Climate Change Committee

The UK's independent adviser on tackling climate change

Briefing

The role of Zero Emissions Vehicles in global road transport pathways meeting the Paris Agreement

Summary and key messages

This paper has been produced by the Climate Change Committee (CCC), the independent advisory body to the UK Government on reducing emissions and adapting to climate change. It provides evidence on the role of Zero Emissions Vehicles (ZEVs), e.g. fully electric vehicles, as part of the wider global road transport transition that will be needed to help achieve the Paris Agreement's long-term temperature goal.

A rapid global transition to ZEVs is an essential part of getting to Net Zero and meeting the Paris Agreement. Sales of all new cars will need to be ZEVs by 2030 – 2040, but this can be achieved without significant additional costs.

The key messages are:

- Global emissions from road transport must fall to (essentially) zero by mid-century as part of global efforts to achieve the Paris Agreement's temperature goal.
- Rapid transition to a fully ZEV fleet by mid-century is required to fully decarbonise road transport, alongside other actions including increased public transport use and walking and cycling. A rapid transition to a ZEV fleet can be one of the largest contributors to the global economy-wide emissions reductions required to deliver the Paris Agreement, given the scale of emissions. It also comes with substantial co-benefits (e.g. improved air quality).
- Transitioning sales of all light vehicles (e.g. cars and vans) to ZEVs by 2030-2040 is the least cost pathway for most regions, cheaper than continued sales of fossil fuel vehicles, or a later transition to ZEVs. This is due to the continuing fall in battery costs and greater efficiency of ZEVs over fossil vehicles, as evidenced by our UK-specific case-study. It is expected to hold more widely across different markets. Transitioning to all-ZEV sales in the 2030s will also avoid costly scrappage schemes for fossil fuel vehicles.
- Achieving this transition will require significant global investments in battery production facilities, EV charging infrastructure, new power generation and the development of ethical supply chains for sourcing battery raw materials in the 2020s. Global cooperation on technologies and standards is needed to facilitate this and ensure that the scale-up is sustainable.
- Governments have an important role to play to ensure the transition is smooth and addresses challenges in scaling up of ZEVs. Measures to provide clear signals to firms to invest in ZEVs and supporting infrastructure, and in network and system capacity, are needed in most regions.

The need and opportunity are aligned to increase global ZEV transition ambition ahead of COP26.

The potential for cost-savings from early action in transitioning to ZEVs and the requirement to deliver on the Paris agreement presents a significant opportunity for raising global ambition ahead of COP26:

- ZEVs are expected to be cheaper than fossil fuel vehicles (on both a lifetime and upfront basis) before or at the start of the 2030s.
- The transition to 100% of sales of new light vehicles in major markets is needed by 2030-2040 to be Paris compliant.

Our analysis is set out in the following sections:

1. The Implications of the Paris Agreement for road transport
2. Modelled pathways for global road transport transition
3. Policy implications of the transition to ZEVs

1. Implications of the Paris Agreement for road transport

Delivering the Paris Agreement will require Net Zero by mid-century, as well as increased ambition for emission reductions this decade.

This section summarises the global challenge of decarbonisation to keep to the Paris Agreement long-term temperature goal and the role of road transport within this. It emphasises the need for road transport emissions to reduce to essentially zero as part of economy-wide Net Zero efforts.

At the UNFCCC 21st conference of parties (COP21) countries around the world agreed a global climate framework known as the Paris Agreement. This contains a long-term temperature goal to 'hold the increase in global average temperature to well-below 2°C above preindustrial levels and to purse efforts to keep it below 1.5°C above preindustrial levels'.

