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EV Uptake in the Transport Fleet: Consumer Choice, Policy Incentives and Consumer-Centric Business Models

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A QUARTERLY JOURNAL FOR DEBATING ENERGY ISSUES AND POLICIES

EV UPTAKE IN THE TRANSPORT FLEET: CONSUMER CHOICE, POLICY INCENTIVES AND CONSUMER-CENTRIC BUSINESS MODELS

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INTRODUCTION

This issue of the *Oxford Energy Forum* follows on from OIES's third transport workshop, held in Oxford in late 2019. The workshop focused on three factors that are likely to influence the uptake of electric vehicles (EVs) in the transport fleet: government policy incentives, consumer choice, and the need for consumer-centric business models.

EVs are still a nascent technology and rely heavily on government incentives. Governments have a range of instruments at their disposal, from subsidizing EVs to taxing or banning internal-combustion-engine vehicles (ICEVs). These policies are not equivalent in terms of effectiveness, efficiency, and public acceptability. For instance, consumers may prefer subsidies on EVs to taxes on ICEVs, but subsidies are inefficient. Similarly, bans on ICEVs may be effective, but may not be publicly acceptable if they limit consumer choice. This suggests that government incentives and policies to encourage EV uptake need to be designed with careful consideration of the possible trade-offs between efficiency, effectiveness, and consumer preferences. Meanwhile, consumer choices take into account not only government incentives but also their own preferences (e.g. for shared mobility or car ownership) and constraints (e.g. budgets). Understanding the determinants of consumer choice is therefore crucial to avoiding misalignments between the design of government incentives and consumer preferences. To be viable, transportation-sector business models need to be consumer-centric – in other words, built around a deep understanding of customers' needs, preferences, and values and the contribution that each of these makes to the company's profitability.

The eight articles in this issue debate different aspects of these fundamental trade-offs and their policy implications.

Scott Hardman and Daniel Sperling argue that there is a need for sustainable and persistent incentives for electric vehicles. Unlike supply-side regulations, which tend to become more stringent over time, incentives tend to decrease in value over time, as increasing sales make them more costly for governments. The authors argue that initially this does not appear to be problematic, as research shows that government-funded programs are having their intended effect on the EV market. However, government commitment to incentives is wavering because of the increasing cost burden, especially when plug-in EVs (PEVs) constitute higher percentages of the new-vehicle market. Studies have found as many as 50 per cent of buyers in some markets would not purchase a PEV without incentives. Thus, if incentives are phased out at a time when consumer adoption still depends on them, the market is likely to shrink. The authors propose revenue-neutral 'feebates' – a combination of fees for higher-emission vehicles and rebates for lower-emission vehicles – as a solution. They discuss the effectiveness of feebates in shifting consumer preferences, arguing that feebates could continue to operate even in a 100 per cent battery EV (BEV) market.

Ahmad O. Al Khowaiter and Yasser M. Mufti argue that today's EVs are designed primarily to satisfy regulatory policies for reducing greenhouse gas emissions, and only secondarily to meet customer expectations. While these policies have generated significant financial and capital investments in BEV technologies, they have not stimulated consumer demand commensurate to these investments. To comply with regulations, automakers have to either significantly reduce the tailpipe emissions of their ICEVs or introduce an EV model to offset tailpipe emissions and avoid monetary penalties. The authors argue that there is a mismatch between regulations and consumer preferences. Further, the move to EVs is transferring ownership of a core technology and competency of automakers – the engine – to the battery supplier, limiting the ability of automakers to take in-house action to respond to consumer demand. The authors argue that to reach the level of EV sales set by regulators and create a profitable product, EVs will have to come in a variety of models and classes, with a similar range to and price-competitive with conventional vehicles, while encouraging consumer interest in the product. Incentives, subsidies, and regulations alone will not sustain EV market share. With all of these factors considered, the uptake of EVs is not expected to capture all of the automotive market by 2040 even in the most aggressive projections. Thus, the authors argue, investment in improved ICEV technologies will continue to help reduce transport-sector greenhouse gas emissions.

George Beard draws on data for the UK to show that continuing growth in mild hybrid EV (MHEV) sales relative to BEVs reflects continued support for conventional vehicles, as an MHEV cannot be driven with zero emissions at the tailpipe, and its battery cannot be recharged by plugging in. The author unpacks some key factors influencing the uptake of EVs, drawing on evidence from choice experiments. These factors include consumer attitudes towards purchasing EVs, which are based not just on instrumental attributes such as cost, range, and reliability, but also on 'hedonic' and 'symbolic' attributes. Financial factors are a key influence – particularly the upfront purchase price, even if the running costs are lower for an EV than for an ICEV, as most consumers fail to accurately factor in the total cost of ownership (TCO) in their purchasing decisions. Actual and perceived availability of charging infrastructure also influences adoption. The author infers that while these are barriers to EV adoption, different consumers prioritize different barriers, and the market can be differentiated on this basis. The author presents a case for taking a holistic, evidence-based approach to policymaking which considers not just the end goal of increasing consumer adoption of EVs but also interim objectives that account for the heterogeneity of the EV market.



Akshima Ghate and Mandar Patil investigate the role of incentives on EV uptake among consumers in an emerging market – India – which is making a move towards clean and sustainable transportation. The authors look at the impact of fiscal incentives provided by the national and state governments in reducing the Total Cost of Ownership (TCO) of electric cars in Delhi, where there are six categories of incentives for which an electric car user is eligible, depending on how the car is used. The authors estimate the TCO (cumulative expenses incurred throughout the life of the vehicle) for four auto fuel technologies (electric, diesel, petrol, and compressed natural gas) and four ‘use cases’ defined by ownership (individual or firm), registration (private or commercial), financing (self-financing or loan) and driver (self-driven or paid driver). The article discusses whether EVs (with and without incentives) are at cost parity with their ICEV counterparts. It demonstrates that the structure and types of incentives for EV uptake play a crucial role in reducing the TCO of electric cars and helping them achieve cost parity with ICEV counterparts in Delhi, the study area. It also shows that the electric car market in Delhi is much more attractive for commercial cars, given their greater daily use. The article concludes that incentives will need to continue in order to encourage EV uptake in India, but it also highlights a need for EV policies and incentive structures to evolve so that EV sales become self-sustaining, eventually making it possible to gradually phase out incentives.

Nicolò Daina explores the argument around electric mobility freeing private drivers, who can park off-street at home and charge overnight, from the need to visit a refuelling station, except during infrequent long trips. The provision of public charging infrastructure in residential areas is intended to encourage car buyers to switch to EVs as (near) home overnight charging is a strong consumer preference. However, this ideal vision hardly applies to residents of densely populated metropolitan areas where a large share of private car drivers do not park their cars on private premises overnight. On the contrary, a disproportionate focus on residential on-street charging infrastructure creates demand for a product that, while providing significant benefits for society as a whole, generates marginal benefits to individual consumers. The author argues that this focus fails to capitalize on the more responsive demand segment of commercial and public-service fleets, the economics of which also stack up more favourably based on TCO. The author draws on survey evidence to argue that electrification aligns with the strategic goals of organizations that operate fleets. However, significant barriers exist in terms of high purchase costs and inadequate infrastructure. The author argues that public charging infrastructure should not be optimized for specific fleet types. Instead, the author proposes a holistic approach in which the locations, types, and number of public charging stations are optimally deployed to serve multiple EV use profiles over a specific area, maximizing the use of charging infrastructure by servicing fleets that are already economically motivated to electrify.

Toon Meelen and Brendan Doody explore the potential for vehicle-to-grid (V2G) technologies for vehicle fleets. V2G is a system that makes it possible for EV batteries to discharge back to the electricity grid, which is potentially useful for stabilizing the grid and for integrating renewable energy sources such as solar and wind. Revenues generated with V2G services could also help accelerate the transition towards electric mobility. The authors make three main points. First, fleets are a potentially useful application context for V2G for multiple reasons – such as helping with peak shaving, frequency regulation, and renewable energy storage. Second, the fleet market is highly variegated, based on attributes such as ownership structure, fleet size, vehicle type, and industry type. Further variety is found in fleet management practices – such as purchasing, financing/leasing, and day-to-day operations. Third, the fleet market has traditionally been dominated by small and medium enterprises, each of which operates only a small number of vehicles. Their importance seems to be increasing further, which could pose a barrier for V2G implementation, as small and medium enterprises face particular barriers in the uptake of sustainable innovations due to financial capacity and investment constraints. The authors propose three policy strategies to stimulate EV and V2G use in smaller fleets, which include a rethink of how certain sectors that use fleets are regulated and organized.

Pierpaolo Cazzola reviews the status of electric mobility during the coronavirus pandemic and argues that, although early data for 2020 suggest that EVs will not be exempt from the impact of COVID-19 on the automotive market, fundamental drivers are likely to keep the longer-term outlook for the EV market positive – if clean mobility remains a policy priority and economic stimulus packages reflect the role of electric mobility as a driver of broader innovation. The author discusses a number of factors which could lead to a short-term contraction of EV sales, possibly even in terms of market share, including delays in the implementation of policies aiming at transport decarbonization, constraints on consumer borrowing, and prolonged low oil prices. In the longer term, however, the outlook for EVs remains positive, due to persistent, self-reinforcing cost reductions in EV production and synergies with government policies and priorities on climate change. The author states that policy should therefore continue supporting the transition to electric mobility. In the near term, insurance will be important to ensure that a range of different players – including large, established companies and small, innovative start-ups – continue to operate. Stimulus packages that are currently in preparation could maintain, reinforce, or introduce measures that foster the transition. In the longer term, the increased pressure on government revenues could mean that additional fiscal instruments (such as bonus/malus schemes that tax vehicles based on their environmental performance, as well as distance-based charges for road use) are adopted to raise revenues to finance the transition.



The issue ends with seven key takeaways from OIES's third transport workshop, held in late 2019 on EV Uptake in the Transport Fleet: Consumer Choice, Policy Incentives and Consumer-Centric Business Models, summarized by *Anupama Sen*. First, a lack of policy coordination between national and local governments could slow the EV transition, as while national governments set targets for EV penetration, much of the responsibility for their implementation ultimately falls to local authorities that act as the main interface with stakeholders. Second, governments have favoured 'carrots' over 'sticks' when designing incentives to promote EV uptake – but their targeting has differed in advanced and emerging economies. In advanced economies with high levels of car ownership, governments provide upfront purchase and other incentives to private passenger vehicle owners, whereas in emerging markets, incentives are targeted at transport modes that have higher shares in terms of passenger kilometres. Third, timelines for EV incentive schemes need to be consistent with the minimum timelines required for auto manufacturing supply chains to adapt. Incentive programmes typically lack long-term time frames, whereas the planning of auto supply chains requires a minimum of three to five years. Fourth, interoperability of infrastructure is a key objective of government EV policies but could conflict with business innovation: government policies aim for standardization, while private companies may need to base their business models on specialization. Fifth, EV uptake policies need to take consumer choice into account, while also promoting consumer education. Sixth, fleet-based business models provide an opportunity to rapidly scale up EV use. This is partially due to favourable economics, but also because decisions on EV purchases for fleets made by fleet managers are likely to be more rational than private EV purchase decisions. Finally, EV policies in advanced economies need to adopt whole-systems approaches to mitigate externalities beyond the boundaries of their own societies.

THE NEED FOR SUSTAINABLE AND PERSISTENT INCENTIVES FOR ELECTRIC VEHICLES

Scott Hardman and Daniel Sperling

By the end of 2019, over 7.5 million battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) had been sold globally. The growth of sales is partially a result of government interventions, which typically take the form of supply-side regulations or demand-side incentives.

Supply-side regulations

Supply-side regulations encourage or require automakers to sell more electric vehicles – in terms of either a percentage of vehicles sold or the average emissions of vehicles sold. California's Zero-Emission Vehicle Program, for example, requires automakers to sell a certain number of zero-emission vehicles – which include BEVs, PHEVs, and hydrogen-fuel-cell vehicles – with a credit-trading provision (California Air Resources Board, 2020). If automakers generate surplus credits by selling more than the required number of zero-emission vehicles, they can sell credits to other automakers; and if they have a shortfall in credits, they can buy credits from those with a surplus or pay a fine.

The European Union sets CO₂ emissions standards for new passenger cars and vans. For 2021, this standard is set at an average of 95g CO₂ per km. Automakers are fined per gram of CO₂ per km above this target. This regulation (Regulation (EU) 2019/631 of the European Parliament and of the Council) encourages sales of plug-in electric vehicles (PEVs, which include both BEVs and PHEVs) by counting vehicles with less than 50 g CO₂ per km as two vehicles. The same regulation sets targets for BEV, PHEV, and hydrogen-fuel-cell vehicle sales of 15 per cent by 2025. Some national governments have more aggressive targets (not yet codified in regulation), such as the United Kingdom, which has targeted 100 per cent PEV sales by 2035.

Demand-side incentives

While supply-side regulations focus on automakers, demand-side initiatives focus on consumers, providing incentives to buy PEVs. These include financial incentives that discount the purchase price (e.g. the UK Plug-in Car Grant), provide post-purchase rebates (e.g. the California Clean Vehicle Rebate), give tax credits after purchase (e.g. the United States Federal Tax Credit), or exempt PEVs from sales tax (e.g. exemption from value-added tax in Norway).

Policymakers' rationale for incentives is that they reduce the cost of PEVs and thus encourage consumers to buy them. Unlike supply-side regulations, which tend to become more stringent over time, incentives tend to decrease in value over time, as increasing sales impose a higher overall cost burden on the government.

Consumer response to incentives

Most academic studies have found that consumer incentives have an impact on electric vehicle sales (Hardman et al., 2017). According to the research, rebates, tax credits, grants, and tax exemptions are all effective to varying degrees. Studies have



found as many as 50 per cent of buyers would not purchase a PEV without incentives. Initially this does not appear to be problematic, as research is showing that government-funded programs are having their intended effect on the electric vehicle market. However, the phase-out of incentives raises problems. If incentives are phased out at a time when consumer adoption of PEVs is still dependent on incentives, the market would shrink.

Policymakers may be hoping that as the market for electric vehicles grows, fewer buyers will rely on incentives. However, a recent study from California, one of the more developed PEV markets, showed that each year more consumers are relying on incentives. Controlling for income and other sociodemographic variables, Jenn et al. (2020) found that PEV buyers in each successive year from 2010 to 2016 were more likely to report that their purchase decision depended on incentives.

These results show that incentives are becoming more important, and not because lower-income buyers are beginning to purchase the vehicles. The increase in importance is due to changes in buyers' attitudes. Early buyers of electric vehicles were enthusiastic early adopters or innovators who would have made the same purchase without a financial incentive; however, later buyers have been more pragmatic and less willing to change their behaviour without incentives. While the increasing importance of incentives was first reported in California, a similar trend is likely in other states and outside of the United States.

Removal of incentives

The increasing importance of incentives over time is problematic because governments' commitment to incentives is wavering. In the United States, a federal tax credit of up to \$7,500 (£5,744) is available to PEV buyers, but it is limited to 200,000 credits per automaker. Tesla and Chevrolet have reached this limit, so buyers of their vehicles no longer receive the tax credit.

The state of California recently reduced its BEV rebate from \$2,500 to \$2,000 (£1,915 to £1,531) and its PHEV rebate from \$1,500 to \$1,000 (£1,171 to £780). Furthermore, eligibility for the rebate is becoming more limited as a result of income caps and vehicle purchase price caps. The rebate has also been plagued with funding issues. Between 2011 and 2019 there were six periods of 60 to 143 days each when funding was unavailable for incentives, meaning buyers cannot be certain of whether they will actually receive an incentive.

Incentives are also being reduced in other markets. In the United Kingdom, the plug-in car grant no longer applies to PHEVs, and the BEV rebate has been reduced from £5,000 to £3,000.

Some buyers will continue to purchase PEVs in the absence of incentives, especially those whose decisions were not influenced by incentives, such as high-income early adopters. However, the removal of incentives may make a large proportion of the population unwilling to purchase a PEV.

