in making EVs available to all segments of society.

c) Industry regulation and support

Regulation and support should ensure that EV sales ramp-up at the rates required to reach 100% by 2030.

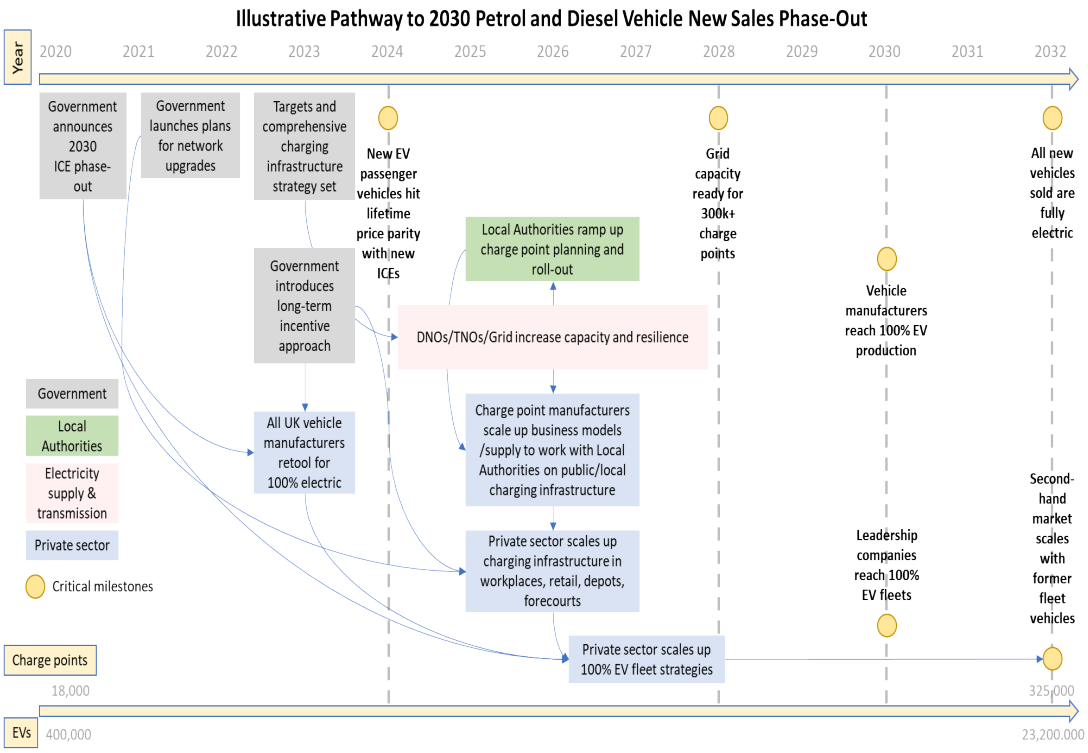
- A zero-emission vehicle mandate should be introduced, requiring car and van manufacturers to sell a rising proportion of zero-emission vehicles, reaching nearly 100% by 2030, with at most only a very small proportion of hybrids allowed alongside until 2035. This should strengthen incentives to sell EVs in the UK market.
- In parallel, ambitious UK regulations on new car and van CO_2 emissions should be set to 2030, to provide a strong incentive to manufacturers to continue to improve fuel-efficiency of petrol and diesel cars and vans.

  - There should be a coherent framework that incentivises greater fuel-efficiency of petrol and diesel vehicles and encourages a rapid transition to EVs. This should give OEMs the flexibility in meeting emissions targets in a way that works best for them.
  - This should be backed by a rigorous testing regime, with more regular intervals than the EU's five years.