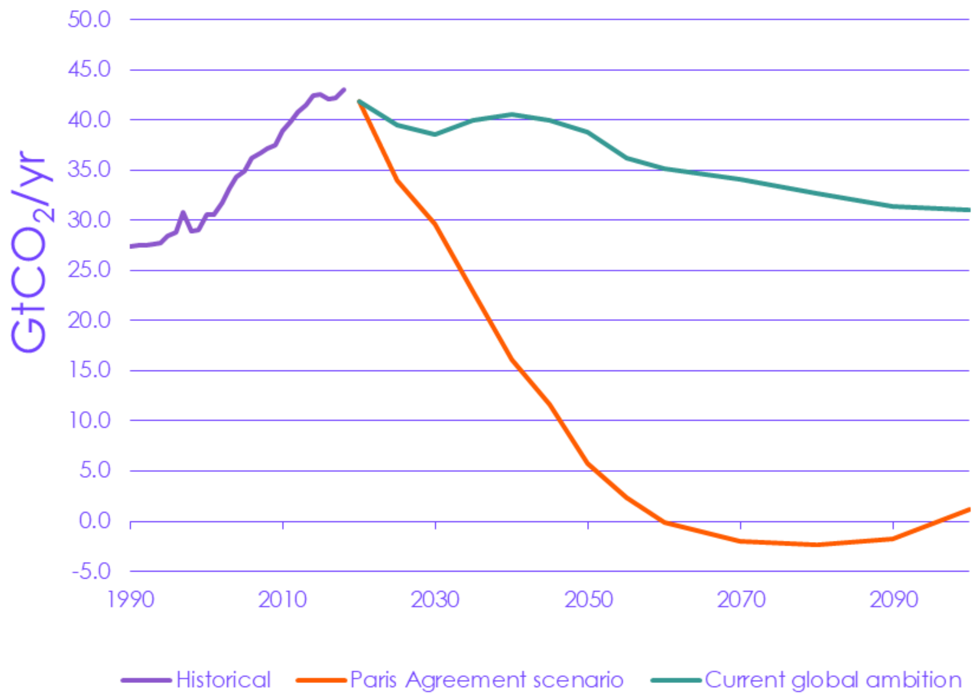
Delivering this long-term temperature goal requires:

- Global emission of long-lived GHGs (e.g. carbon dioxide and nitrous oxide) to fall to Net Zero, with global Net Zero CO_2 emissions reached around mid-century or soon afterwards.
- Rapid and deep near-term reductions by 2030 in global long-lived GHG emissions on the pathway to Net Zero
- Deep and sustained cuts in shorter-lived GHG emissions (e.g. methane)

Current global commitments to emission reductions are not yet sufficient to achieve this. A growing percentage of global carbon dioxide emissions (~65%) are covered by Net Zero commitments around mid-century, but revised pledges for 2030 submitted thus far have only improved by around 3% from pledges submitted before COP21 in 2015.[1] If decarbonisation rates currently expected over 2020 – 2030 are maintained across the rest of the century (green line in Figure 1), then global warming could reach around 3ºC above preindustrial levels by 2100.

[1] UNFCCC (2021) *NDC Synthesis Report*

Figure 1 Global CO_2 emissions in a 'leadership-driven' Paris Agreement consistent scenario and under current global decarbonisation ambition



Source: Vivid Economics (2020) *Unpacking leadership-driven scenarios towards the Paris Agreement* .
Notes: Current global ambition is modelled through constraints requiring regional emissions to match those from current NDCs in 2030 followed by further improvements in the overall emissions intensity of the economy after 2030 consistent with the improvement over 2020 - 2030 needed to meet current NDC targets. Pledged targets for Net Zero are not included.

Achieving Net Zero will require most sectors to reduce their emissions to (essentially) zero

Delivering the additional global ambition to move from a current ambition trajectory to a Paris Agreement consistent scenario (orange line in Figure 1 – consistent with an estimated peak warming around 1.75ºC above preindustrial levels) will require increased ambition from all sectors of the economy. Nearly all sectors will ultimately need to reduce their emissions to zero. Offsetting greenhouse gas (GHG) removals to achieve Net Zero should only be used for the small sub-set of sectors for which zero-carbon substitutes are likely to be limited by mid-century (e.g. agriculture and aviation). Sustainable GHG removals will be limited so must be used strategically across the economy only in sectors that most need them – this is unlikely to include road transport.

The emerging low-carbon opportunities in passenger road transport mean that a near total decarbonisation of road transport will be part of all plausible Paris Agreement pathways.

Road transport emissions have risen over the last two decades and currently produce 16% of total global CO_2 emissions, predominantly from passenger (car) transport, rising to around 22% of total emissions for countries of the ZEV transition council. [2,3]

[2] EDGAR (2020) *Fossil CO_2 emissions of all world countries, 2020 report.*

[3] The Zero Emission Vehicle Transition Council is made up of global Ministers and representatives to discuss and address accelerating the pace of the global transition to zero emission vehicles. It's members currently include: UK, Denmark, California, France, South Korea, Canada, Norway, Japan, Netherlands, Spain, Sweden, Mexico.