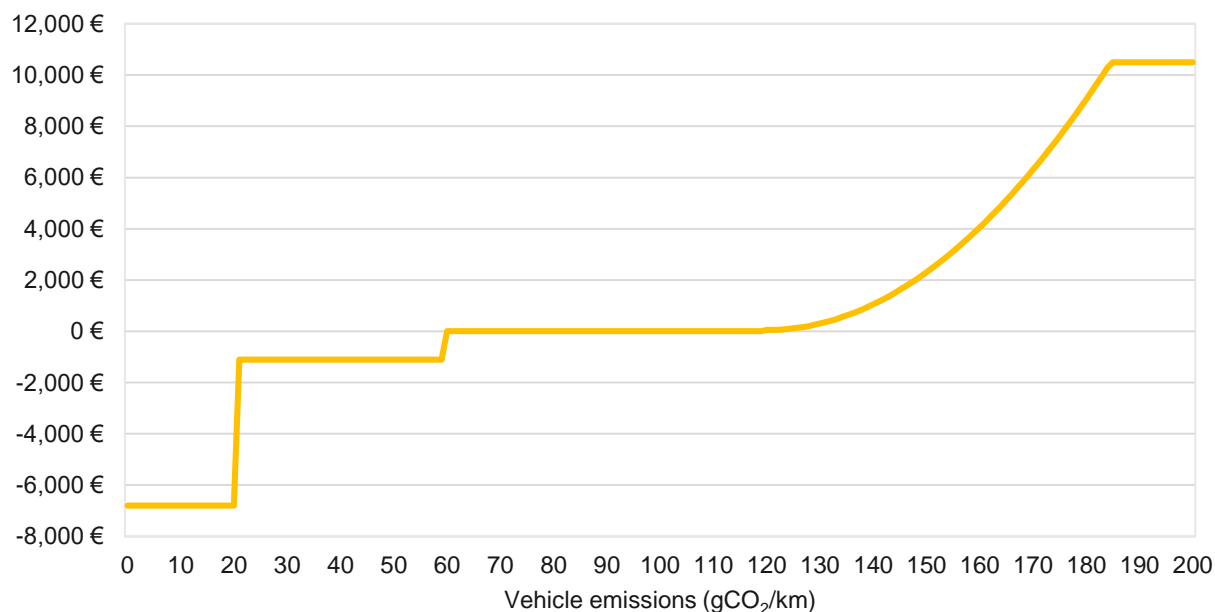
A sustainable incentive mechanism

Purchase incentives such as rebates or tax credits cannot continue indefinitely, because the cost burden to governments would be too high, especially when PEVs' percentage of the new-vehicle market increases. What is needed are incentives that can persist without negatively impacting government budgets.

One such solution could be 'feebates', sometimes known as bonus-malus arrangements, in which a fee (or malus) is charged on higher-emission vehicles and a rebate (or bonus) is paid for lower-emission vehicles. The fees pay for the rebates, creating a revenue-neutral system.

Both France and Sweden have introduced feebates. Under France's system, introduced in 2008, buyers of vehicles emitting less than 20 g CO₂/km (typically BEVs) received a rebate of €6,800 (£5,645), vehicles with 20-60 g CO₂/km (typically PHEVs) received a rebate of €1,100 (£913), and purchasers of vehicles with emissions of 120 g CO₂/km or more paid an exponentially increasing fee capped at €10,500 (£8,717). The French government's goal has been for this feebate to be revenue neutral. However, due to difficulties in anticipating consumer and automaker response to the regulation, changes were continually needed to balance the feebate budget. In 2008–2010 the program resulted in a budget deficit; however, since 2011 the budget has been balanced or has had a slight surplus (ICCT, 2018).

The more recently introduced system in Sweden is similar to that in France. Buyers are given a bonus of 60,000 Swedish kronor (£4,746) for BEVs and 10,000 kronor (£791) for PHEVs, and buyers of conventional vehicles pay a fee (over a three-year period) based on their CO₂ emissions (Kong and Hardman, 2019).

Bonus-malus system in France, 2019 (negative numbers indicate rebates and positive numbers indicate fees)


Source: Kong and Hardman, 2019.

Feebates deliver many benefits. In addition to shifting preferences toward lower-emitting vehicles and being revenue neutral, they make it politically and economically easier to continue strengthening vehicle CO₂ and fuel economy standards. This is because feebates are more equitable than other PEV incentives, which mostly benefit high-income households (because most BEV and PHEV buyers have a high income). Feebates charge fees to the buyers of expensive less-efficient vehicles (also purchased by higher-income households) and redistribute these fees to buyers of very low or zero emission vehicles (including BEVs and PHEVs). Buyers of less expensive low emission (but not zero emission) vehicles which tend to be purchased by lower- and middle-income households, do not receive a rebate but also do not pay a fee.

Feebates also benefit consumers by solving the problem of conservative consumer purchase behaviour – the tendency to resist paying more for a more fuel-efficient vehicle, even though the buyer comes out ahead in the long term through large savings in fuel payments. Finally, feebates ensure that incentives are available for BEVs and PHEVs for the long term, such that government budgets do not need to be continually reassessed, and buyers have greater certainty of receiving an incentive.

Introducing feebates may be politically challenging in some regions, notably the United States, where vehicle purchase taxes are tied to the vehicle purchase price and not the vehicle emissions. This makes introducing an incrementally increasing emissions-based fee for conventional vehicles difficult. Second, existing BEV or PHEV rebates and tax credits are not delivered at the point of purchase, so cannot function as the rebate part of a feebate. Third, vehicle taxes and PEV incentives are administered by different government bodies. A feebate, depending on its design, would likely require entirely new legislation.

Some countries may have an easier path to introducing feebates than the United States. The United Kingdom, for example, already has a vehicle tax (known as vehicle excise duty) that is paid at the point of sale and incrementally increases based on vehicle emissions. A vehicle with emissions of 91–100 g CO₂/km pays £130, and a vehicle with emissions of more than 255 g CO₂/km pays £2,135. Second, the UK Plug-in Car Grant is applied at the point of sale. From a consumer perspective, the UK vehicle tax and electric vehicle grant already looks like a feebate (though with lower fees). It is not budget neutral, however, which is one reason the BEV grant has fallen from £5,000 to £3,000.

With a BEV market share of 1.6 per cent (the 2019 UK market share), the average vehicle tax payment for new cars would only have needed to increase by £56 to fund the Plug-in Car Grant. Ideally more of the fees would be collected from more expensive higher-emitting vehicles. The fee would increase over time as BEVs gain a higher market share, and, at the point where BEVs have a very high market share, some BEV buyers may also need to pay a fee.

Even in a 100 per cent BEV market, a feebate could still be used. BEV efficiency differs substantially between vehicle models; the most efficient BEVs get up to 141 miles per gallon equivalent and the least efficient get 74, according to US government sources (DOE and EPA 2020). With high BEV market shares, fees could be applied for less efficient BEVs and rebates for more efficient ones.

Conclusions

The evidence is strong that consumers are conservative in shifting to BEVs and PHEVs. Yet governments need to rein in funding of incentives for their purchase. To continue reducing the carbon footprint of vehicles (and increasing their efficiency), substantial PEV incentives will continue to be needed. Feebates may be a necessary and practical way for policymakers to fund incentives while limiting government expenditure.

BATTERY ELECTRIC VEHICLES AND CUSTOMERS BEYOND THE FINAL CONSUMER

Ahmad O. Al Khowaiter and Yasser M. Mufti

This past decade marked a pivotal transition for battery electric vehicles (EV): the number of EVs on the road increased from a few hundred at the beginning of the decade to 5 million by the end. A vehicle class that was on few people's radar only a decade ago has become the major topic of conversation for every automaker.

Even with this precipitous rise of EV sales, few would argue that the increase in sales is a result of strong consumer demand. In fact, this article argues that today's EVs are designed to satisfy regulatory policies first and to meet customer expectations second. These policies have successfully generated significant financial and capital investments in battery EV technologies; however, policies have not stimulated consumer demand commensurate with these investments. Ultimately, this suggests a severe mismatch between regulations and consumer sentiment towards the current EV. While some of the mismatch results from a lack of consumer knowledge, other aspects are more substantial. Limited affordability, range anxiety, long charging times, and lack of charging infrastructure are real and non-trivial concerns. The inability to respond to these concerns should be worrisome for the industry and regulators.

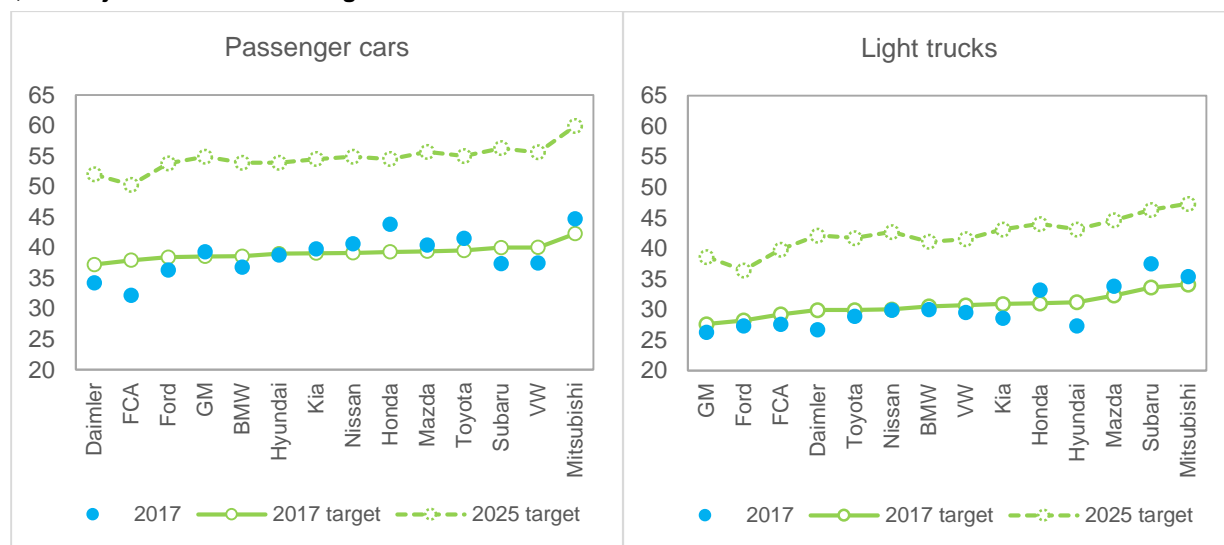
Unlike conventional vehicles, many of the traits limiting EVs are beyond the scope of most automakers, thereby limiting their ability to respond. Previously, an automaker could take actions to meet consumer demand in-house, but responsibilities for lower cost and better performance batteries typically fall on battery suppliers. Correspondingly, EV production may also mean that automakers must relinquish control over one of its major core competencies, engine technology, to battery makers. Over time, the world will become more aware of EVs, batteries will be improved, and the automotive industry will adapt to new business practices. In the meantime, for the coming decades, sales of internal combustion engine (ICE) vehicles will remain significant, and further investment towards improving them will be prudent.

Policy as the primary driver of EV sales

Governments around the world are looking to reduce greenhouse gas (GHG) emissions to combat climate change; for many developed nations, transport remains a major source of GHG emissions. As such, regulations aim to incentivize the production of EVs by penalizing the tailpipe emissions of ICE vehicles and shifting tailpipe emissions upstream where, hopefully, carbon-free electricity can be produced. To comply with these regulations, automakers would have to either reduce the tailpipe emissions of their ICE vehicles significantly or introduce a subset of EVs to offset tailpipe emissions and avoid monetary penalties.

Depending on the regulation of transport emissions, it has become increasingly difficult to meet future standards through improvements of ICE vehicles alone. A major difficulty is the consumer's preference to purchase ever larger and more powerful vehicles. If we consider the U.S. Corporate Average Fuel Economy (CAFE) standards for passenger cars and light trucks as an example, many original equipment manufacturer (OEM) fleets can meet their CAFE targets for model year (MY) 2017 vehicles. As these targets become more stringent, by 2025 almost no traditional OEMs will be able to meet their targets with their existing fleet without significant investments and powertrain changes.

Corporate Average Fuel Economy (miles per gallon) for Model Year 2017, compared to 2017 target and 2025 (projected) targets, for major automakers selling vehicles in the United States



Most policies are technology neutral, which suggests that automakers are free to adopt a number of different vehicle technologies – including EVs, plug-in-hybrid EVs, and fuel-cell vehicles or hybrid electric vehicles, to meet regulatory standards. This flexibility has also made it more difficult for OEMs to determine the direction of their investment. However, the direction became clearer when China approved the New Energy Vehicle (NEV) mandate policy as a part of the 13th Five year plan. Under the plan, manufacturing of EVs became a key strategy under the Made in China 2025 initiative. Support from the Chinese government hastened the production of EVs for global automakers, as China is fast becoming the world's largest auto market. Modelled after California's Zero Emissions Vehicle (ZEV) standard, the NEV policy mandates 10 per cent zero-emission vehicles by 2019 and 12 per cent by 2020, based on a credit system.

Globally, a number of monetary subsidies were also adapted to further incentivize EV growth. Policymakers expect that these subsidies will help producers to build scale and reduce costs to become price-competitive with ICE vehicles. Early incentives that offset cost of EVs by as much as 50 per cent bolstered a flurry of EV sales. The subsidy levels correlated well with EV sales – for example, car sales dropped substantially as soon as subsidies were removed in India and returned with the news that subsidies would be reinstated. Similar trends were observed in month-over-month sales in China as well.

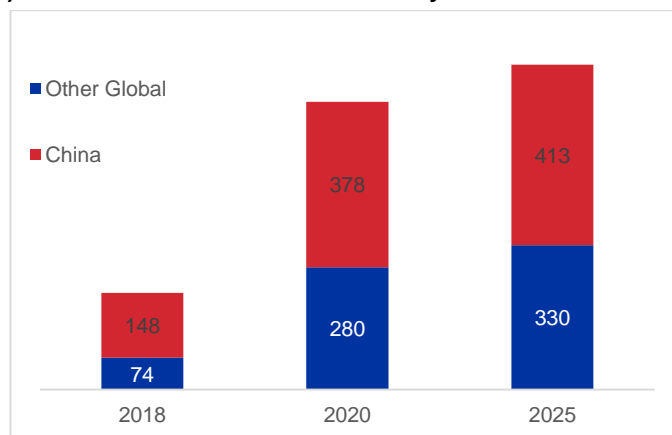
But despite numerous hefty incentives to offset the cost of batteries, EV sales in 2019 were roughly 2 million or about 2.3 per cent of total light-duty vehicles sold worldwide (insideevs.com and ev-volumes.com). As subsidies waned in 2019, global EV sales growth slowed substantially. The high elasticity of sales to subsidies implies that consumers are not yet ready to accept EVs as their mobility solution at current price levels and with current product offerings.

Growing evidence now shows that EV subsidies have not been an effective tool to increase consumer preference, primarily due to the improper distribution of subsidies. For example, a recent study published by the Treasury Inspector General for Tax Administration (TIGTA) of the U.S. (<https://www.treasury.gov/tigta/auditreports/2019reports/201930072fr.pdf>) reported that \$1.44 billion in tax credits was paid to 239,422 claims through 2017 and another \$7.5 billion is expected to be paid between 2018 and 2022. Of these claims, a total of 16,510 claims totalling \$73.8 million was reported to have been awarded potentially erroneously. This underscores the inability of these subsidies to target the proper customer group and to increase their awareness of EVs.

Shifting control from carmakers to battery makers

For most automakers, much of today's vehicle manufacturing is outsourced to suppliers; major automakers are still responsible for the design, assembly, and manufacture of engine technologies, enabling cost efficiency without surrendering quality. For conventional vehicles, core propriety technologies, including engines, are generally wholly owned and manufactured by the automaker. For EV batteries, the ownership of core technologies has become more diffused and is not proprietary to the automaker. The move to EVs is transferring ownership of a core technology, the engine, to the supplier with the battery. This further constrains the ability of automakers to control their product mix to meet consumer and regulatory demand.