- Government should support the manufacturing industry to deliver the necessary ramp-up and mitigate any potential supply chain bottlenecks.
  - We welcome Government plans to develop Gigafactories in the UK to produce batteries needed for EVs at scale. Security of raw materials supply should be enhanced further by a clear assessment of how best to re-use and recycle batteries and through funding development of competitive, large-scale battery recycling facilities in the UK.
  - UK businesses should be supported to innovate and realise business opportunities. There is an opportunity for the UK automotive manufacturing sector to become a world leader in the development and production of EVs. Early investment in EVs will help to deliver this. A UK transition to 100% market share of EVs by 2030 is likely to increase investment in the EV industry, with one study estimating the potential to increase UK production from around 16,000 EVs today to around 880,000 EVs per year, creating 89,000 green jobs in the EV industry.[5]

- The whole system should be directed towards delivering the required EV transition (Figure 4).
  - Establishing and communicating long-term clarity on the availability and approximate timing of incentives and targets – ideally to 2030 – will enable industry and Local Authorities to plan. Linking incentives to targets will also ensure that funding is focussed on the necessary preconditions for petrol and diesel vehicle phase-out, and will allow funding to shift to the next priority once particular targets are met.

Figure 4 Infographic showing an illustrative pathway to deliver the 2030 EV transition[6]



Notes: This figure shows an illustrative pathway through which the sales of EVs could be scaled up to meet the Government's planned 2030 phase-out date for new sales of petrol and diesel vehicles and to deliver 100% of all sales being zero-emission by 2032, as required to meet the Sixth Carbon Budget Balanced Net Zero Pathway. Most dates shown within this infographic are illustrative and are not representative of commitments made or recommended approaches. Other pathways may be possible, and there could be opportunities to deliver some phases of the transition sooner.

3. The particular challenges around decarbonising buses and how these should be addressed

Buses are very heterogeneous, with different routes having very different characteristics. For urban routes, zero-emission options are becoming well established, whereas longer-distance routes (including coaches) experience similar decarbonisation challenges to HGVs. Since buses offer an important low-carbon alternative to car travel, decarbonisation must not be achieved at the expense of service improvement. This will help support a just transition.

a) Progress and opportunites to decarbonise buses

Zero-emission buses are already being deployed on many urban routes around the UK. This is often driven by Local Authority efforts to reduce air pollution.

- The Confederation of Passenger Transport (the trade body for bus and coach operators) has set a target for all new buses to be ultra-low or zero-emission by 2025.

  - Battery-electric buses are already in operation around the UK and Europe. For instance, Nottingham has a fleet of 13 electric buses and 45 electric minibuses.
  - London currently has 8 hydrogen buses in operation, while UK-based manufacturer Wrigthbus has plans to manufacture 3,000 hydrogen buses.
- Zero-emission options can offer substantial fuel savings to operators, while purchase costs are already falling quickly due to increasing interest by local Governments across Europe.

Our Sixth Carbon Budget trajectories for zero-emission bus and coach uptake are based on analysis we commissioned from Element Energy, which assessed the options for all types of heavy-duty road vehicle.[2]

- It found that the more advanced position of this market and local policy factors are likely to enable a much faster uptake of zero-emission options for buses than for HGVs or coaches.
  - Total cost of ownership parity between battery-electric and diesel buses is likely to be reached in the early-2020s, so high uptake could be achieved with lower levels of financial support than for HGVs.
  - The local nature of bus networks and the ability to schedule routes to coincide at key locations could make installation of an effective network of supporting recharging infrastructure more straightforward than in other sectors.
- The transition for coaches and longer-distance buses is more challenging, with similar considerations to HGVs.
  - Coaches are often used on long routes across varied road types, which makes planning refuelling infrastructure more challenging. This could make hydrogen an attractive fuel option, provided there is sufficient on-board storage space available.
- Overall, our Balanced Pathway sees uptake of zero-emission options progressing substantially faster among buses and coaches during the 2020s than for HGVs. Over two-thirds of new sales could be battery-electric or hydrogen by 2030, reaching 100% by 2035.

b) Actions required to decarbonise buses and coaches

Local Authorities and bus operators should be empowered to build upon the progress they have already made in decarbonising their fleets.