Low-carbon options to reduce direct emissions from passenger transport are now emerging at low or minimal additional cost. Globally, electric vehicles (EVs) now make up 2.6% of new passenger car sales, with some jurisdictions having seen significantly higher penetrations (e.g. over 50% of new sales in Norway).[4] Significant year-on-year increases in the market penetration of EVs has been driven in part by a nearly 90% fall in the cost of batteries for vehicles over the past decade (alongside regulations, the provision of infrastructure and purchase incentives).[5] Options for zero-emissions heavy goods vehicles (HGVs), vans and buses are also being developed at increasing pace with electrification and hydrogen solutions amongst promising candidates.

These emerging low-cost zero-carbon alternatives in passenger road transport and competing uses for finite decarbonisation resources such as biomass and GHG removals, means that it is highly likely that road transportation emissions will have to be essentially eliminated by around mid-century through ZEVs as part of a plausible global transition pathway consistent with the Paris Agreement. Using GHG removals to offset road transport emissions would also miss out on the significant air quality benefits from the phase-out of fossil fuel vehicles.

2. Modelled pathways for global road transport transition

Global 'least-cost' simulations are used to inform about the sectoral ambition needed to deliver on the Paris Agreement.

This section describes the emissions abatement arising from accelerated road transport decarbonisation, the implications for the passenger vehicle stock, and the implications for new car sales in delivering a Paris Agreement pathway.

It draws on modelled global pathways commissioned by the CCC to provide evidence about the global ambition needed to deliver the Paris Agreement (Annex Box 1).[6] These pathways balance developed country leadership in setting ambitious economy-wide emissions targets and sectoral decarbonisation commitments with cost minimisation across regions. These pathways contain a representation of the road transport sector and how the stock of vehicles will need to transition to minimise the overall cost of achieving the Paris Agreement long-term temperature goal.[7]

a) Abatement from accelerated road transport decarbonisation

Least-cost pathways indicate that rapid decarbonisation of road transport is one of the largest contributors to aligning the global emissions pathway to the Paris Agreement.

Modelled least-cost pathways consistent with the Paris Agreement see significant near-term falls in global road transport emissions to reach (close to) zero by mid-century:

- Emissions reductions from road transport represent one of the largest sources of emissions reductions (total over 2020 – 2050) needed to align to the Paris Agreement (Figure 2).
- Accelerated decarbonisation of the passenger transport fleet (e.g. cars) is particularly important for achieving the global emission reductions required this decade for the Paris Agreement. Over 80% of road transport abatement in 2030 comes from passenger vehicles in this modelled pathway.

[4] IEA (2020) *Tracking report: Electric Vehicles*.

[5] BNEF (2020) *Electric Vehicle Outlook 2020*.

[6] Vivid Economics & UCL (2020) *Unpacking leadership-driven scenarios towards the Paris Agreement*.

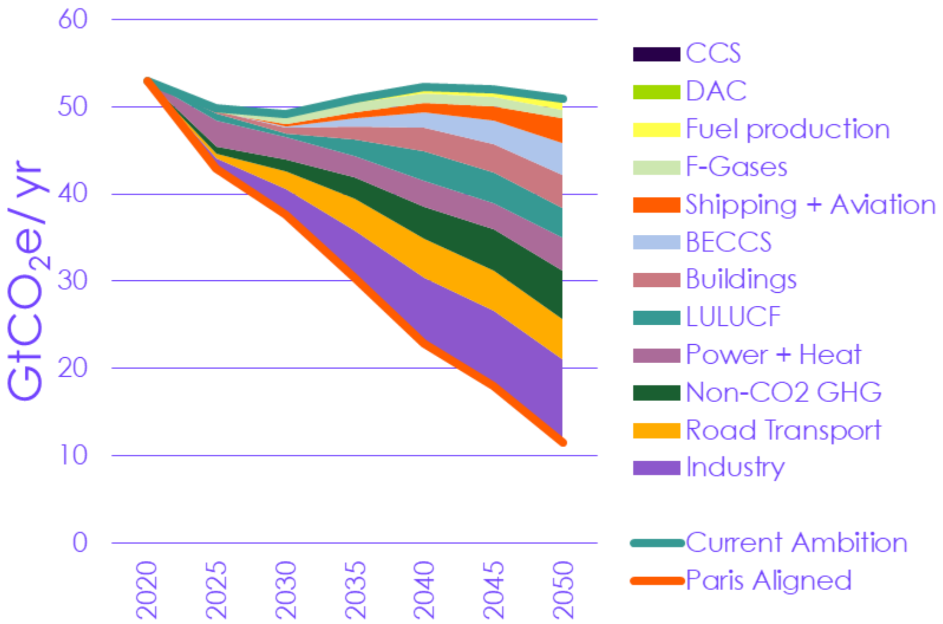
[7] Interactions between sectors are included for example the need for additional low-carbon power generation to meet the additional electricity demand from a rapid roll-out of EVs.