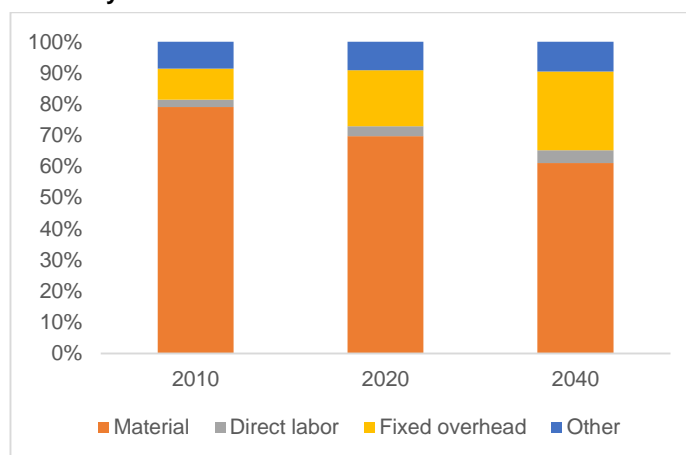
Manufacturing capacity (GWh) for Chinese and non-Chinese battery makers



In 2020, hundreds of major and minor battery suppliers exist around the world; China has the greatest number of battery manufacturing facilities. An internal Saudi Aramco study on battery technology, based on publicly available information, found that these suppliers have the capability of supplying up to 200 GWh today; by 2025, the announced production capacity will be over 700 GWh. Major suppliers such as LG Chem, Panasonic, and CATL will make up over 40 per cent of this production capacity. LG Chem, for example, one of the largest EV battery producers, has been supplying battery cells to multiple international automakers, which is a typical OEM–supplier relationship. Unlike other suppliers, future advancements in battery EVs will be made from innovations in material chemistry and cell manufacturing – core competencies of major battery suppliers.

The same battery technology study showed that even as battery prices fall, an estimated 60 per cent of total battery manufacturing cost is attributable to materials cost including 50 per cent to cathodes. Conversely, battery manufacturing is a highly automated process, and direct labour accounts for less than 3 per cent of total battery cost. Currently, battery manufacturers are working to reduce material costs by altering battery chemistry and using cheaper active cathode materials (e.g. less cobalt, more nickel) and improving yield. As an automaker increases the production of EVs in its portfolio, the automaker also risks the erosion of its core competency to battery makers. To maintain competitiveness (and profit), automakers will have to adapt to new business practices in the future.

Costs of making an automotive battery



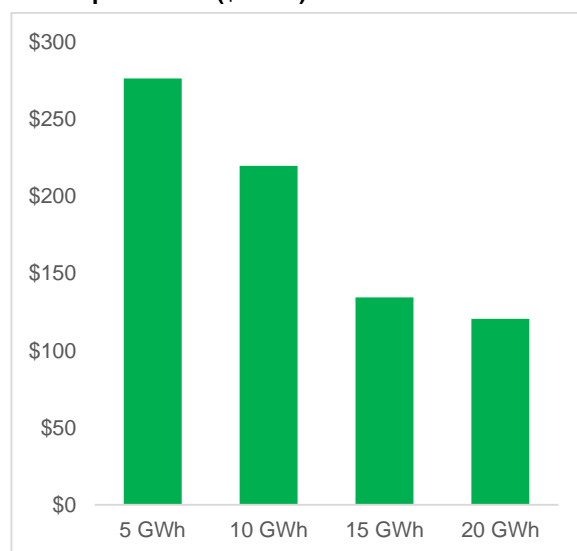
Consumers have less influence today

Ultimately, the 77 million vehicles sold in 2019 were purchased by consumers, and EVs accounted for 1.8 million of these sales. Despite the policy push, consumer awareness of EVs remains very low. In California, where EV sales comprise more than half of the US total, a survey conducted by the University of California, Davis (Kurani and Hardman, 2018) found that the vast majority of residents of the state remained unaware of EVs and the state's charging infrastructure. The difficulties in EV adoption are not only limited to awareness; over the years, consumers have expressed concern about EVs' numerous practical

limitations, and many of the problems that have plagued EVs in the past still exist today: high cost, long charging time, limited range, limited availability of vehicle classes, and limited charging infrastructure. Almost all these problems can be attributed to the limitations of batteries.

While significant improvements have been made in the past decade, and prices have dropped, specifications for today's batteries are still insufficient. To achieve a level of success and profit comparable to conventional vehicles, automakers need to make EVs that have cost parity, which the US Department of Energy, multiple consultants, and experts assume to be approximately \$100–125/kWh (Nykqvist and Nilsson, 2015). Recent announcements from Tesla state that the Tesla battery cell price should reach \$100/kWh at the end of 2020, which is similar to our internal cost projections for volume EV manufacturers. Our internal projections also show there is a significant difference between low volume battery producers and high-volume producers. This price also neglects to show whether some smaller automakers can purchase the products low enough to reach cost parity with conventional vehicles. Due to economies of scale, a high-volume producer such as Panasonic or Tesla, at about 15 GWh, can make a battery pack for \$135/kWh, whereas a low-volume producer's cost may be as high as \$275/kWh. This cost disparity will most likely shift production of batteries to a few large battery suppliers. Since the cost of the battery pack is a function of kWh price (\$/kWh) and pack size (kWh), even as the price of batteries falls on a \$/kWh basis, the total cost of a battery pack in a vehicle is unlikely to fall as automakers will likely shift to larger battery packs to increase performance of the vehicle or produce a wider range of product offerings.

2019 battery pack costs for different-size producers (\$/KWh)

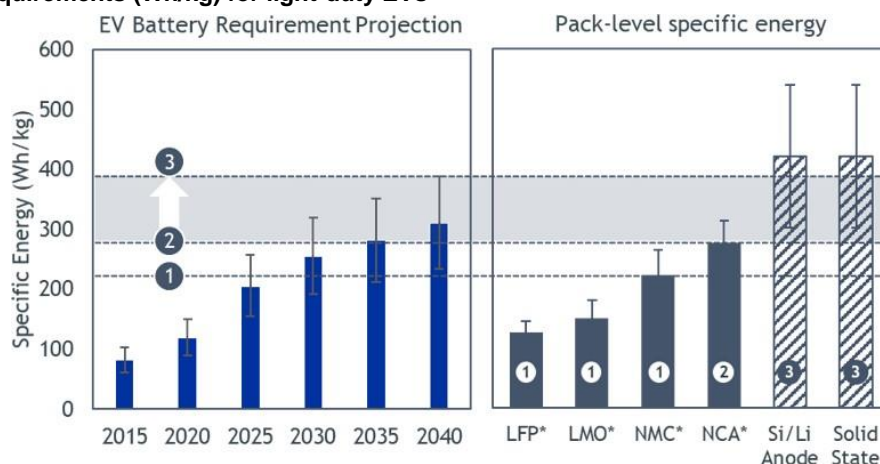


Automakers will be pressured to make longer range and larger size vehicles to compete with conventional vehicles. The range of conventional vehicles is primarily determined by their fuel economy and the size of the fuel tank. Likewise, Larger vehicles can be made without sacrificing range because a larger fuel tank can be used for negligible cost increase. Conversely, for EVs, the range and physical size of the vehicle is determined by the “size” of the battery. This “size” of the battery is, in-turn, determined by the energy per unit weight or unit volume (fuel economy) coupled with the number of these units (fuel tank size).

To increase the range of an EV, an automaker can either increase the number of battery cells (or unit) of a vehicle or increase the energy density within each battery cell. Ideally, fewer units, and thus less weight and volume, yield the most desirable results. The Tesla Model 3 battery, with a range of 240 miles, weighs an impressive 478 kg; comparatively, the Chevy Bolt, with a similar 256-mile range, is slightly modest at 440 kg. In theory, Tesla or GM could increase the number of battery cells to achieve a desirable range or vehicle size. Designing and producing a profitable EV will be challenging, given that most vehicles are constrained by cost; weight and physical size of the battery pack serve as important physical constraints as well.

Our internal study found that LG Chem, CATL, and Panasonic have a battery energy density of 170 Wh/kg today; to reach a vehicle range of 300 miles for large SUVs, these batteries will have to reach an energy density of over 300 Wh/kg. The practical energy density of nickel-manganese-cobalt based lithium ion battery used by many major OEMs (Tesla uses nickel-cobalt-aluminium) has a pack-level limit of 250 Wh/kg. By 2035, automakers will have to use some version of solid-state batteries or lithium ion batteries with some amount of silicon in the anode to meet the size and range demand of larger vehicles.

Projected battery requirements (Wh/kg) for light-duty EVs



While consumers desire longer range and larger vehicles, the battery maker has significant control over the ability for an automaker to meet these demands. As such, the consumer is now in a position to yield control of the products available to them to regulators first and battery makers second. This upends the supply chain where the traditional model was for the automaker to focus on consumer demand first and force suppliers to meet product specifications while satisfying regulations.

Mobility transition must go hand in hand with energy transition

An artificial transition in mobility will achieve little, especially if it is not accompanied by a transition in the energy sector. Automakers may argue that the car industry has no control over the decarbonization of the electricity grid or other forms of energy production, and thus tailpipe emissions of electric or fuel cell vehicles should, justifiably, be zero emissions. From a climate change perspective, it makes no difference whether the CO₂ comes from the tailpipe of a vehicle or the smokestacks of a power plant; therefore, a holistic analysis is a prerequisite to ensuring that CO₂ emissions are not simply being moved to another sector. In countries that have a high level of renewable energy in their electricity systems, displacement of gasoline and diesel powered vehicles by EVs would yield almost a 100 per cent CO₂ savings. In countries that have a high reliance upon coal (e.g. China) a significant increase in EV penetration would to a significant degree call upon power generated by coal. Likewise, the efficiency of an EV is also significantly reduced if loss from upstream energy production is accounted for. Therefore, on a well-to-wheel basis, such a scenario could show more CO₂ emissions through increasing the number of EVs on the road. Therefore, improvements in the efficiency of gasoline-powered cars would make a significant contribution to reducing CO₂ emissions on two fronts: first, high EV sales will take decades to achieve and, by most aggressive EV uptake projections, ICE technology remains at 50 per cent of total vehicle sales in the next two to three decades; second, even with high EV sales, the sales of these vehicles may not necessarily occur in locations with the cleanest energy grid. Any technological advancements that can contribute to a significant improvement in ICE efficiency can lead to large CO₂ savings that will take EVs a few decades to match.

Going forward

While the total cost of EVs can be augmented using various financial tools at the disposal of regulators, the intrinsic properties of a battery pack will be more difficult to resolve. Unless the latter is resolved, the battery size and costs will pose severe limits to EVs. Furthermore, the lacklustre response toward EVs from many traditional OEMs are rooted in cost, profit margins and vehicle limitations of EVs. In fact, the shift away from ICE vehicles and the loss of a major core competency spells trouble for some automakers. Therefore, “buy-ins” from traditional automakers will force them to lower the cost of EVs and develop new business strategies to avoid further eroding their control and capabilities in the sector. Finally, to reach the level of EV sales set by regulators and create a profitable product, EVs will have to come in a variety of models and classes, with a similar range, and be price competitive with conventional vehicles while enticing the average consumer’s desire for the product. Incentives, subsidies and regulations will not sustain the market share alone. With all of these factors considered, it is prudent to acknowledge that the uptake of EVs will not capture all of the automotive market by 2040 even amongst the most aggressive projections. These uncertainties suggest that complete further investment in ICE research will only aid in reducing transport sector GHG emissions.

DRIVING FORWARD THE ELECTRIC REVOLUTION: CONSIDERATIONS FOR POLICY

George Beard

In the first two quarters of 2020, sales of new vehicles were dramatically impacted by the COVID-19 global pandemic. According to the Society of Motor Vehicle Manufacturers and Traders, sales of all vehicle types were 51 per cent lower in the period from January to May 2020 compared with the equivalent timeframe in 2019 (SMMT, 2020). During this extraordinary period, sales of electric vehicles actually increased, however; zero-emission battery electric vehicles (BEVs) grew 132 per cent, and plug-in hybrid electric vehicles (PHEVs) grew 13 per cent. Whilst this is encouraging, the public health and economic climate across the globe is unprecedented, and the long-term impacts on the automotive industry and consumer purchasing behaviours are not yet known.

Looking at sales figures for 2018 and 2019 allows us to examine longer term trends and remove anomalies caused by COVID-19. In 2019, overall sales of new vehicles fell by 2.4 per cent compared with 2018. This was largely accounted for by more than 160,000 fewer sales of diesel vehicles, a 21.8 per cent reduction compared with 2018 (SMMT, 2019). The story for electric vehicles (EVs) was mixed: sales of zero-emission battery electric vehicles (BEVs) grew 144 per cent, but sales of plug-in hybrid electric vehicles (PHEVs) fell by 17.8 per cent.

Sales of 'mild hybrid' diesel vehicles (a relatively new vehicle type), on the other hand, grew a staggering 740 per cent. Sales of mild hybrid petrol variants also grew by 170 per cent. Together, mild hybrid diesel and petrol vehicles represented 2.5 per cent of market share in 2019, up from just 0.6 per cent in 2018. In comparison, BEVs accounted for just 1.6 per cent of market share.

Mild hybrid power trains operate with an internal combustion engine and an electric motor. This enables fuel and emissions savings, as the engine can switch off when stationary or travelling at low speeds, and energy can be recuperated into the battery during coasting and braking. These benefits are similar to those of PHEVs, but crucially a mild hybrid electric vehicle (MHEV) cannot be driven with zero emissions at the tailpipe, and its battery cannot be recharged by plugging in. For the ordinary consumer, therefore, an MHEV provides the same fundamental owning and driving experience as a conventional internal combustion engine vehicle (ICEV); both are refuelled at filling stations, and there is no need to worry about running out of electric range or to figure out where to plug the vehicle into a charging point. In this sense, the rapid growth in MHEV sales in 2019 shows continued support for conventional vehicles which are principally powered by fossil fuels. Even more recent figures during the COVID-19 crisis suggest sales of MHEV continue to increase (SMMT, 2020).

In other words, whilst continued positive growth in EVs is being seen, it remains that most consumers are still choosing the conventional option. This article discusses the reasons for this and how policymakers can help to tip the balance and encourage mass-market adoption of EVs in the UK.

Barriers to change

To promote change, it is first necessary to understand the factors that influence consumers' car purchasing decisions. These include consumer attitudes, financial and vehicle-related factors, and infrastructure.

Consumer attitudes

Fundamental to the goal of increased EV adoption is an assumption that consumers are willing to replace their conventional vehicles with EVs. Consumers are not, however, purely rational agents who base their purchasing decisions solely on a vehicle's 'instrumental' attributes, such as cost, range, reliability, or recharging time (e.g. Graham-Rowe et al., 2012). Also relevant are consumers' perceptions of 'hedonic' attributes (the emotional experience of owning and using the vehicle) and 'symbolic' attributes (the extent to which the vehicle is congruous with one's sense of self-identity) (Skippon and Garwood, 2011; Graham-Rowe et al., 2012).

Positive perceptions of EVs' instrumental, hedonic, and symbolic attributes have been shown to be associated with a stronger intention to purchase (Schuitema et al., 2013). For example, people who perceive BEV drivers to have characteristics much like their own are more likely to consider owning a BEV (Skippon et al., 2016). In other cases, though, positive attitudes towards EVs have been shown to be poor predictors of stated intention to adopt (Beard et al., 2019). Positive attitudes may not be sufficient on their own to stimulate increased adoption, but their role should not be ignored (Schuitema et al., 2013; Skippon et al., 2016).

Financial factors

The high purchase price of EVs is a commonly cited barrier to adoption (e.g. Brook Lyndhurst, 2015; Kinnear et al., 2017). Among 200 mainstream consumers who took part in an EV trial, over 85 per cent rated purchase price as either very or extremely important when considering purchase of a PHEV or BEV (Beard et al., 2019). Generally speaking, EVs are more expensive than equivalent ICEV models, and this increased upfront cost is a barrier for consumers.

Reduced running costs compared with ICEVs, on the other hand, can be a motivator for adoption (Kinnear et al., 2017). A choice experiment found that mainstream consumers were willing to pay £4.70 for every £1 saved per year as a result of reduced costs of running an EV (Beard et al., 2019). This suggests that participants were willing to accept a higher initial upfront cost if the payback time associated with running cost savings was 4.7 years. In reality, though, whilst the total cost of ownership for EVs can be favourable compared to ICEVs, most consumers fail to accurately and reliably factor it in when making purchasing decisions (Biresselioglu et al., 2018).

Data on depreciation rates for EVs is more limited than for ICEVs due to their relatively recent introduction to the market. Some evidence shows EV depreciation rates can be substantial, and in some cases higher than equivalent ICEV models (Biresselioglu et al., 2018). Significant negative relationships between vehicle depreciation rate and intention to adopt EVs have been found (Beard et al., 2019). Here, doubling the perceived rate of depreciation from 40 per cent to 80 per cent of vehicle value lost over three years led to a reduction in the proportion of study participants reporting they would be likely or very likely to adopt in the next five years from about 70 per cent of the sample to about 5 per cent. This suggests that concerns about EV depreciation rates can affect adoption.