- This includes supporting trialling zero-emission options and maintaining subsidy/taxation gradients between more and less emitting vehicles.
- Buses also play a valuable role as an alternative lower-carbon mode to which car users can switch their travel. It is important that bus services are improved to make such shifts possible and desirable.
  - Bus usage and service provision have both declined in recent years. This trend needs to be reversed to enable buses to provide a high-quality low-carbon transport alternative for all communities. This will help support a just transition.

[2] This analysis is discussed in more detail in Section 4 on HGVs below.

  - Local Authorities can work jointly with bus operators to provide a bus network that is rapid, reliable and affordable (e.g. through a bus strategy and bus quality partnership). However, improving bus services is more challenging because most Local Authorities do not control routes, frequencies and fares.
  - Driving a rapid transition to zero-emission buses should not be achieved at the expense of improving bus services.
- Consideration should be given to how suitable the infrastructure deployed as part of HGV decarbonisation trials (see Section 4) could be for use by long-distance buses and coaches.

In line with our recommendation for HGVs, our assessment is that sales of new diesel buses and coaches should end by 2040 at the latest. However, most operators (particularly those running services on urban routes) should be encouraged to switch over much sooner.

4. The Government's ambition to phase out the sale of new diesel heavy goods vehicles, including the scope to use hydrogen as an alternative fuel

Phasing out sales of diesel HGVs is important to delivering a transport system that meets Net Zero.

- HGVs account for 17% of total surface transport emissions, despite making up just 5% of road vehicles.
- Typical HGV lifetimes are 8-13 years, meaning that new HGVs sold around 2040 are likely to remain in operation by 2050.

a) Potential zero-carbon alternatives to diesel HGVs

Unlike for cars and vans, zero-carbon HGV technologies are currently at an early stage and it is too soon to say which will emerge as market-leaders. However, advancements and demonstrations are beginning to take place.

- Battery-electric HGVs. If battery technology continues to advance quickly, then it is projected to become suitable for many HGV applications within ten years. In the long-term, this is likely to be the most cost-effective solution for most HGV operations.
  - Many major HGV manufacturers now offer electric options for smaller, short-range models. DAF Trucks is aiming to offer electric versions of all its models by 2023 and Mercedes intends to offer a battery-electric truck with 300 miles of range by 2024.
  - The volumetric and gravimetric densities of a battery pack are 50-60 times lower than those of diesel, which makes it difficult to package sufficient battery range into the vehicle. Therefore, a network of ultra-rapid chargers would be required to support recharging during longer-range operations. Analysis shows that these would need to be at least every 50 km along the strategic road network.
- Electric road systems (ERS). Pantrographs connecting to overhead catenary systems avoid the need for vehicles to stop to recharge and are a proven commercial technology (primarily in railways). However, once other zero-emission technologies become widely available, the use of an ERS may become expensive relative to other options.

  - Both Germany and Sweden have an operational ERS (of 10 km and 2 km in length, respectively), while Siemens now offers a commercial ERS product.
  - An ERS network could be attractive to fleet operators who are concerned about the impact of the need to recharge on operations. However, electricity prices are likely to be relatively expensive in order to recoup the significant infrastructure cost, so many operators are likely to prefer alternative technologies once these are suitable for their needs.