- Reducing emissions from HGVs to close to zero is also an important part of the challenge. Emissions reductions from decarbonising HGVs contribute around half of the in-year abatement from the road transport sector in 2050.

Limited additional opportunities in other sectors would exist to compensate for insufficiently ambitious road transport decarbonisation.

If these emissions reduction opportunities in road transport are not fully realised over the next three decades there will be limited opportunity to compensate with additional reductions in other sectors. Delivering global emissions pathways expected to meet the Paris Agreement already requires decarbonisation of all other sectors as rapidly as plausible, with limited scope to undertake faster emissions reductions in these sectors.

Figure 2 Sectoral abatement to deliv er a global emissions scenario aligned to the Paris Agreement



Source: Vivid Economics & UCL (2020) *Unpacking leadership-driven scenarios towards the Paris Agreement.*
Notes: DAC stands for direct air capture, CCS for carbon capture and storage, LULUCF for land-use land-use change and forestry. The 'Current Ambition' scenario is expected to keep warming in 2100 to around 3ºC above preinudstrial levels whereas the Paris Agreement scenario is expeced to keep it to around 175ºC above preindustrial levels. All greenhouse gases are shown in this figure (unlike Figure 1 which just shows carbon dioxide).

b) Accelerated transition of the passenger vehicle fleet

These emissions reductions from the road transport sector will require a combination of actions to deliver them:

- Reductions in vehicle demand and a shift to alternative modes of transport
- Improved fuel efficiency of fossil fuel cars (the increasing sales of larger, less efficient new vehicles around the world is currently acting to reduce the overall efficiency of new fossil fuel vehicles).

- Replacement of fossil fuel vehicles with ZEVs.

A transition to a 100% ZEV fleet of passenger vehicles will be needed to achieve Net Zero.

All these actions are important to help rapidly reduce emissions from global road transport. However, it is only by shifting the vehicle fleet to be fully comprised of ZEVs that road transport emissions can be (essentially) eliminated by mid-century. Our modelled global pathways indicate that developed country markets (including those in the ZEV Transition Council) achieve a 100% ZEV fleet by 2050, with ZEV penetration reaching over 90% globally by the same date.

A transition direct to genuine ZEVs will be needed to reach Net Zero at least-cost – large-scale shifts to plug-in hybrids poses risks to this transition.

The modelled global pathway consistent with the Paris Agreement sees a direct transition of the passenger vehicle fleet to genuine ZEVs (Battery electric vehicles – BEVs – in the modelled pathways) across all regions. Plug-in hybrid vehicles (PHEVs) have the potential to reduce emissions if they drive mainly on electricity. However, real-world emissions of PHEVs can be two to four times officially certified values, which could make PHEV driving emissions similar to those of fossil fuel cars.[8] Therefore, large increases in the share of PHEVs in the on-road fleet would still result in tail-pipe emissions through to mid-century. To achieve Net Zero, these cars would either need to be scrapped or their emissions offset with expensive GHG removals, resulting in increased costs. PHEV vehicles are therefore not seen in the cost-effective pathway.

A decarbonised power system is essential to ensure that the large-scale electrification of transport and the transition to ZEVs achieves maximum global emissions reductions. Expanding and decarbonising the electricity systems entails different challenges in different regions around the world, however, a fully decarbonised power system by mid-century (or earlier) is itself an essential part of all Paris Agreement pathways in all regions.

c) Rapid phase out of new fossil fuel vehicle sales

Transitioning to a 100% ZEV car fleet by mid-century requires 100% of new car sales to be ZEVs around 2030-2040 to avoid potentially costly scrappage of cars.