Vehicle-related factors

The electric range of EVs is a critical barrier for consumers. In Beard et al.'s (2019) trial of EVs, 98 per cent of participants reported that the electric range of BEVs was either very or extremely important when considering a future BEV purchase. The electric range of PHEVs was also considered very or extremely important by 83 per cent of participants. Perceived importance of range is negatively associated with likelihood to adopt a BEV, and the stated intention to adopt increased with increasing EV range (Beard et al., 2019). When considering a BEV as the main car for the household, 50 per cent of participants said they would have one with a range of 200 miles, whilst 90 per cent said they would choose a 300-mile BEV.

Recharging an EV takes considerably longer than refuelling an ICEV. Using a standard domestic 2.3 kW three-pin socket can give a charge time of 15 hours or more. Shorter charge times (typically about 45–60 minutes for an 80 per cent charge) are possible using a rapid (50 kW) charge point. Ultra-rapid (up to 350 kW) charge points also exist which can achieve shorter charge durations (e.g. Ionity, 2020), but availability is currently low, and few EV models are compatible.

The long charge times for EVs can be an important barrier to adoption. For example, in the EV trial by Beard et al. (2019), over 60 per cent of study participants were willing to consider a BEV as the main household car if the charge time required to deliver 100 miles of driving was around two hours. About 90 per cent of participants said they would consider one if the charge time was one hour.

Charging infrastructure

Actual and perceived availability of charging infrastructure also influences adoption. A recent review of the literature concluded that it is most important to have charging infrastructure at home, followed by the workplace, and then public locations (Hardman et al., 2018). In a recent choice experiment, participants were willing to pay £564 more for a BEV if there was access to charging at work, £1,677 more if there was access to public charging, and £1,808 more if there was access to charging both at work and in public places (Beard et al., 2019). This suggests that consumers place considerable value on the availability of public charging infrastructure when considering whether to purchase a BEV. However, for PHEVs, the study identified no statistically significant increase in willingness to pay with access to charging at work or in public, suggesting that availability of charging infrastructure may have less impact on PHEV adoption.

Designing holistic policy

The relative importance of these multiple and varied barriers to adoption will also vary across the consumer population. Data can be gathered to understand trends in consumers' most commonly reported barriers. For example, a public attitudes tracker administered to about 3,500 consumers by the UK Department for Transport (2019) identified the following top disadvantages of EVs perceived by consumers:

1. 'recharging – where/how to charge' (reported by 41 per cent of the sample)
2. 'battery: distance travelled on charge' (38 per cent)
3. 'not enough charging points' (32 per cent)
4. 'cost to buy' (22 per cent)
5. 'time taken to recharge' (11 per cent).

This suggests priority areas for policy to target. However, consumers are not a single homogenous market. One consumer segmentation model (Anable et al., 2011) used responses to attitudinal statements in a survey with 2,700 participants to classify individuals into one of eight consumer segments. Each segment represented a combination of self-reported likelihood to adopt a BEV or PHEV and different perceptions, anxieties, and importance attached to the symbolic, hedonic, and instrumental factors of car ownership and use. Five key factors were identified which most strongly distinguished the segments:

1. **identity** – the degree to which individuals feel their identities fit those of 'typical' EV owners;
2. **anxiety** – the perceived suitability of EVs, in particular the driving range and the difficulty associated with plugging in to charge;
3. **parking** – the perceived ease of parking and charging an EV at home;
4. **willingness to pay** a premium for an EV; and
5. **symbolic values** – individuals' perceptions of the status and social acceptability associated with owning an EV.

This information suggests that there are diverse barriers to EV adoption and that different consumers weigh these barriers differently. Thus, a holistic approach is likely to yield the most effective policy interventions. Broad interim policy objectives that take this diversity into account can best serve the ultimate goal of accelerated EV adoption. Three such objectives are proposed below.

Objective 1: Consumers have a good understanding of EVs, have positive attitudes towards them, and perceive them as a good fit with their self-identity.

Raising awareness and understanding of new technologies is key, particularly in the early stages of adoption when use and knowledge of the technology are not widespread. The 'diffusion of innovations' model (Rogers 2003) incorporates the concept of relative advantage, where for a new technology to be adopted, consumers must perceive that it is superior to the technology it will replace. For this to occur for EVs, consumers must have an accurate understanding of the vehicles themselves and of the charging technologies required to power them. Rogers (2003) explained that increased awareness of new technologies can be achieved through social diffusion, whereby the 'innovators' (who are first to adopt) act as sources of knowledge, awareness, and positive attitudes, and subsequently pass on these attributes to the 'early adopters', who in turn diffuse information to the 'early majority', and so on, until mass adoption by mainstream consumers is achieved.

Government and industry interventions which raise awareness and knowledge of EVs may facilitate or supplement the natural social diffusion process in order to accelerate adoption. Awareness and understanding are a prerequisite for adoption, so information should be clear and easy to access for consumers (Tietge et al., 2016). Policy measures known as 'reoccurring incentives' can be a good way of increasing consumer awareness of EVs, for example (Tietge et al., 2016). These provide various perks which consumers can benefit from during their day-to-day use of EVs, including access to bus or transit lanes, free parking, exemptions from an annual road tax, free access to toll roads, free charging from public charge points, or discounted access to alternative transport modes (e.g. public transport or hire cars). Whilst these principally benefit current EV drivers, communication of the benefits to the wider population will help to raise awareness of EVs in non-EV drivers.

Whilst positive attitudes towards EVs are not necessarily a precursor to EV adoption, the role of consumer attitudes should also not be ignored in the pursuit of mass-market adoption. Interventions which improve individuals' attitudes towards EVs are likely to help increase their social desirability and normalize them in society. Gaining experience with EVs can be an effective way of influencing attitudes. In a trial of both BEVs and PHEVs, attitudes became more positive after consumers had experience with both types of vehicles (Beard et al., 2019). The greatest positive shifts were seen in instrumental attitudes related to vehicle performance, including acceleration and driving smoothness. Increasing experience with EVs will also help to improve awareness and knowledge of how to use and charge EVs.

Reoccurring incentives may also help to make EV ownership a more attractive proposition for consumers. A range of reoccurring incentives are available in international EV markets including Norway, the USA, Canada, and the Netherlands (Hardman, 2017). Establishing precise impacts is difficult as these incentives are typically implemented in combination with financial incentives and other market factors (Kinnear et al., 2017). In a review of the literature, Hardman (2017) found evidence for a positive impact of bus lane access, parking incentives, toll road exemptions, and road or vehicle tax exemptions, but impact varied between studies and between markets. No one incentive emerged as having the greatest impact on EV adoption. This may be due to variations in consumers' preferences, local environments, and travel habits. For example, the effectiveness of providing EV drivers in the USA with access to high-occupancy-vehicle lanes depends on how close consumers live to such lanes and whether they can use them regularly in their daily journeys (Hardman, 2017; Liao, Molin and van Wee, 2017). Similarly, providing EV drivers with access to bus lanes may only be effective at incentivizing individuals who live in areas with high traffic congestion (Bjerkkan, Nørbech, and Nordtømme, 2016).

Objective 2: Consumers needs are met by the functionality of EVs and supporting charging infrastructure.

Clearly, vehicle functionality is a key factor in purchasing decisions. This includes attributes such as performance, reliability, size, and payload, but particularly important for EVs are the driving range, charging time, and availability of charging infrastructure. A clear policy objective here is to drive advancements in battery and vehicle technology to increase driving range and reduce charging time (whilst also reducing cost). Policy development must also recognize the importance of focused investment in charging infrastructure; for example, survey results from 20 countries suggested that installation of charging infrastructure on motorways is essential for increasing EV market share (Lieven, 2015). Managing perceptions of these issues is just as important as addressing the reality; that is, poor consumer perceptions about the availability of charging infrastructure, for example, can negatively impact likelihood to adopt an EV, even if the actual availability of charging infrastructure is adequate.

Objective 3: EVs are affordable for the majority of consumers.

Financial factors which influence likelihood to buy an EV include purchase price, running costs, and vehicle depreciation. Consumers are most likely to be influenced by purchase price because this cost is clear and understandable. Consumers tend to place greater weight on costs which affect them immediately, and less weight on costs which will affect them later, a bias sometimes referred to as 'temporal discounting'.

Key policy measures to address this barrier are financial purchase incentives, including grants administered at the point of sale, exemptions from VAT and other purchase taxes, and post-purchase rebates. An assessment of the EV market in the UK, Germany, France, the Netherlands, and Norway found that countries with higher financial incentives had higher EV market share (Tietge et al., 2016). Of 35 studies reviewed in a recent analysis (Hardman et al., 2017), 32 found a positive effect of purchase incentives on EV (and hybrid EV) adoption. Purchase incentives which provide upfront cost reductions, such as grants or exemptions from purchase taxes, are more effective than rebates, which delay receipt until after the purchase. It is also important that incentives are applied consistently and not removed prematurely, to promote a stable market for EVs and signal long-term governmental support (Tietge et al., 2016; Hardman et al., 2017).

Thus, research has provided good evidence for the effectiveness of financial incentives, although the scale of the reported impact varies widely, and it has not been possible to establish direct causal relationships (Kinnear et al., 2017). Comparisons of the EV markets in the UK, France, and the Netherlands also shows that financial purchase incentives on their own are not sufficient to drive adoption; historically, similar incentives have been offered yet growth in market share has differed considerably (Tietge et al., 2016).

Closing remarks

In its Road to Zero strategy (Department for Transport, 2018), the UK government set out its vision for almost every car and van to be zero emission by 2050, and to end the sale of conventional petrol and diesel cars and vans by 2040. At the time of writing, a consultation was underway to assess whether to bring the latter target date forward to 2035 or even earlier (Department for Transport and Office for Low Emission Vehicles, 2020). At the heart of these aims is the UK's commitment to bring all greenhouse gas emissions to net zero by 2050 (Department for Business, Energy & Industrial Strategy, 2019). Light-duty road vehicles account for about 70 per cent of all transport emissions (Department for Business, Energy and Industrial Strategy, 2020), so transitioning to EVs, particularly zero-emission BEVs, can help to achieve the major reductions in CO₂ emissions needed to meet the net-zero target.

This article presents a case for taking a holistic, evidence-based approach to policymaking which considers not only the overall goal of increasing adoption of EVs by consumers but also a set of complementary interim objectives. It proposes three broad objectives, but other objectives could also be effective. The key point is to establish a framework which can enable holistic interventions to be designed. It is not necessarily a requirement for all objectives to be met for any one policy measure to have an impact. However, introducing a range of policy measures which target different objectives is recommended to effectively drive adoption of EVs.

THE ROLE OF INCENTIVES IN REDUCING THE TOTAL COST OF OWNERSHIP OF ELECTRIC VEHICLES IN DELHI, INDIA

Mandar Patil and Akshima Ghate

In India's transition towards clean and sustainable transportation, increased use of electric vehicles (EVs) is a crucial element. One major barrier to achieving this goal is the vehicles' high initial cost. India's central and state governments have offered multiple fiscal and non-fiscal incentives to make the economics of owning an EV more attractive.

In Delhi, the focus of this analysis, electric car buyers are eligible for one or more of the following six incentives, depending on how the car is used:

- **Goods and services tax (GST) reduction** – the GST, based on the ex-factory price of the car, is 5 per cent for electric cars but 29–31 per cent for internal combustion engine (ICE) cars.
- **Exemption from road tax and registration charges** – this exemption applies to all battery-enabled cars.
- **FAME (Faster Adoption and Manufacturing of Electric Vehicles) II** – under this three-year incentive scheme implemented by India's central government, buyers of all commercially registered electric cars with an ex-factory price below INR 1.5 million (\$21,000) are eligible for a subsidy of INR 10,000 (\$142) per unit of battery capacity of the vehicle.
- **Delhi state incentive** – all electric cars registered in Delhi, irrespective of their use-case, receive a state government subsidy of INR 150,000 (\$2,131) upfront.
- **Income tax deduction** – the central government provides an income tax deduction of INR 150,000 (\$2,131) for up to three years on the interest paid on loans taken to purchase an EV.
- **Tax collected at source** – all the vehicles sold at an ex-showroom price of more than INR 1 million (\$14,200) are eligible for a rebate of 1 per cent of that price.

To assess the effectiveness of these incentives, we analysed their impact on the total cost of ownership (TCO) – defined by Ellram (1995) as the price of a purchased good or service plus all other costs related to owning and using it – of EVs and conventional vehicles in Delhi. The TCO of a vehicle can be interpreted as the expenses incurred by the user throughout the life of the vehicle.

The analysis was carried out on car models that are comparable in terms of market segment and performance features in four categories: electric, diesel, petrol, and Compressed Natural Gas (CNG). It considered a variety of use cases, defined by ownership (individual/firm), registration type (private/commercial), financing (self-financed/loan), and driver type (self-driven/paid driver). It estimated TCO for the different use cases and car types and examined whether electric cars (with and without incentives) are at cost parity with their ICE counterparts.

The following assumptions were made:

- **The life span of each car** was assumed to be 10 years or 300,000 km, whichever came first. Each car was assumed to have a salvage value at the end of its life; for the electric cars, the salvage value of the battery was assumed separately.
- **Vehicle fees and taxes** – such as road tax, registration fee, parking fees, and commercial vehicle permits – were assumed to be those in force in Delhi.
- **Car prices** were taken from a market survey of auto dealers and validated during interviews with stakeholders.

- **Daily distance driven** was assumed to be independent of the car's fuel technology. All cars in private individual use were assumed to be driven an average of 30 km per day throughout the life of the car. Cars in commercial use (taxis) were assumed to travel 160 km per day.
- **Charging time:** For electric cars, the driver/owner was assumed to charge the vehicle at any available opportunities throughout the day (i.e. "opportunity-based" charging).
- **Fuel efficiency** of all cars was assumed to be 75 per cent of the efficiency claimed in the vehicle specifications provided by the Original Equipment Manufacturers.
- **Maintenance and battery replacement cost:** Based on stakeholder interviews, the maintenance cost of the electric cars was assumed to be one-third that of the ICE counterparts. The battery replacement cost was not included in the maintenance cost of the electric car and was accounted as a separate cost. Replacement batteries in electric cars were assumed to be of the same technical specifications (like range and capacity) as the original. The cost of the battery was assumed to decline at a compound annual rate of 8 per cent.
- **Depreciation** was calculated using a straight-line depreciation methodology.
- **Fuel price:** The electricity tariff was assumed to be INR 7/kWh (\$0.10/kWh) (based on the Delhi average) and to decline at a compound annual rate of 3.5 per cent throughout the life of the car (based on the last two years' trends). The cost of diesel, petrol, and CNG was assumed to rise by a compound annual growth rate (CAGR) of 2.5 per cent throughout the life of the vehicle (based on the last three years' trends). The current average retail prices of diesel, petrol, and CNG were taken as INR 66/litre, INR 72/litre, and INR 47/kg, respectively.
- **Parking expenses** were assumed to be INR 50 (\$0.71) per slot per day and to increase at a rate of 10 per cent CAGR.
- **Loan interest rates** were assumed (based on interviews with dealerships) to be 15 per cent per year for electric cars and 10 per cent for ICE cars. Loans were assumed to be repaid in monthly instalments over three years.
- **Insurance premiums** were assumed to be paid in yearly instalments; amounts were taken from market surveys and expert interviews.
- **Place of purchase and operation** was assumed to be Delhi.

In assessing TCO, costs were broadly categorized as capital expenses (capex) or operational expenses (opex) as follows:

- **capex** – the cost of the car itself, any loan financing, and other upfront costs such as registration tax, road tax, and the cost of charging infrastructure.
- **opex** – the cost, throughout the life of the car, of fuel, parking, insurance, maintenance and repairs, battery replacement for electric cars, certifications and permits (e.g. pollution-control certification and taxi permits), tolls, and any costs associated with hiring a driver.

Expenditures were converted to cash flows, and Net Present Value analysis was conducted to calculate the TCO for each use case, assuming a discounting rate of 6.75 per cent, which at the time of writing was the rate on 10-year Indian government bonds and assumed to be an approximation of the "risk-free" rate in India.

The table below shows the results of the analysis for one use case: a car purchased for use as a taxi.