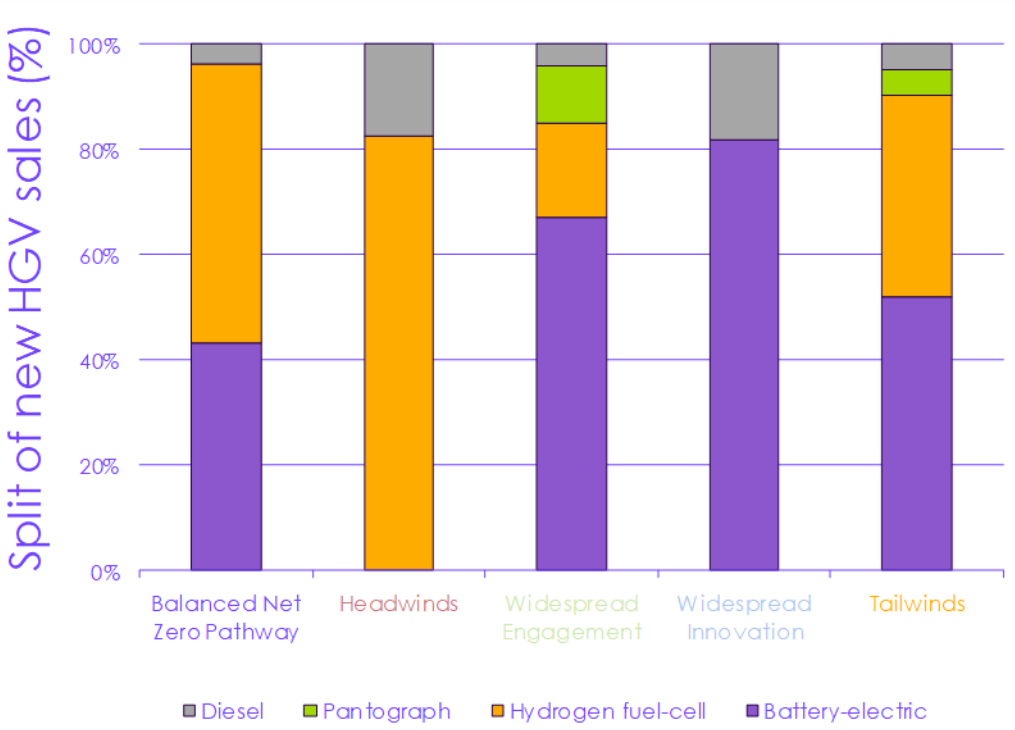
- Hydrogen fuel-cell vehicles. Hydrogen offers the closest user experience to current diesel operations. Given sufficient hydrogen refuelling infrastructure, fleet operators would be able to fill up vehicles either in-depot or from filling stations en route as currently, or both. Hydrogen is also a particularly attractive solution for vehicles requiring longer independent range.
  - Hydrogen fuel-cell HGVs are expected to take slightly longer to reach the market than battery-electric options but could offer longer range. Mercedes and Iveco are developing models that could offer up to 500-600 miles of range. A partnership between Hyundai and H2 Energy is aiming to deploy 1,600 hydrogen HGVs in Switzerland by 2025.
  - Refuelling would be similar to current diesel operations, with around 500-600 hydrogen refuelling stations potentially required by 2050.[7] However, fuel prices are likely to remain higher than for battery-electric options, so many shorter-range operators are likely to prefer electrification.
  - The viability of hydrogen in transport is intrinsically linked to the wider hydrogen strategy.

For our Sixth Carbon Budget analysis, we commissioned Element Energy[8] to assess trajectories for uptake of these zero-carbon options for HGVs. While the optimal pathway is currently unclear, this analysis demonstrated several pathways by which zero-carbon HGV deployment can scale up rapidly through the 2030s (Figure 5).

- In our Balanced Pathway, we explored a scenario in which commercial-scale trials of all technologies take place from the early-2020s, and intrastructure deployment then continues for the most cost-effective solutions.
  - Each of battery-electric, hydrogen and ERS could play a role in decarbonising the HGV sector. Small rigid trucks are likely to predominantly adopt BEVs, while hydrogen or ERS could be valuable for heavier vehicles with longer range requirements. By 2050, BEVs with ultra-rapid public chargers are likely to become the cost-optimal choice.
  - Due to the high upfront costs, we expect there to be total cost of ownership (TCO) shortfall of £24,000-33,000 for a private owner of a rigid truck in 2035 relative to a diesel vehicle, with only higher-mileage articulated HGV owners realising a TCO saving. For smaller HGVs, TCO parity may take until 2050 to be reached.
  - Government subsidies are therefore likely to be needed to ensure TCO parity between zero-emission and diesel options in the mid-2030s.
  - Assuming the existence of appropriate subsidies, Element Energy's analysis found that BEVs could make up 12% of new HGV sales in 2030, rising to 51% in 2040. Hydrogen fuel-cell vehicles could make up 7% of new HGV sales in 2030, and 48% in 2040.