A move to all new sales of passenger vehicles as ZEVs within the next two decades is critical to delivering the required rapid transition of the passenger vehicle fleet consistent with an economy-wide Paris Agreement scenario:

- The modelled cost-effective transition to the Paris Agreement would see ZEV Transition Council regions reach 100% of new sales as ZEVs around in the early to mid 2030s (Table 1).[9] This will require an acceleration compared to current trends in many regions. In this scenario the large vehicle markets of China and India reach near to 100% ZEV sales soon after (around 2040) meaning that overall global sales of new vehicles are close to 100% ZEV from the early 2040s.

- A transition to 100% ZEV sales in the 2030s would be 10 to 20 years ahead of when a fully ZEV fleet is required, which is consistent with average vehicle lifetimes. This helps to ensure that fossil fuel vehicles can be naturally retired at the end of their economic lifetime while essentially eliminating GHG emissions by mid-century.[10]

- A slower transition to all new car and van sales being ZEVs leads to higher cumulative emissions and risks requiring early scrappage of vehicles to achieve Net Zero by mid-century. It would also result in higher costs.

[8] ICCT (2020) Real-world usage of plug-in hybrid electric vehicles

[9] These dates are generally supported by analysis from other modelled least-cost global pathways in the literature: Climate Action Tracker Initiative (2020) *Sectoral benchmarks consistent with the Paris Agreement*; IEA (2020) *World Energy Outlook*; Shell (2021) *The Energy Transformation Scenarios: An overview*.

[10] Typical lifetimes for new vehicles are around 10 – 15 years.

- The phase out of fossil fuel Heavy Goods Vehicles (HGVs), buses and coaches should occur by 2040 at the latest, with most operators encouraged to switch to zero carbon options much sooner.

The rapid fall in the cost of batteries for passenger vehicles over the past decade means that ending sales of new ICEs by the dates required in this cost-effective pathway consistent with the Paris Agreement does not have to pose any additional costs compared to high-carbon alternatives or slower ZEV roll-outs. The detailed study of the UK's transition to ZEVs that the CCC conducted for its advice on the UK's pathway to Net Zero indicates that battery electric vehicles (BEVs) are projected to have reached both lifetime and upfront cost parity for new vehicles by 2030 in the UK (Box 1). This conclusion is expected to hold more widely outside the UK, at dates similar to those needed to deliver the Paris Agreement scenario. This strongly suggests that earlier phase-out dates for fossil fuel light vehicles will result in lower transition costs for most regions.

Tackling other non-cost barriers will be important for a rapid global scale-up of ZEV sales.

A global scale-up in ZEV sales consistent with the dates in the modelled Paris Agreement scenario will also have to address additional supply-side and demand-side challenges (Annex Box 2). These include scaling up global battery production, requiring new sources of raw materials; widespread investment in charging infrastructure and updating grid networks where needed, and producing an attractive consumer offer that delivers on price and range across different market segments. In particular, steps must be put in place to ensure that the significant scale-up in the supply chains for the materials required for battery production is genuinely sustainable. Some of these challenges may be particularly apparent in developing nations, many of which currently import used fossil fuel cars from large producer markets.

Table 1
Transition date to 100% ZEV new sales of passenger vehicles in developed regions (and globally) for a Paris Agreement aligned emissions scenario

Global	~2040
Australia	2030
Canada	2030
Eastern Europe	2035
Japan	2030
Mexico	2030
South Korea	2030
USA	2030
Western Europe	2030

Notes: All dates are given to the nearest five years. This scenario corresponds to the 'Paris Aligned' scenarios in Figures 1 and 2.

Box 1
Costs and benefits of a rapid shift to BEVs - UK case study

CCC analysis shows that battery electric vehicles (BEVs) will reach lifetime cost-parity with fossil fuel vehicles by the mid-late 2020s across the UK car and van fleet as a whole. By 2030 we expect upfront cost parity to be reached (i.e. by 2030 electric cars and vans will be no more expensive to buy, and considerably cheaper to run). This is based on an assessment that strips out any current taxes and subsidies to provide a 'social costs' comparison, and it includes the costs of producing the electricity and installing the required charging infrastructure.