Total cost of ownership (INR/km) for privately owned, commercially registered, self-driven vehicle with loan financing

Cost	EV without incentive	EV with incentive		Diesel	Petrol	CNG
Fuel	0.97	0.97		2.89	3.44	2.45
Parking	0.31	0.31		0.31	0.31	0.31
Insurance	0.29	0.29		0.18	0.16	0.17
Maintenance/repair	0.48	0.48		1.44	1.44	1.44
Battery replacement	1.02	1.02		0.00	0.00	0.00
License and permits	0.54	0.54		0.54	0.54	0.54
Driver expenses	0.00	0.00		0.00	0.00	0.00
Total opex	3.62	3.62		5.36	5.89	4.93
Financing	7.63	4.20		3.56	2.92	3.51
Total capex	7.63	4.20		3.56	2.92	3.51
Total cost of ownership	11.25	7.82		8.92	8.81	8.44

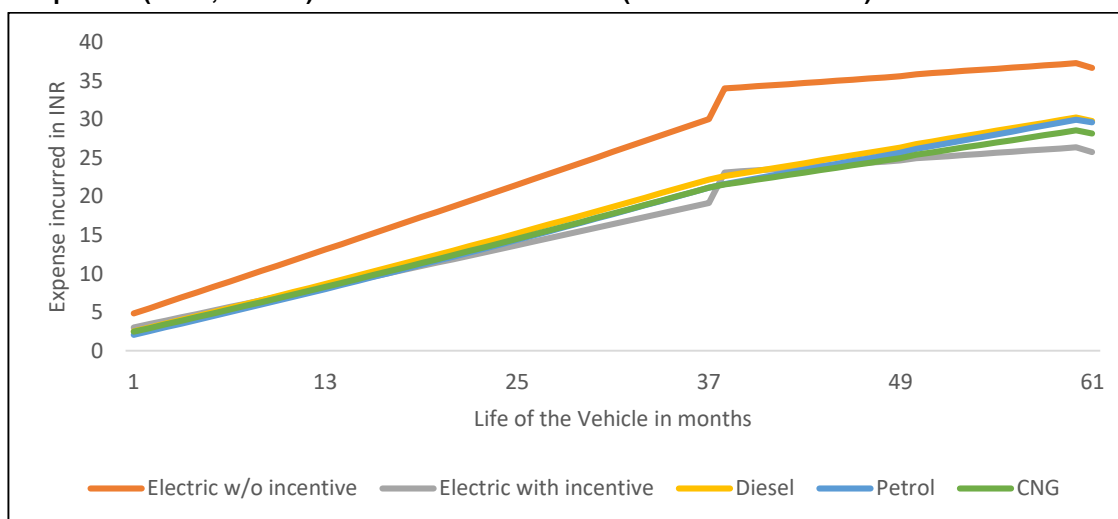
For this use case, the TCO of an electric car without government incentives was higher than that of its ICE car counterparts; but with the available incentives, its TCO was lower.

The capex cost of the electric car in this use case was much higher than that of the ICE cars, but the electric car had lower operational costs. The 'payback' period – the time it took for these lower operational expenses to bridge the capex gap – is another useful point of comparison. Without government incentives, payback could not be achieved even with a utilization of 160 km per day; but with government incentives, electric cars achieved cost parity with diesel, petrol, and CNG cars in 1.9, 2.8, and 2.6 years, respectively. Thus, incentives play a crucial role in bringing electric cars to cost parity with their ICE counterparts.

For electric cars in private use, the model indicated a minimum use of 75 km per day would be needed to achieve cost parity with ICE counterparts over 10 years of operation. ICE fuel prices fluctuate with the price of oil. Over the last six months, the price of fuels for ICE vehicles has dropped around 10 per cent from their peak prices. If this drop continues, the minimum travel per day needed to achieve cost parity for an individually owned and privately-operated electric car will rise from 75 km to 82 km.

This analysis highlights daily distance travelled as a critical parameter for TCO: with greater utilization, the benefits of lower operational expenses have an increased effect.

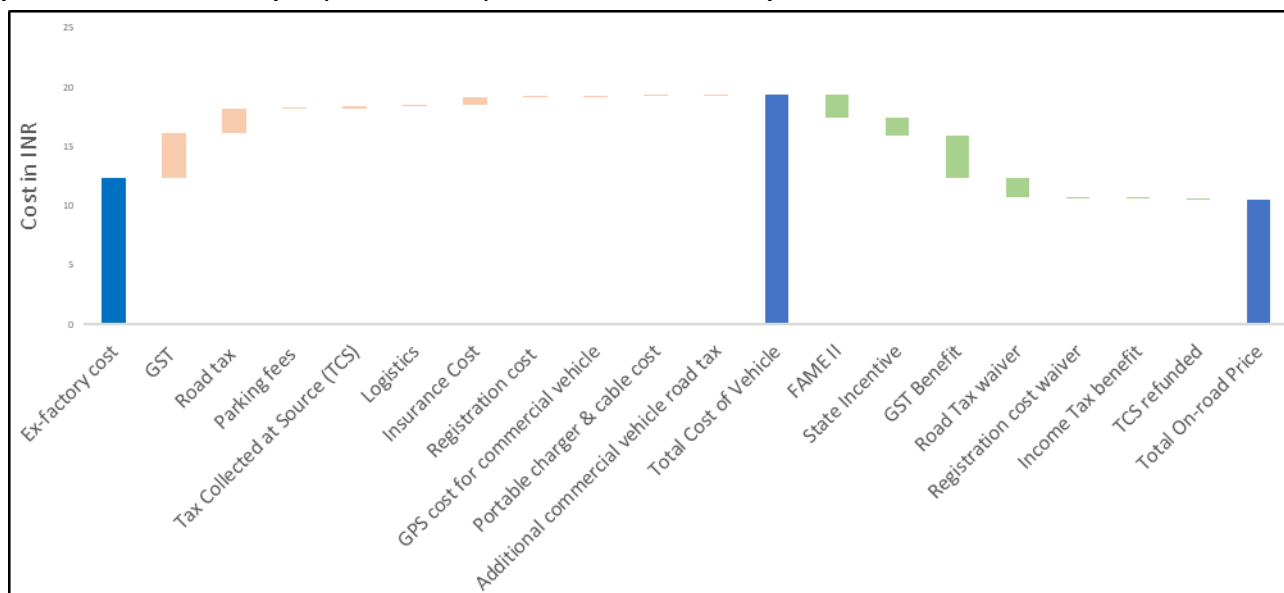
Cumulative expenses throughout the life of the vehicle are compared in the figure below for electric cars with and without incentives and for ICE cars.

Cumulative expenses (× 100,000 INR) over the life of the vehicle (measured in months)


Role of incentives in capex and TCO reduction

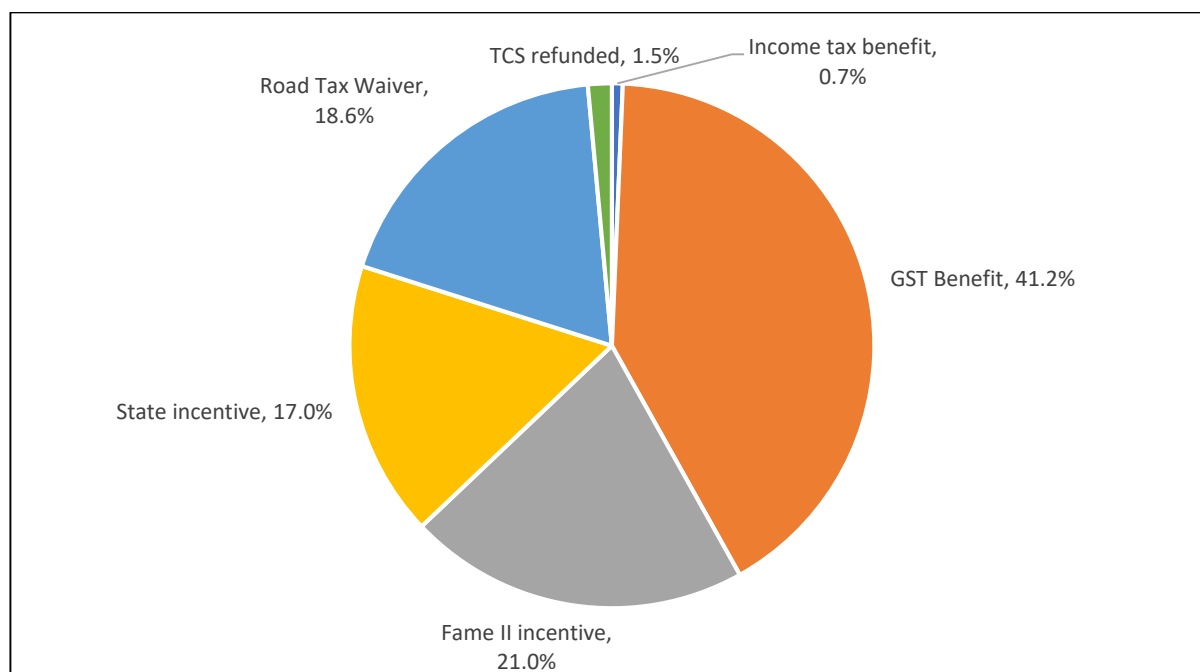
The cost structure of purchasing an electric car in Delhi based on current incentives is shown in the figure below.

Impact of incentives on capex (× 100,000 INR) of electric car ownership for commercial use, Delhi



For this use case, government incentives reduced capex for an electric car by almost 46 per cent, which reduced its TCO by around 27 per cent. The upfront (capex-reducing) incentives had a higher share in TCO reduction for electric cars than the opex-reducing incentives received over a vehicle's lifetime.

Distribution of Incentives



The importance of each available incentive on bringing about cost reductions is shown in the table below. Goods and Services Tax (GST) reduction contributes the highest impact, followed by waivers in road tax and registration charges, incentives under India's "Faster Adoption and Manufacturing of Electric Vehicles" (FAME) II scheme, and the state government incentive.

Impact of incentives on TCO for commercial EVs in Delhi

Incentive	Contribution to TCO reduction	Importance	Remarks
GST reduction	About 25 per cent of capex	Very high	Charged as a percentage of the vehicle's ex-factory price; 5% for EVs and 29–31% for ICE vehicles
Road tax and registration charges waiver	About 12 per cent of capex	High	Applies to all battery-enabled cars
FAME II incentive	INR 150,000-200,000 (\$2,131 - \$2,841) upfront	High	INR 10,000 (\$142) per unit of battery capacity; applies to all commercially registered electric cars with ex-factory price below INR 1.5 million (\$21,000)
State government incentive	INR 150,000 (\$2,131)	High	Applies to all electric cars registered in Delhi region
Income tax deduction	About 1 per cent of capex	Low	Up to INR 150,000 (\$2,131), for up to three years, for interest paid on loans taken to purchase an EV
Refund of Tax Collected at Source (TCS)	About 2 per cent of capex	Low	Applies to any car priced above INR 1 million (\$14,200) ex-factory

Conclusion

This analysis demonstrates that incentives can play a crucial role in reducing the TCO of electric cars and helping them achieve cost parity with ICE vehicles, and that in the electric car market, commercial cars are much more attractive given their higher daily utilization. For non-commercial users, who are ineligible for the FAME II subsidy and have much lower daily use rates, the TCO is still more favourable towards ICE cars than EVs. There is hence a case for considering an appropriate incentive framework for private cars that encourages their adoption.

The incentive structure plays an important role in driving adoption of electric cars in India. Prematurely withdrawn incentives will increase TCO for EVs and might lead to a drop in sales. This would mean that the incentives need to continue for a few years to come. It also highlights a need for policy to evolve in a way that ensures that EV sales become more self-sustaining. As EV sales pick up, economies of scale will drive prices down, which could eventually mean that subsidies are no longer needed.

As much as EV adoption depends on cost parity, it also depends on the mindset and behaviour of users. It is equally important to understand the operational differences between EVs and ICE vehicles, like operating hours, charging time, and the presence of charging infrastructure. TCO parity alone will not guarantee EV adoption. There are multiple other equally important factors on which EV sales depend, which will need to be addressed to drive adoption.

The authors would like to acknowledge and thank the following experts for their review and inputs: Vikash Mishra (Lithium Urban Technologies Pvt Ltd); Anup Bandivadekar (International Council on Clean Transportation), Clay Stranger (Rocky Mountain Institute), Shomik Mukherjee (Independent EV Expert).

PRIVATE E-MOBILITY VS E-FLEETS: FIXING THE PUBLIC CHARGING INFRASTRUCTURE PARADOX

Nicolò Daina

Ideally, private drivers of electric vehicles (EVs) would be able to park off-street at home and charge overnight. In this ideal scenario electric vehicles would free drivers from the need to visit a refuelling station except on infrequent long journeys. But this ideal vision hardly applies to residents of densely populated metropolitan areas in Europe, where a large share of private car drivers do not park their cars on private premises overnight. The 2018 National Travel Survey shows that about 25 per cent of car owners in England usually park on the street overnight, that figure rises to a third amongst residents of extended urban areas. (See [here](#)).

Therefore – as a recent policy guide by the International EV Policy Council argued – governments and local authorities should invest in on-street public charging infrastructure in residential areas and encourage employer-based charging via 'green



business programs and air quality programs' (Hardman, S., et al. 2020, *Exploring the Role of Cities in Electrifying Passenger Transportation*. Research Reports. UC Davis: Plug-In Hybrid & Electric Vehicle Research Center, available [here](#)). Provision of public charging infrastructure in residential areas is intended to encourage prospective car buyers to switch to EVs, as home or near-home overnight charging is preferred where possible.

A disproportionate focus on residential on-street charging infrastructure is, however, not unproblematic. First, in the years-long transition to greater penetration of EVs in urban car stocks, an over-dimensioned on-street public charging infrastructure with dedicated parking spaces in residential areas will waste space and reduce the parking space for conventional vehicle owners. This competition for parking space is already causing conflicts and inducing illegal parking. Second, an oversupply of charging infrastructure in the transition period would make public charging services economically unsustainable, meaning they would continue to require public investment. These two issues are aspects of the chicken-and-egg problem that arises when demand must be created for a product that, while providing significant benefits for society, generates marginal benefits for individual consumers.

A third issue associated with a disproportionate focus on slow residential on-street public charging is that it fails to capitalize on the potentially much more responsive demand segment of commercial and public services fleets. Fleet electrification makes economic sense on a total cost of ownership (TCO) basis. However, the lack of adequate charging infrastructure at corporate fleet depots is a primary concern for fleet managers. To significantly increase EVs in their fleets, organizations need, in most cases, to upgrade the electrical capacity at their sites, which translates into significant investments and time-consuming processes riddled with regulatory hurdles.

Government support for public charging infrastructure for fleets exists, but almost only in the form of rapid charging stations for taxis. Strategies for deploying public charging infrastructure should be revisited to account for multiple use cases, including use by a broad range of public and commercial fleets.

Fleet electrification

According to the International Energy Agency (IEA), EVs are still not competitive with their conventional counterparts based on the purchase price without incentives (IEA, 2019, *Global EV Outlook 2019*, International Energy Agency, Paris, available [here](#)). Purchase price is considered a major barrier for both private drivers and commercial fleets, but it gives only a partial view of this cost comparison – TCO offers a more comprehensive view, as it combines capital cost with operational costs.

IEA's analysis showed that TCO per km is lower for EVs than for conventional vehicles, but only for intensively utilized vehicles – that is, those belonging to commercial or public services fleets. Therefore, based on TCO, electrification makes economic sense for fleets. According to a 2018 joint study by United Parcel Service (UPS) and Greenbiz, fleet operators tend to agree with this view (UPS and GreenBiz Group, 2018, *Curve Ahead: The Future of Commercial Fleet Electrification*, available [here](#)). This study collected views from over 200 organizations, 46 per cent of which were large (that is, with revenues of \$1 billion or above). Of the large organizations interviewed, 64 per cent recognized that fleet electrification makes economic sense on a TCO basis. UPS itself expects that over a working life of 20 to 25 years, the lower operating costs of EVs will ensure lower TCO when compared to diesel trucks, as reported in the 2018 *Harvard Business Review* article 'Inside UPS's Electric Vehicle Strategy' (Winston, A., 2018, *Inside UPS's Electric Vehicle Strategy*. Harvard Business Review. Boston, Harvard Business Publishing).