- Each of our Exploratory scenarios then explored uptake rates if infrastructure for only one of the three zero-emission options outlined above were deployed. Each demonstrated a pathway by which new HGV sales could be almost completely decarbonised by 2040.

Figure 5 Proportion of all new HGV sales in 2035 by powertrain type



Source: Element Energy analysis for the CCC (2020).
Notes: Assumes that sufficient financial support is available to make zero-emission options cost-competitive versus diesel vehicles from 2035.

Therefore, our assessment is that sales of new diesel HGVs should end by 2040 at the latest, to be on track to nearly fullly decarbonise this sector by 2050. This date should be moved earlier if information suggests this to be feasible.

b) Actions required to deliver a 2040 phase-out

While it is too early to decide what combination of zero-carbon technologies for HGVs will be optimal for the UK, action is needed now to support market development and put plans in place to enable the sector to deliver the transition to zero-emission vehicles.

- Large-scale trials of zero-carbon HGVs should commence in the early 2020s. We welcome Government's announcement of £20 million in 2021 to fund zero-emission trials for HGVs. Funding needs to continue in future so that commercial-scale trials can continue for up to five years, to demonstrate the feasibility of these technologies and establish which is the most suitable and cost-effective technology mix for the UK. These should involve:

  - Deployment of supporting infrastructure for refuelling/recharging.
  - At least 50-150 zero-emission HGVs covering a range of sizes and across multiple operators. Vehicles should be in operation for a minimum of 1-2 years.
  - Real-world operations, with the demonstrations located on major freight corridors to enable the technologies to be implemented across a wide range of real-world haulage operations.
  - Strong communication of the findings widely across the UK HGV sector, to help operators better understand the zero-emission options available to them.

- The Government is planning to consult on a date for phasing out the sale of new diesel HGVs, and a comprehensive plan should be published in the early-2020s setting out how this will be delivered to give freight and vehicle operators time to plan for this transition.
  - This plan should cover stronger purchase and other incentives, infrastructure plans and support (e.g. ultra-rapid chargers for battery-electric HGVs and hydrogen refuelling stations for hydrogen HGVs) and clean-air zones.
  - Given that diesel HGVs are likely to remain on sale for longer than cars and vans, UK CO_2 emission standards for HGVs should be at least as ambitious as those set by the EU requiring a 15% reduction in carbon-intensity by 2025 and 30% by 2030. This is achievable with options that are market-ready including hybridisation, improving aerodynamics and lighter-weight construction.
  - The UK's approach will also need to integrate with that in mainland Europe, to ensure that fleets can operate across both territories without barriers. Emissions standards that apply to UK-registered vehicles should also apply to overseas vehicles operating on UK roads, in order to avoid placing UK fleets at a commercial disadvantage.
  - In parallel, schemes to reduce HGV and van usage, particularly in urban areas, should be supported. This includes opportunities to reduce travel demand and increase efficiency through logistics measures such as improved routing, better loading and reduced empty-running.

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Endnotes

[1] Transport and Environment (2020), *How clean are electric cars?*

[2] International Council on Clean Transportation (2020), *Real-world usage of plug-in hybrid electric vehicles – fuel consumption, electric driving and CO_2 emissions*.

[3] Bloomberg New Energy Finance (2019), *Battery price survey*.

[4] Society of Motor Manufacturers and Traders (2020), *Car registrations data*.

[5] Vivid Economics and Imperial College London for the CCC (2019), *Accelerated electrification and the GB electricity system*.

[6] Terri Wills for the CCC (2020), *The UK's transition to electric vehicles*.

[7] Ricardo for the CCC (2019), *Zero emission HGV infrastructure requirements*.

[8] Element Energy for the CCC (2020), *Analysis to provide costs, efficiencies and roll-out trajectories for zero-emission HGVs, buses and coaches*.