Since the lifetime cost of BEVs will be cheaper overall than fossil fuel cars by the mid-to-late 2020s, having more BEVs on the road from this point will lead to cost-savings for society. Moving the switchover date from 2040 to 2030 saves a total of £8 billion over the transition period (2030-2040) and saves an estimated 11% (120 $MtCO_2e$) of UK emissions.

Switching to BEVs later than this point will incur higher costs. (Figure B.2) This is based on annualised costs to society, including both capital expenditure and running costs.[11] The key factors in the comparison between BEV and fossil fuel car costs are:

- A typical new conventional vehicle is currently around 30% cheaper to purchase than a BEV. This additional purchase cost is currently only partially offset by the cheaper running costs of BEVs.
- Battery costs currently make up around one-third of the cost of a typical BEV. Rapidly falling battery prices, due to advances in technology and manufacturing, will have a significant impact on the cost of a BEV. These reductions have been faster than many sources had previously anticipated.[12]
- Significant investment in vehicles and charging infrastructure, per year, is required and investment costs will 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 investments will be offset by lower operational expenditure from around 2030, with annual operating cost savings coming from lower fuel consumption (see Annex Box 2), efficiency improvements, reduction in home charger installation costs and fuel/maintenance cost savings.
- By mid-2020s, we expect these operating costs savings to outweigh the upfront cost premium, so that owning an EV will be cheaper than a conventional vehicle across its lifetime.[13] Further, by 2030 we expect upfront cost parity to be reached, so that EVs will also be cheaper to purchase for the customer at the point of sale than fossil fuel cars before this date.[14]
- In addition to significant emissions reductions and cost savings, wider benefits include improvements in air quality and noise reduction from widespread uptake of ZEVs.

Our analysis is consistent with other international studies[15,16] that highlight the cost-benefits of moving to BEVs by 2030, including reaching cost-parity in the next 5-10 years, falling battery costs and improved efficiency.

[11] Costs associated with building and running the low-carbon generation capacity needed to meet additional electricity demands from electrified road transport are not included in the cost estimates in this box but are included elsewhere in the CCC's advice to the UK Government. Our cost assessment here takes account of the infrastructure and grid costs associated with building the charging network for EVs.

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

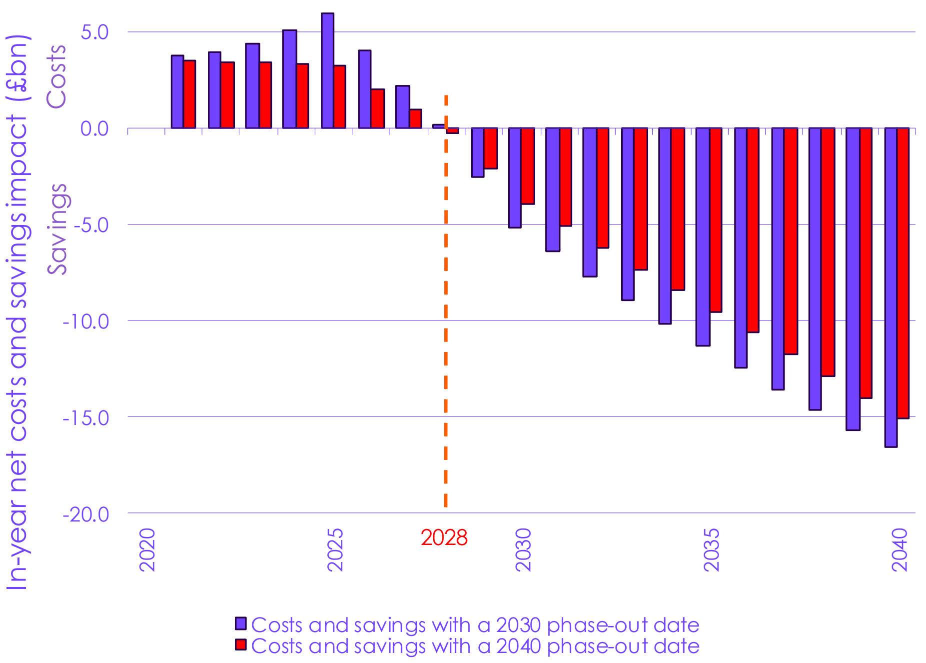
[13] We assume an average lifetime of 14 years for our UK analysis, consistent with UK car usage patterns.