Lower TCO by itself does not remove the high purchase price as a barrier to EV electrification. Ability to finance the initial capital expenditure is still required. For smaller organizations with limited access to capital markets, government incentives and financing mechanisms will still be needed to address the initial cost hurdle. Lower TCO can, however, open the way to smart financing by energy service companies, which can operate with similar business models as those they apply in energy-efficiency projects.

An additional factor weighing substantially in the economic case for fleet electrification is urban air quality regulation. The combination of air quality and traffic congestion regulatory levers being pulled by local authorities means that it will be increasingly costly for fleets to operate conventional vehicles in urban areas. In Central London, congestion charge and Ultra Low Emission Zone (ULEZ) levies add up to a hefty toll, surpassing £20 a day for light-duty vehicles not conforming to ULEZ standards. As the ULEZ is set to expand in October 2021, London businesses and public authorities operating large fleets view it as a significant driver of a speedy increase in the penetration of EVs in their vehicle holdings.



Aside from the economic case, organizations are motivated to consider fleet electrification as a means to achieve internal environmental-sustainability goals. A recent qualitative research study identified corporate social responsibility as a key driver irrespective of whether vehicle acquisition decisions are taken in a centralized fashion or by ‘users-choosers’ (Skippon, S. and J. Chappell, 2019, *Fleets’ motivations for plug-in vehicle adoption and usage: U.K. case studies*, Transportation Research Part D: Transport and Environment 71: 67-84).

In 2019, a survey of 500 UK-based fleet managers was commissioned as part of E-FLEX, a co-innovation project intended to demonstrate vehicle-to-grid technology for electric fleets (E-FLEX 2020, *Moving towards more sustainable fleet management with vehicle-to-grid systems*, London, available [here](#)). Of the surveyed fleet managers, 79 per cent agreed that meeting environmental and sustainability goals is amongst the key priorities they are tasked to ensure, which traditionally are topped by safety and vehicle costs. Furthermore, 65 per cent of the interviewees agreed that introducing electric vehicles could help their business as a whole meet sustainability targets. These findings broadly align with views from large organizations found in the 2018 UPS/Greenbiz study, which identified achieving sustainability goals as the most cited motivating factor for fleet electrification.

Electrification aligns with the strategic goals of organizations that operate fleets and makes economic sense for them on a TCO basis. However, significant barriers still exist. The most cited barriers include high purchase costs and inadequate infrastructure. As pointed out earlier, the initial price barrier can be overcome by combining government incentives with smart financing. But the inadequate charging infrastructure and electric capacity limits at depots may be much more difficult to address and as such requires more attention from policymakers.

Charging infrastructure policies seem to require rebalancing. Instead of devoting the largest efforts to slow on-street charging facilities for overnight residential charging, the deployment of public charging infrastructure should be more strategic and also address the potential needs of public and commercial fleets with limited capacity at depots.

Inadequate charging infrastructure in fleets’ depots

Amongst the large organizations interviewed for the 2018 UPS/Greenbiz study, 44 per cent cited inadequate charging infrastructure at their facilities as a barrier to electrification. Of fleet managers participating in the 2019 E-FLEX study, 30 per cent said that their businesses have ‘inadequate infrastructure to cope with the introduction of EVs’. This concern is not, in this author’s experience, a pretext to justify slow progress in fleet electrification. On the contrary, it is a significant practical barrier. The author is involved in a study intended to identify suitable charging infrastructure pathways to enable a London borough council to fully electrify in response to the 2021 extension of the ULEZ. The council fleet manager’s main concerns are the inadequacy of the depot’s electrical capacity and the procedural complexities and investment required to upgrade it.

To maximize the number of EVs that can be charged at a single depot, smart-charging management strategies can be put into effect. Indeed, smart charging can not only reduce the requirement for infrastructure upgrades but also help to further reduce the energy costs for fleet operations if the energy is supplied under time-of-day tariffs. Furthermore, smart charging, vehicle-to-grid, and behind-the-meter services can help to reduce the overall energy costs of depots and potentially generate additional revenues, as the E-FLEX co-innovation project was set up to demonstrate.

However, for large fleets, smart charging may not be sufficient, and infrastructure upgrades may be too costly to achieve full electrification. Public charging infrastructure may offer an option for off-site charging of fleets that have limited potential to develop adequate charging infrastructure at their own facilities.

A multi-user public charging strategy

The provision of public charging infrastructure for commercial and public service fleets should not be limited to the deployment of rapid charging stations, as has been the case for electric taxis or ride-hailing fleets. Indeed, public charging infrastructure should not be optimized for specific fleet types. Instead, a holistic approach should be adopted in which the locations, types, and number of public charging stations serve multiple EV use profiles. Such an approach would maximize the use of charging infrastructure by servicing fleets that are already motivated and have economic reasons to electrify, without excluding current and future private EV owners.

The effective costs and benefits of this next-generation public charging infrastructure strategy would need to be evaluated through desktop studies and demonstrations. Both the practice and the academic literature have largely focused on user-specific charging infrastructure strategies, so the evidence base for multi-user public charging still needs to be built.



Government-sponsored co-innovation projects involving businesses, public authorities, and transport researchers seem the appropriate mechanism to carry out such an evaluation and generate transferable blueprints that can be adopted for upscaling the strategy.

Could a holistic design of public charging networks and smart operations management be created to jointly meet the demand from diverse organizational fleets and residential users? Could this approach fuel a more rapid transition to EVs in a demand segment far more ready to electrify than private drivers? Could this alternative path be a faster route to economically sustainable public charging services, through increased utilization rates? These questions need to be addressed quickly, to devise accelerated pathways for urban transportation electrification.

EXPLORING THE ADOPTION POTENTIAL OF ELECTRIC VEHICLES AND VEHICLE-TO-GRID IN FLEETS

Toon Meelen and Brendan Doody

Introduction

Carbon dioxide (CO₂) emissions from transport have continued to increase despite reductions in other economic sectors. Road transport is responsible for 19 per cent of European CO₂ emissions (EEA, 2019a). The use of electric vehicles (EVs) can help to reduce CO₂ emissions. Vehicle-to-grid (V2G) is a system in which EV batteries return electricity to the grid as needed. This is potentially useful for stabilizing the grid and integrating renewable energy sources such as solar and wind. Revenues generated with V2G services could help accelerate the transition towards electric mobility.

Vehicle fleets operated by businesses, government agencies and other organisations are considered a useful context in which to potentially deploy V2G technology. Despite this, existing studies of V2G have not engaged in-depth with developments in the fleet market and research on EV adoption has focused primarily on private consumers and paid limited attention to fleets.

At least 50 per cent of new passenger vehicles in Europe are registered by companies, this equates to approximately 8 million vehicles per year (ACEA, 2019a; EEA, 2019b). Additionally, over 2 million new light goods vehicles (LGVs) were registered in 2019 in Europe (ACEA, 2019b). Although the exact size of the fleet market remains unknown due to definitional issues, it is clear it will be important in making the transport sector more sustainable.

The remainder of this article makes three points:

1. There are various reasons why fleets are a potentially useful application context for V2G.
2. An understanding of the heterogeneity of the fleet market is needed for successful upscaling of V2G in fleets.
3. An increase in the number of small and medium-sized enterprises (SMEs) in the fleet market could complicate a transition to EVs and V2G.

Synergies between vehicle-to-grid technologies and fleets

V2G can become an important part of the energy system by allowing for controllable 'bi-directional electrical energy flow between a vehicle and the electrical grid' (Briones et al., 2012, p. 5). In this two-way system, the battery of an EV is charged from the grid and, if required, the electricity stored in the battery is discharged back into the grid. The main benefits of V2G are (Briones et al., 2012):

- *Helping with 'peak shaving' and providing grid services such as 'frequency regulation'* – electricity companies now have special 'peaking plants' to help manage high electricity demand. Having these dedicated plants is costly and environmentally unsustainable. Assuming that other grid services such as inertia can also be accounted for, these plants could be replaced by V2G electricity from EV batteries when demand is high. 'Frequency regulation' refers to the ongoing fine-tuning of the frequency of the grid, to which V2G vehicles can contribute by withdrawing and providing energy.
- *Renewable energy storage* – the amount of energy produced from solar and wind varies and is relatively unpredictable. V2G can be used to store energy when production is high and feed it back to the grid when it is needed.

V2G could accordingly contribute to a transition to more sustainable and reliable sources of energy and enable cost savings for grid operators and energy suppliers. Fleet managers and drivers may also benefit financially from the use of their vehicles for V2G services. Financial benefits may take a number of forms, including reduced energy tariffs and payments for guaranteed storage capacity at specific locations or times and/or export of electricity into the grid. At present, there is uncertainty about the effect V2G might have on battery longevity. Multiple trial projects are ongoing around the world to estimate the effects of V2G use on battery degradation. Depending on the results, owners might also be compensated for possible resale value lost due to degradation. This is one example of the multiple technical, regulatory, and operational challenges that need to be overcome for V2G benefits to be realized.

Fleets are often seen as suitable for V2G services for a number of reasons. First, they have scale-related advantages: the purchase of multiple V2G chargers and vehicles could provide cost savings. A fleet with a substantial number of centrally managed V2G vehicles is also more likely to meet capacity requirements for providing electricity back to the grid.

Second, there are operational advantages. The controlled environment of a fleet makes it possible to closely monitor V2G implementation. Fleets also often use telematics software that could be used for combined planning of routes and V2G charging.

Third, and related, the space-time patterns of fleet use fit well with V2G. Fleet vehicles tend to be used on fixed and limited schedules. Moreover, they can be stored collectively at depots, facilitating infrastructure installation. The following case study illustrates the implementation of V2G in a delivery fleet.

Case study: Incorporating V2G into a delivery company's operations

Some organisations we interviewed as part of the V2GO (Vehicle-to-grid Oxford) project (TSU, 2018) were already starting to consider how they might implement V2G. One manager noted how he has multiple electric delivery vehicles on his fleet which arrive back at the depot between 4 and 6 p.m. with about half the battery capacity remaining. The vehicles are then charged using a smart charging system. An analysis carried out by the firm's smart charging supplier revealed that the vehicles were fully recharged by 10 p.m. Thus, the vehicles were charging during the evening, when demand for electricity is highest because most people return home from work. Given the timing of existing operations and the capacity remaining in the batteries, this organisation could potentially participate in V2G services. In this scenario, remaining battery capacity would flow into the grid during the evening peak, helping with peak shaving and reducing demand. The vehicles could then start recharging after midnight, when demand and energy prices are lowest, and still be fully charged and ready for operation again in the morning.

Variety in the fleet market and fleet management practices

As shown above, there certainly seems to be a fit between certain fleets and V2G applications. The variegated nature of the fleet market and the diversity of fleet management practices create challenges for upscaling of V2G beyond initial test fleets. Reliable data on the market is notoriously hard to obtain because of registration problems and the lack of a commonly accepted definition of what constitutes a fleet. While recognising these limitations, a broad segmentation of the UK fleet market can be delineated.

The first criterion on which to segment the UK fleet market is ownership structure. In an industry survey of 3,313 fleet managers in Europe, 45 per cent of UK respondents indicated that they bought their vehicles, 20 per cent had a financial lease, and 33 per cent had an operational lease (CSA, 2018).

Fleet size is another segmentation criterion. There are a few large fleets, such as those operated by the Royal Mail and British Gas, but as experts interviewed as part of V2GO stressed there is also a very 'long tail' with many SMEs operating only a handful of vehicles.

Considering vehicle type, a distinction can be made between passenger vehicles, LGVs (light goods vehicles) (<3.5 tonnes), and heavy goods vehicles (HGVs) (≥3.5 tonnes). Of commercial vehicles, 52.6 per cent are passenger vehicles, 34.7 per cent LGVs, and 9.6 per cent HGVs (DfT, 2018a, 2018b, 2018c).

We can also segment according to the industry in which the vehicle is used. Some data is available for LGVs (vans), in which the importance of the construction sector stands out (see Table 1).

Table 1. Estimated number and distribution of vans by sector, 2017

Rank	Sector	Total vans	% of van fleet
1	Construction (new work, repair and maintenance)	587,438	32.1
2	Transport and storage	281,370	15.4
3	Manufacturing	209,133	11.4
4	Wholesale, retail, repair of vehicles	207,023	11.3
5	Agriculture, forestry and fishing	94,906	5.2
6	Other service activities	86,392	4.7
7	Information and communication	62,779	3.4

Source: FTA, 2018, p. 21.

Ownership structure, fleet size, vehicle type, and industry are all likely to influence the use of EVs and V2G. For example, the number of electric passenger vehicles is currently growing rapidly from a low base, but growth is markedly slower for vans. Of new LGVs registered in the UK in December 2019, 97 per cent were diesel (SMMT, 2019a).

Further variety is found in fleet management practices – i.e. the different activities involved in operating a vehicle fleet. Over the course of a fleet cycle, typical fleet management activities are purchasing, financing/leasing, day-to-day operations (e.g. driver checks, driver support, fuel management, insurance, repair and maintenance), and remarketing and reselling of the vehicle. Many organisations now outsource some or all aspects of the operation and management of their fleet, largely due to issues of cost and legal compliance. The number of employees exclusively dedicated to managing vehicles has declined as these responsibilities have been reallocated to leasing and fleet management companies.

In many organisations, fleet vehicles are the second largest expense after payroll (Venson, 2018). The ‘fleet manager’, particularly in smaller companies, is often the director or someone from the financial or human resources department who has limited time allocated to the task of fleet management. This likely has implications for the implementation of EV and V2G in fleets, as discussed in the next section.

Small and medium enterprises in the fleet market

Traditionally, the fleet market has been dominated by SMEs, each with only a few vehicles. Their importance seems to be increasing further, which could pose a barrier for V2G implementation. The number of businesses in the UK has grown considerably, particularly due to a rise in the number of small businesses and self-employed people. Self-employment increased by 34 per cent between 2008 and 2017 (IPSE, 2017). This increase seems particularly pronounced in sectors with an important contribution to transport, such as construction and delivery.

In the delivery sector, firms have increasingly adopted a ‘gig-based’ approach in which drivers are self-employed contractors, many of whom use their own cars and vans. Large firms have also encouraged people to start their own small delivery businesses (Field, 2019). These sectoral changes have had an effect on fleet statistics. After the financial crisis of 2008, the number of privately registered vans overtook the number of vans registered by companies. The large majority of these privately registered vans are in use by self-employed people and SMEs (SMMT, 2019b).

Small businesses face particular barriers to the uptake of sustainability innovations such as EVs and V2G (Demeulenaere, 2019). They tend to have less financial capacity to take risks with new technologies and less ability to invest, for example in charging infrastructure. SMEs also lack the ability that larger firms have to trial EVs and V2G in vehicles with specific tasks, particularly those that require less mileage per day.

The absence of a dedicated fleet manager in smaller firms can also form a barrier to EV and V2G use. EVs and, in particular, V2G are perceived as complex, and it takes time and resources to assess the potential for implementation within an organization. Moreover, with the increasing number of self-employed drivers, fewer vehicles are stored in depots, as people take their vehicles home at night. Consequently, the cost and coordination advantages of large-scale V2G installations in depots could only be realized to a more limited extent.

At least three policy strategies can be employed to stimulate EV and V2G use in smaller fleets:

1. Dedicated intermediary organizations can facilitate knowledge sharing on innovations (an approach that has often been used in the past); SME-specific subsidies could also be provided.
2. Leasing companies, which increasingly take on fleet management roles and advise on long-term fleet strategies, can help to promote EV and V2G. Some UK leasing companies already seem to take a proactive approach facilitating EV use among their clients.
3. A fundamental rethink about what social, economic and environmental impacts the increasing fragmentation of various sectors might have should it continue unabated. For example, the delivery sector's increasing reliance on self-employed individuals and small firms operating at low margins – could suggest changes to the ways in which those sectors are regulated and organized. This could yield new opportunities for transition towards sustainable innovations such as EV and V2G.

Conclusion

Vehicle fleets are key for reducing CO₂ emissions in transport. V2G technology may become an important part of energy and mobility systems of the future. By potentially providing additional revenues, V2G may encourage fleet managers to start or increase the use of EVs within their organization. This could further facilitate the transition to EVs, which appears to be slowly gaining momentum in the fleet market.