[14] Upfront cost parity is based on manufacturing costs of average (medium-sized) cars and doesn't take into account government grants.

[15] McKinsey (2020), Charging electric-vehicle fleets: How to seize the emerging opportunity.

[16] ICCT (2019), Update on electric vehicle costs in the United States through 2030.

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



Source: CCC analysis.
Comparison between the annual cost to society (cost of vehicles, infrastructure, fuel and maintenance) of the EV transition under two phase-out dates for new petrol and diesel car and van sales (including PHEVs): (i) 2030 and (ii) 2040

While PHEVs are often advertised as low-emission vehicles, recent studies by Transport and Environment[17] and the International Council on Clean Transportation[18] show that PHEVs emit two- to four-times more during real-world driving than test values, in the UK. This makes their real-world emissions more comparable with conventional vehicles than with BEVs. Therefore, our recommendations to the UK are that they should play a minimal role and that the transition should focus on the uptake of zero-emission BEVs.

To ensure the UK has a near zero-carbon freight industry by 2050, the CCC has recommended a 2040 phase out date of new diesel HGVs in the UK. Significant HGV infrastructure investment will be required in the 2020s and 2030s, with large-scale trials to determine the most cost-effective and feasible decarbonisation option.

Source: CCC (2020) *The Sixth Carbon Budget – The UK's path to Net Zero*.

[17] Transport and Environment (2020), The plug-in hybrid con.

[18] International Council on Clean Transportation (2020), Real-world usage of plug-in hybrid electric vehicles.

3. Policy implications of the transition to ZEVs

Our analysis has presented a strong case for early action in transitioning to ZEVs. This is both feasible and cost-effective relative to later transitions and one of the largest contributors to the global economy-wide emissions reductions required to deliver the Paris Agreement.

Despite evidence on battery development and significant cost reductions over the past and projected into the future, the transition will not be delivered by the market alone. There needs to be a strong policy framework, and actions required from now to 2040, to ensure the transition is as seamless as possible, addresses barriers to change and the challenges to scaling up ZEVs. Based on an assessment of existing policies and a review of evidence, key elements of government strategies should include:

- Introduction of phase-out dates for sales of new fossil fuelled light vehicles by 2030-2040 to provide industry with certainty to transform supply chains and make investment decisions.
- These phase-out dates should be supported by measures to incentivise manufacturers to increase the share of ZEVs sold over time and by policies to incentivise demand e.g. tax incentives for ZEV purchase, which can be scaled back as costs fall, or ZEV mandates requiring an increasing share of sales to be ZEVs.
- Incentives to invest in EV charging infrastructure to ensure it is not acting as a barrier to take-up of ZEVs. These need to be scaled up from relatively low levels currently to support a fully decarbonised car and van fleet by 2040.
- Investment in battery capacity and development of new ethical supply chains of battery raw materials to meet higher demand. New mining facilities, appropriate battery-sizing and re-use and recycling can help to meet demand cost-effectively. Global cooperation on technologies and standards is needed to facilitate this and ensure that the scale-up is sustainable.
- Increased investment in networks and system capacity as well as upgrades to the distribution networks where needed to meet higher demands from ZEVs.
- Implementation of measures to limit road travel demand and incentivise shifts to walking, cycling and use of public transport. These are often highly cost-effective, can bring significant early emissions reduction and important co-benefits e.g. improved air quality and health.

Annex Box 1
Global integrated assessment models

Integrated assessment models (IAMs) are state-of-the-art coupled models of the global energy, agriculture, land-use and climate systems. They simulate the reduction of GHG emissions where they are least expensive across the whole century in order to achieve a specified climate goal. IAMs require external assumptions such as future population and GDP growth, as well as present technology costs and how these will develop over time. Countries are aggregated into a small number of regions (typically 10 - 20) due to computational constraints.

IAMs also have a number of acknowledged limitations:

- They generally do not incorporate many non-economic barriers to mitigation action (such as consumer behaviour) which can often be as important as technical ones. Other geo-political factors relevant for international climate policy (e.g. equity between countries) are also typically not captured.
- Mitigation options that reduce the demand for energy and GHG-intensive activities (e.g. moving from car use to walking and cycling) are commonly represented in less detail and have received less attention within IAMs than technological solutions.
- IAMs have recently been criticised for being too conservative on future price declines of renewables, as well as failing to reflect how innovation in some low-carbon sectors can spill over to accelerate innovation across the global economy.
- IAM pathways often rely heavily on the use of very large amounts of low-carbon harvested biomass in the energy system. Such large amounts may not be sustainable in the real world.