Large depot-based fleets seem highly suitable for V2G. To encourage the uptake of V2G in other parts of the fleet market, it is important to take into account the variety in the market and in fleet management practices. Barriers to upscaling might arise due to the increasing number of SMEs in the market, since these organisations are likely to experience more difficulties in adopting and implementing these technologies. Strategies to stimulate EV and V2G in sectors with many small firms include knowledge sharing intermediaries, a facilitating role for lease companies, and a more fundamental rethink of the way the sector is organized and regulated.

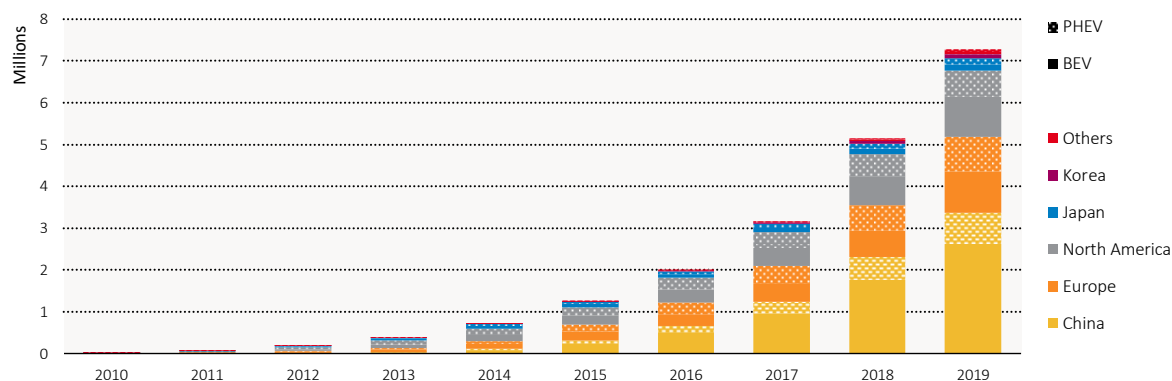
THE ELECTRIC CAR MARKET IN THE TIME OF CORONAVIRUS

Pierpaolo Cazzola

The number of electric vehicles (EVs) on the world's roads continued to grow in 2019. Early data for 2020 show that they will not be exempt from the impact of COVID-19 on the automotive market. But the persistence of fundamental drivers suggests that the longer-term outlook for the EV market is likely to remain positive – if clean mobility remains a policy priority and economic stimulus packages reflect the role of e-mobility as a driver of broader innovation.

Consumers have adopted electric cars at a rapidly accelerating pace since the mid-2010s. By the end of 2019, the global electric car fleet exceeded 7.2 million units, up more than 40 per cent from the previous year. Worldwide sales of EVs in 2019 totalled 2.1 million units, above the record 2018 total.

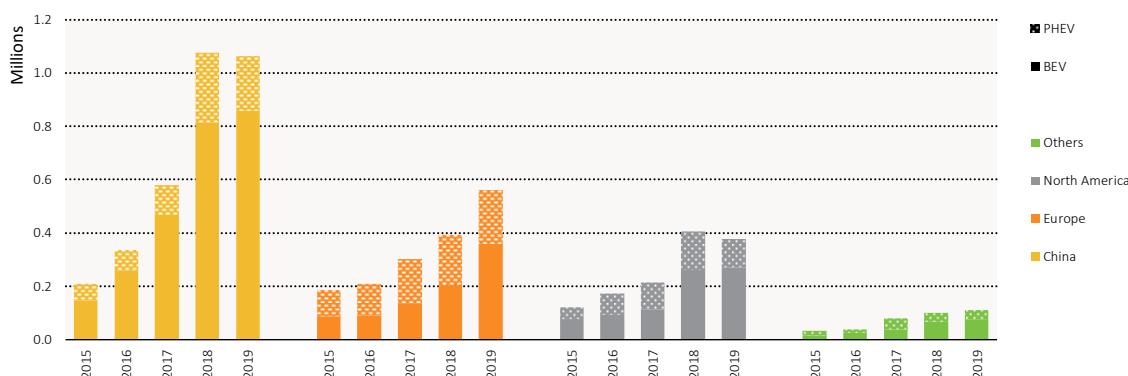
Global electric car stock, 2010–2019



Data sources: CAAM, 2020a; EAFO, 2020; DOE EERE, 2020; Pontes, 2020; EV-Volumes, 2020; MarkLines, 2020d; Kane, 2020; IEA, 2019.

Behind this growth lies a mixed performance in different markets, with electric car sales increasing in Europe but stagnating or declining in the other major markets. In China, the reduction of subsidies for EVs in late June 2019 led to a decline in annual EV sales. Japan and the United States also saw fewer EVs being sold. In all world regions, sales of battery electric vehicles (BEV) exceeded those of plug-in hybrids (PHEVs).

Global electric car sales, 2015–2019



Data sources: CAAM, 2020a; EAFO, 2020; DOE EERE, 2020; Pontes, 2020; EV-Volumes, 2020; MarkLines, 2020d; Kane, 2020; IEA, 2019.

Transport electrification encompasses a wide variety of vehicles. These range from small personal mobility devices used for urban trips – such as three-wheelers, mopeds, kick-scooters, and e-bikes – to electric cars, buses, and delivery vans. More than 300 million electric two-wheelers roamed the world's roads in 2019. The number of electric buses in service approached 600,000, with new deliveries in 2019 close to 100,000 units (IEA, 2019; Businesswire, 2020; EV-Volumes, 2020; more detailed analysis will be available in the International Energy Agency's forthcoming *Global EV Outlook 2020*).

Declining sales but rising market share

COVID-19 has led to a significant decline in car registrations across all major automotive markets. EVs are not exempt from this, but so far they have been hit less severely.

In China, sharply reduced car production and sales have been reported by the Chinese Association of Automobile Manufacturers for early 2020, with a decline for both of roughly 80 per cent in February compared to the same month of 2019, and close to 50 per cent in March (CAAM, 2020b, 2020c).

Similar drops were registered for Italy (a fall of 85 per cent year-on-year in March), France (more than 70 per cent) and Spain (almost 70 per cent). In the United Kingdom, the car market contracted by 44 per cent in March; it shrank by 38 per cent in both Germany and the United States (UNRAE, 2020; CCFA, 2020a, 2020b; ANFAC, 2020; VDA, 2020; SMMT, 2020; MarkLines, 2020a). In Japan and Korea, the market contraction was comparatively small, with a drop of 10 per cent for Japan and 15 per cent for Korea (passenger car sales) in March 2020 compared to the same month of 2019 (MarkLines, 2020b, 2020c).

Against this backdrop, the market share of EVs has continued to grow in the first months of 2020, at least in Europe. Sales of BEV in the United Kingdom almost tripled in March 2020 compared to one year earlier. They increased by almost 50 per cent in Italy and by almost 20 per cent in France. The EV market in Spain contracted by 44 per cent, but this was less than the overall car market contraction (SMMT, 2020; UNRAE, 2020; CCFA, 2020b; Lemaur, 2020; ANFAC, 2020). In the United States, Tesla was estimated to see a 3 per cent year-on-year sales increase (MarkLines, 2020a).

Plug-in hybrid vehicles also did comparatively well in the first months of 2020. In the United Kingdom, new PHEV registrations were up by 38 per cent year-on-year in March. In Italy PHEV registrations fell by 16 per cent and in Spain by 22 per cent, but in both cases this was less than the drop in the overall car market (SMMT, 2020; UNRAE, 2020; ANFAC, 2020).

In China, the market dynamics were closer to the overall car market, with sales of BEVs falling by 75 per cent and those of PHEVs 83 per cent in February 2020 (CAAM, 2020b, 2020c).

Challenging near-term impacts

The freeze on virtually all activities in the automotive industry, practical constraints on the access to car retailers, and deferred purchases due to COVID-19 are already leading to lower production and falling sales across the whole car market. A



contraction is also inevitable for EV sales in the short run, possibly even in terms of market shares. A number of factors could contribute to such a development:

- The implementation of regulations and policies aiming at transport decarbonization may be delayed. This was suggested by European car industry associations in a letter to the European Commission on 25 March, while a coalition of companies, cities, and civil society organizations opposed the move in a letter dated 16 April (ACEA et al., 2020; AVERE et al., 2020).
- There may be greater constraints on consumer borrowing, and this may hamper EV sales due to higher-than-average purchase prices. This effect may be limited for EVs because they tend to fall into the premium market segments where capital-constrained customers are fewer. For two-wheelers, it may be mitigated by the wide variety of models and purchase prices, especially in China. For buses, this may make it more difficult to justify loans on the basis of lifetime cost savings.
- The recent fall in oil prices following the worldwide introduction of mobility restrictions (aggravated by a supply shock) has lowered the total cost of driving vehicles using petroleum fuels, which makes EVs less attractive.
- Car manufacturers may decide to delay or reduce investments that they had lined up to diversify the offer of EV models and meet the preferences of a broader range of consumers.

Encouraging longer-term outlook

On the other hand, a number of factors suggest the longer-term outlook for the EV market can remain positive over the next decade and beyond:

- Opportunities for self-reinforcing cost reductions in EV production will persist. These result from the increasing scale of battery production as well as battery technology improvements and will make it easier for BEVs and PHEVs to compete with vehicles using internal combustion engines in terms of total cost of ownership (IEA, 2018, 2019).
- Governments around the world are expressing strong determination to protect citizens and businesses from the negative economic impacts of COVID-19, and to provide an economic stimulus to reverse the forced slowdown, and major financial institutions like the International Monetary Fund are calling for even more global action (Wemer, 2020).
- The interest in, and need for, policy action on priority objectives – such as mitigating climate change, improving local air quality, improving economic productivity, and fostering industrial development – will continue. This is demonstrated by growing political attention – especially among EU officials (see Piccard and Timmermans, 2020; Shultz, 2020), but also increasingly in the United States (see Baker et al., 2020) – for the orientation of stimulus packages towards a recovery that not only provides income and jobs, but also has broader goals, integrates strong climate and biodiversity action, and builds resilience. These priorities require support for innovation, including industrial progress in the EV and battery value chains (IEA, 2020a).
- Oil prices will progressively increase from their current levels as the global economy recovers from the COVID-19 shock, even if they could remain lower than before the pandemic, at least until the medium term (Tagliapietra, 2020).

Implications of COVID-19 for future e-mobility policy

Like other sectors of the economy, electric mobility requires rapid government interventions to handle the immediate economic impacts of COVID-19. A specific characteristic of e-mobility is that these interventions concern a variety of stakeholders. These range from large, established corporations such as car manufacturers, public utilities, and energy companies to small but often fast-growing companies without stable and substantial cash flows.

In the near term, sticking to policy requirements on clean mobility would help to reduce risks for investments in e-mobility that have already been made. Derogations or delays and modifications of policy targets would offer advantages for stakeholders that have not yet taken action. Should derogations or delays be allowed, they should include guarantees that the requirements will be met in due course.

Economic stimulus packages geared towards decarbonizing transport would benefit e-mobility and could help strengthen the pace of economic recovery over time. This is because e-mobility, like other energy-efficiency improvements, can improve economic productivity by reducing the cost of travel, starting with high-mileage vehicles (IEA, 2020b). E-mobility can also be a



driver of innovation, due to its importance as a stimulus for progress in battery technology, which has wider implications for the clean-energy transition and, more broadly, the growth-enhancing impacts of self-reinforcing innovations.

Increased public debt as a result of stimulus programmes will likely mean that in the mid to long term, policies will need to help recover government revenues, and not just fulfil policy goals like economic development and clean mobility. This may increase interest in taxing carbon-intensive fuels, implementing bonus/malus schemes that tax vehicles based on their environmental performance, and introducing distance-based charges for road use that are well suited to managing a decline of fuel tax revenues resulting from the decarbonization of transport (OECD, 2019; IEA, 2019).

Conclusions

Recent data on electric mobility developments show that EV numbers continued to rise in 2019, despite mixed performances across major markets. Early data from 2020 indicate that COVID-19 has hit the EV market much like it has the automotive market as a whole. Near-term developments induced by the pandemic and the subsequent lockdown suggest that a contraction is inevitable for EV sales in the short run, possibly even in terms of market share.

Despite this inevitable hit, which is likely to delay EV deployment in terms of its share of the global vehicle stock, the fundamental drivers of electric mobility remain in place. First among these is the self-reinforcing capacity of cost reductions in EV production resulting from scale increase in battery production and increased investments already made in battery technology development. Second is the centrality of EVs as a driver of positive spillovers for the clean energy transition and economy (which will require increased reliance on electricity storage), thanks to the improved economic productivity that accompanies energy efficiency.

Policy should therefore continue to support the transition to e-mobility. In the near term, it will be important to ensure that a range of different players, including large established companies and small innovative start-ups, continue to operate. Stimulus packages that are currently in preparation should then maintain, reinforce, or introduce measures that foster the e-mobility transition. In the longer term, the pressure on government revenues could mean that additional fiscal instruments will have to be adopted to raise revenues to finance the transition.

[This article is based on a policy brief for [The International Transport Forum](#).]

EV UPTAKE IN THE TRANSPORT FLEET – CONSUMER CHOICE, POLICY INCENTIVES AND CONSUMER-CENTRIC BUSINESS MODELS

Anupama Sen

The third Oxford Institute for Energy Studies workshop on the impact of disruptive change in the transport sector, held in October 2019, focused on electric vehicles (EVs). This article summarizes its key takeaways. The full version is available [here](#).

1. Lack of policy coordination between national and local governments could slow the EV transition.

National EV targets are set by national governments and guided by multilateral institutions and international agreements. Ultimately, however, local authorities are responsible for implementing the targets and interacting with the local residents and businesses who must adapt to change. The pace of the EV transition is set largely at the local level, so efficient coordination between national and local levels is imperative. However, local authorities face some barriers to coordination.

First, the needs and preferences of local residents and businesses often temper initial expectations on a policy's pace or extent. For example, the planned boundaries of low-emission zones sometimes need to be altered to take into account local business requirements.

Second, funding of EV initiatives requires better coordination. For instance, the UK's Road to Zero strategy provides grants for promoting EV uptake. Yet until recently, local authorities could draw directly on only one scheme, the On-Street Residential Charge Point scheme, which provided only 75 per cent of required funding. (Funding under the scheme has now increased.) Fiscal incentives also need coordination. For example, tax incentives for company-owned EVs in the UK were set to be reduced in 2020, although company fleets are a key driver of EV penetration.



A third barrier relates to EV charging infrastructure, on which there are varying views on the role of local authorities. One preference is for local authorities to partner with third parties (e.g. private companies) on this – for instance, a scheme is being trialled in the UK where local district council car parks are offered as overnight charging hubs for residents who do not have off-road parking. Scalability can be a challenge to public–private partnerships, as local authorities can best administer small or medium-scale projects and may prioritize areas with the most potential to catalyse change, while private developers may not find such areas attractive from a business perspective.

Fourth, national EV goals may conflict with local priorities such as reducing traffic congestion. For example, EV promotion could incentivize greater private vehicle uptake and undermine efforts to promote public transportation. Some local authorities have worked to align national and local priorities – for example, the UK's Workplace Charging Levy will utilise funds from parking charges levied on company parking spots in city locations to improve local public transportation.

Finally, local authorities are often a complex mix of city and district institutions with different yet related policy remits. But rapid EV uptake requires a coordinated approach which is also aligned with other aspects of local infrastructure planning and environmental management, as well as the behaviour of local residents and businesses.

2. Governments have favoured 'carrots' over 'sticks' when designing incentives to promote EV uptake – but their targeting has differed in advanced and emerging economies.

Governments worldwide have favoured incentives for consumer EV uptake rather than bans on internal-combustion-engine vehicles (ICEVs). But advanced and emerging economies have differed in three areas: their approach to incentives, the incentives' effectiveness, and their longer-term sustainability.

Approach

The types of incentives and the consumer base they target have varied in advanced and emerging economies. Governments in advanced economies such as the Nordic countries, the UK, and France have set dates for ending sales of new petrol and diesel vehicles, and have provided upfront incentives aimed at making EVs (or zero emission alternatives) the 'natural vehicle of choice' for private passenger vehicle owners. For example, in California, which is considered one of the more advanced EV markets, a US-wide \$7,500 tax credit for an EV is supplemented by a state 'clean vehicle rebate' of \$1,500 for a plug-in hybrid EV or \$2,500 for a battery EV, as well as non-fiscal incentives such as exclusive vehicle lane access for EV owners.