Despite these drawbacks, IAMs are useful for providing insights into how quickly sectors need to decarbonise. This report primarily draws upon trajectories developed using the TIAM-UCL model. These model runs have been specifically designed to help minimise a number of the above limitations: technology costs (including ZEV costs) have been updated to reflect a very recent picture of current and projected costs for low-carbon technologies, global biomass use is restricted to stay within sustainable limits, and 'leadership' by developed countries with high historical emissions is built in by mandating more ambitious Net Zero dates for these regions.[19]

The modelled Paris Agreement scenario represents a global emissions trajectory that is expected to have a ~50% probability of keeping peak warming to 1.75°C above preindustrial levels, consistent with the 'well-below' 2°C objective of the Paris Agreement long-term temperature goal. To keep warming to below 1.5°C (the more ambitious end of the Paris Agreement long-term temperature goal) with around a 50% probability then an even more rapid global transition would be required – reaching global Net Zero CO_2 emissions by around 2050 and more rapid near-term reductions. Most of the additional effort to fully align to a 1.5°C trajectory is expected to fall outside of the road transport sector, but the road transport trajectories in this pathway should be taken as indicative of a minimal level of ambition consistent with a 1.5°C pathway.

Source: CCC analysis; Vivid Economics & UCL (2020) *Unpacking leadership-driven scenarios towards the Paris Agreement*.

[19] ZEV costs are taken from Bloomberg New Energy Finance (2019) *Electric Vehicle Outlook 2020*. By 2050, EVs around 46% of their current day cost, and at rrice parity with conventional fossil fuel cars in 2030 for most regions,

Annex Box 2
Supply-side and demand-side challenges

EVs currently make up 2.6% of the global car market but are increasing rapidly in China, Europe and the US. Together, these markets account for around two-thirds of new global car sales[20]. To reach 100% market share by 2040, annual EV sales would need to rise from around 2 million currently to around 110 million by 2040. This rate of growth is achievable, but there are several supply-side and demand-side challenges that will need to be resolved in order to deliver this rapid transition.

Supply-side challenges:

- Global supplies of key raw materials for battery production such as cobalt, lithium, aluminium, graphite and manganese will need to scale up significantly, but are expected to remain a low proportion of estimated global reserves (e.g. lithium demand for EVs could be 1-2% of global reserves).
- Policies are required to ensure raw materials are ethically sourced alongside sustainability requirements covering the re-use, remanufacturing and recycling of batteries.
- Significant new investment in battery manufacturing capacity is needed. Steps should be taken to minimise the emissions embedded in these production processes.
- Installation of charging infrastructure that is widespread, accessible, easy to use and relatively inexpensive, will be needed.
- Further investment is required in low carbon power networks and upgrades, such as increasing renewable generation capacity and ensuring that distribution grids can support the increased demand. Differential pricing will be important to help lower demand at peak times, while innovations such as vehicle-to-grid technology should also be supported.
- Investment in original equipment manufacturer (OEM) manufacturing capability: this will need to increase EV production to deliver the increased vehicle volumes that will be required to deliver an effective global transition.

Demand-side challenges:

- OEMS need to make EVs more attractive to consumers, including pricing, range and choice of models and delivery times.
- Overcoming charging anxiety: a mix of charge points will be required, covering slow, fast and rapid chargers. These should provide a convenient, reliable and engaging consumer experience.
- Dealers should actively promote and sell EVs, and ensure staff are well informed on technical performance and financial support available.
- Reducing global growth of EV mileage is important to reduce particulate matter from brakes and tyres[21] and operational emissions, of which account for around 50% of total BEV emissions[22].
- Demand reduction and modal shift measures include active travel, shared mobility, reversing the shift towards SUVs and increased home-working, all of which require increased investment and improved infrastructure.

[20] Statista (2020), Largest automobile markets worldwide in 2019, based on new car registrations.

[21] Air Quality Expert Group (2019), Non-Exhaust Emissions from Road Traffic

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

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