In contrast, India, an emerging economy, has targeted incentives at two- and three-wheeler vehicles, taxis, and buses – all of which provide 'last mile connectivity' – rather than at private passenger vehicles, as the focus is to promote shared EVs, and modes that have high shares in terms of passenger kilometres carried. Incentives are primarily aimed at bringing down the capital costs of EVs, through federal and state tax exemptions and upfront purchase incentives. Delhi has had the highest tax exemption for EVs, up to nearly 30 per cent on the ex-factory price – funded at least partly by Delhi's Air Ambience Fund, which is derived from a tax on diesel. These measures are supported by other non-fiscal incentives, such as special 'green' license plates, a waiving of commercial permit requirements (e.g. for electric taxis or other commercial transport) and road taxes, and tax deductions on loans for EVs.

Effectiveness

In advanced economies, incentives may have contributed to income-based inequities in EV ownership, as they do not target the low- and middle-income consumers who would most need the incentive to consider buying an EV. For instance, a survey of EV consumers in California concluded that high-income households which are a smaller proportion of consumers, accounted for a larger proportion of EV purchases relative to middle-income households. While high-income households could access all EV incentives, they did not consider the incentives essential to their purchase decision.

In contrast, in emerging economies, for example India, incentives are targeted to modes of transport which log the most passenger kilometres and in which new models can be quickly introduced with the requisite charging infrastructure – two- and three-wheeler vehicles and buses. There is also an upper cap on the price of EVs eligible for subsidies, to ensure that resources are not disproportionately allocated to wealthier private owners.

Sustainability

In terms of the sustainability of incentives, advanced and emerging economies face the same issue: EV sales tend to spike towards the end of the incentive period and then drop sharply, indicating that the market depends heavily on incentives. For example, California's Clean Vehicle Rebate has to be continually funded from the general budget, and gaps in funding have

diminished its longer-term effectiveness. Policymakers in many countries are considering exit strategies for EV subsidies, as incentives cannot be guaranteed in perpetuity given political constraints.

When planning the phaseout of incentives, it is important to ask what threshold would trigger long-term, self-sustaining growth in the EV market. In the absence of a clear answer (which may differ for different markets), one policy option being explored by researchers and academics, used in France and Sweden, is the ‘feebate’ – fees for high-emissions vehicles, which fund rebates for low-emission vehicles. As more EVs are sold, higher fees are imposed on ICEVs to meet the rising cost of rebates. These fees have to be continuously balanced with the rebates, and thus adjusted upward each year as more EVs are sold and higher fees need to be imposed on ICEVs.

In emerging markets like India, where feebates are difficult to implement, incentives are used to strengthen local supply chains. For instance, EV manufacturers have to use local content equivalent to around 50 per cent of the factory price to qualify for fiscal incentives. In China, there is a policy effort to shift the subsidies provided for EV purchases, towards infrastructure charging service providers.

3. Timelines for EV incentive schemes need to be consistent with the minimum timelines required for auto manufacturing supply chains to adapt.

Auto manufacturers (original equipment manufacturers or OEMs) are at the heart of the EV transition – they must meet increasingly strict standards for fuel efficiency and emissions while developing the technological powertrain necessary to meet governments’ EV targets, and also meeting the needs and expectations of consumers. As emissions targets have tended to be technology-neutral, OEMs have developed a range of EV technologies for different customers, expecting that the market will determine which models are continued. More affordable models (e.g. the Hyundai Kona) tend to be over-subscribed, leading to long waiting periods for delivery.

Given global climate change mitigation goals, regulatory standards have moved faster than consumers’ buying habits – so incentives are important in promoting EV uptake. OEM supply chains require at least three years to repurpose existing technologies and possibly longer to develop new technologies. But incentive timelines are sometimes inconsistent with this reality. In many countries, EV purchases spike near the end of an incentive scheme and then drop. There is a need for greater coordination between these two timelines, to allow the industry enough time to bring models onto the market.

Manufacturing supply chains for two- and three-wheelers (e.g. in India) appear to be the exception, with models reaching the market much more quickly after an incentive scheme is announced. However, the introduction of local-content criteria for incentives, alongside other regulations, could prove a barrier to increasing EV uptake. In India, where the auto industry has had to invest heavily to prepare to leapfrog from Euro 4 to Euro 6 efficiency standards, the addition of local content requirements has led to demands for greater long-term consistency on incentive policies.

4. Interoperability is a key objective of government policies to promote EV uptake, but could also slow innovation around new business models.

A key element of consumer-centric EV policy is making charging infrastructure widely and easily accessible. Many government EV policies envision interoperability between EV charging networks – such that drivers would have unconstrained access to charging in different areas. However, some emerging industry players are developing business models around innovations that are specific to their companies. While governments may aim for standardization, private initiatives may at least initially require specialization.

For instance, in many jurisdictions, charge-points and smart-charging operators use proprietary equipment, such as technology that enables EVs to deliver electricity to the grid. Services can be provided by these EV ‘aggregators’ locally (on-site, to fleet owners/operators), or at the network level if there is congestion, or at the transmission system level to help balance the grid. EV aggregators also partner with retail electricity suppliers (e.g. in the UK, California, and France) to allow EV owners to take advantage of cheaper charging tariffs from these suppliers at specific times of the day or night.

Another version of this model is for aggregators to facilitate the participation of EVs in the frequency regulation market, payment for which would help lower the cost of ownership. In a sense, these models reduce the need for large, grid-scale storage, and potentially minimize the need for grid reinforcements by making better use of local resources.

These business models appear likely to continue to evolve as the markets and regulations affecting EVs and their integration into the electricity system also change. For instance, there is an ongoing debate over which agent in the system would have primacy over a customer's usage patterns – the charge point service operator (e.g. directing the consumer to the least-cost option), or the distribution network operator that manages grid interaction.

The implications of the latter for charging service providers are that their equipment may need to be designed more uniformly and specifically for the jurisdiction in question (e.g. the UK), potentially constraining innovation and consumer choice. In India, for instance, distribution utilities have indicated that they would want specific chargers and communication protocols to be followed.

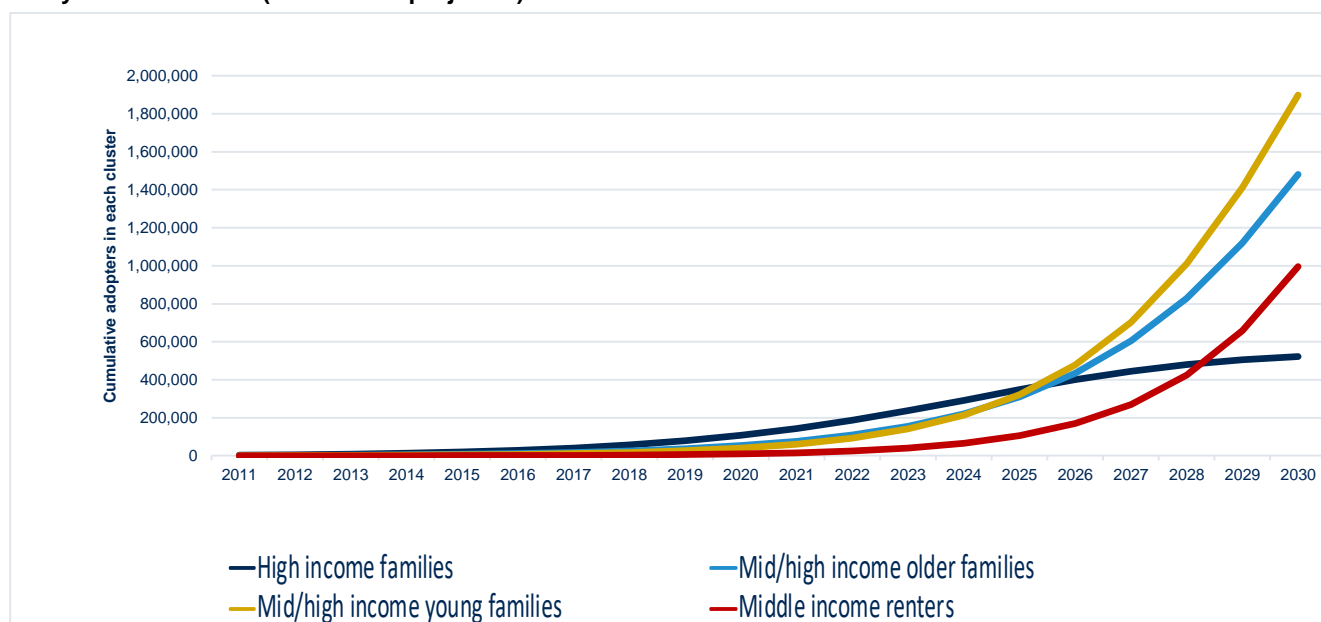
There are also debates over the ownership of the data generated from customers' EV usage. Given that the market for EVs has arguably yet to reach maturity in many jurisdictions, business models based on a single value-generating proposition could end up cannibalizing themselves. Therefore, companies are also looking at 'circular value propositions' which identify a wider range of revenue streams within an EV business model.

5. The design of EV uptake policies needs to take consumer choice into account, while also promoting consumer education.

The frequency with which EV sales appear to drop sharply when incentives are withdrawn indicates that economic incentives alone may be insufficient to promote EV uptake at the desired pace. Consumer preferences are a key element in EV uptake. Survey research from four northern European countries has found that while transportation accounts for the largest proportion of households' carbon footprints, people were least likely to volunteer to decarbonize transportation as this involved significant lifestyle disruptions (Dubois et al., 2019).

Consumer preferences also change over time. The early adopters of EVs were likely to be enthusiastic consumers with higher disposable incomes and more than one private vehicle, whereas governments now often aim to persuade more middle/low-income consumers to opt for EVs (sometimes as their sole vehicle purchase) in order to achieve the scale of uptake needed to meet policy targets. Low- and middle-income consumers also depend more on incentives. While the planned phaseout of subsidies (e.g. the federal tax credit in the US) may not have much of an impact on sales of high-end EVs, it will affect low-end, affordable models.

EV buyers in California (current and projected)



Source: Lee et al. (2019).

The 'consumer-centric' strategies that most OEMs have appeared to follow offer EV drivers a familiar experience, as close as possible to driving an ICEV. In other words, 'balance policy aspirations and visions with something that most people can use so that you get scale.' There is some debate over whether this approach, if carried too far, might impede the achievement of EV



targets, as it prompts false comparisons. Comparisons with ICEVs over specific metrics such as range risk missing the point and expose a lack of knowledge of EV technologies and usability. Consumers tend to ‘buy much more than they need’ – for example, wanting an EV with a longer range even though their daily commute is quite short. The longer range requires a larger battery, which adds to the cost of an EV, which could act as a disincentive to purchase.

Range expectations can be managed in other ways – for instance, through policies supporting better consumer education. China’s New Electric Vehicle policy reportedly has a consumer education component. Dealerships also need to be trained to provide accurate information to consumers, particularly to assuage any concerns around ‘a new technology with a potentially unknown residual value’. In China, new EV manufacturers (such as Nio) have focused heavily on marketing and after-sales services – offering buyers a lifestyle experience based on an upmarket club membership which includes managing the charging of the car through a network of battery-swapping stations with quick turnaround times. Arguably, such models have yet to achieve full profitability.

As climate change mitigation deadlines grow nearer, will governments enact policies which override consumer choice? Past attempts to use policy to push consumers into making environmentally desirable choices have provoked public opposition – not least because the larger objectives may not have been communicated clearly.

Another way to improve the alignment between EV policy targets and consumer preferences may be to ‘bind consumer decisions within certain scripted technology’, which effectively moves consumers towards making more environmentally sustainable decisions about car purchases. For example, care could be taken to prevent rebound effects (such as EV buyers over-consuming other high-carbon products or services). In other words, policies could be designed to provide constrained choices within the boundaries of sustainability.

6. Fleet-based business models provide an opportunity to rapidly scale up EVs in an economy.

In the UK, data from auto trading websites tends to show that the demand for second-hand EVs significantly exceeds the number of units available for sale. The sale of EVs to high-income consumers is one way to make them available to the wider population, by catalysing the development of infrastructure and markets and eventually making second-hand EVs available.

An alternative, potentially faster route to increasing EV uptake is through commercial vehicle fleets, which can take advantage of economies of scale. These EVs, too, will eventually be replaced and released into the second-hand EV market.

Fleet EV purchases may be made for other than economic reasons, for instance as part of a corporate social responsibility program. Commercial EV purchases are likely to be made by fleet managers or their equivalents, and are therefore likely to be more economically rational than purchases by private individuals.

The economics of fleets and their contribution to rapid EV uptake vary across different markets. For example, roughly 50 per cent of all cars sold in the UK are fleet vehicles, so this market has a higher potential to impact the EV market. In India, a self-sustaining business case for a commercial taxi in a fleet may require its use to exceed 100 km a day.

A fleet can be defined as all vehicles employed within a business, irrespective of ownership structure. Fleets vary substantially depending on the size of the business. Smaller firms are unlikely to have dedicated fleet managers or to actively engage in EV purchases; mid-sized firms tend to carry out total-cost-of-ownership analysis to assess the economic viability of EVs in their fleets; and large firms (e.g. logistics providers) tend to think more strategically about EV acquisition, engage in longer-term scenario modelling, and participate actively in EV trials, especially as they may be affected by low-emission zones in the cities where they operate. Larger firms also tend to renew their fleets in much shorter time periods (around three to five years) than smaller firms, and ideally, the alignment of EV incentives and targets for uptake with these turnover periods would boost the market for second-hand (and more affordable) electric vehicles.

EV uptake by smaller firms could also be boosted by intermediaries – for example, companies leasing EVs to smaller firms instead of the latter making direct purchases.

Fleet-based approaches could thus help increase EV uptake, but they also face barriers. One barrier is the difficulty of incentivizing EV uptake in ‘grey fleets’ – employees’ private cars used to conduct business activities (especially in smaller firms).

A second barrier is the presence of requirements for some incentives that put them out of the reach of smaller businesses. For example, some grants require a business to buy an EV with a battery pack good for 100 miles, which makes the upfront cost prohibitively expensive regardless of the grant size, and is arguably unnecessary, particularly for fleets providing last-mile



deliveries where journeys average tens rather than hundreds of miles. A significant barrier to scaling up EVs in the second-hand market is the effect of battery degradation on the residual value of second-hand EVs. With advancements in battery technology, this is becoming less of a problem, but it may still be a concern for potential buyers of second-hand EVs, and the industry needs to do more to provide clear information about battery life to consumers.

7. EV uptake policies in advanced economies need to adopt ‘whole systems’ or ‘circular’ approaches to mitigate externalities beyond the boundaries of their own societies.

An emerging issue in relation to the EV transition is the pressing need to incorporate equity and social justice within it, as societies among the advanced economies continue to decarbonise. Research has shown that a singular focus on the decarbonisation of transportation within a society via promoting EV uptake can sometimes create negative externalities. One example of this is evident in the effect of incentives on EV uptake among high versus low income consumers and arguably the creation of an ‘elitism’ in transport, privileging one form of transport over others. Rebound effects from ‘consumer-centric’ business models are another example of an externality – when consumers purchase an EV, they may offset the reduction that it brings about in their carbon footprints through increasing other types of carbon consumption. Research on household attitudes and behaviour towards decarbonization in selected European countries shows that people were least likely to tolerate more aggressive reductions – the more revolutionary or meaningful the action (i.e. giving up a car), the less likely a household was to prefer it (Sovacool et al., 2019).

Externalities can also occur beyond the boundaries of a decarbonizing society in advanced economies – for instance, recent research on ‘whole energy systems justice’ has shown that Western Europe is decarbonizing precisely because a lot of the social and environmental costs can be pushed onto other, largely lesser-developed, countries (Sovacool et al., 2019). The social justice aspect of the EV transition relates therefore not just to the EV *per se*, but to all stages across the life-cycle of its production and use, from the extraction of minerals and procurement of materials for battery production, to waste disposal and recycling.¹ Given the disconnect between policies to enable a rapid transition to EVs and the pace of change and adaptation in consumer behaviour, research suggests that building *multiscalar policy mixes* in a number of areas (i.e. not just transport, but also energy, food, buildings, and appliances, among other things) may be necessary – in other words, sustained and coordinated policy mixes rather than just single policies.

¹ An oft-cited example of this angle of the debate is the adverse consequences of rapidly rising demand for lithium and cobalt in on the working conditions of mining workers of the Democratic Republic of Congo – although this is also likely to be exacerbated by poor governance and economic institutions within the country.



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