ELECTRIC VEHICLE TRANSITION

EVs Shifting from Regulatory- to Supply Chain-Driven Disruption

Citi GPS: Global Perspectives & Solutions

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ELECTRIC VEHICLE TRANSITION

EVs Shifting from Regulatory- to Supply Chain-Driven Disruption

Kathleen Boyle, CFA
Managing Editor, Citi GPS

We've been writing in Citi GPS about the potential for electric vehicles (EVs) since 2014, when we featured the topic in our Disruptive Innovations II report. Back then we predicted we'd see an early-mover leader emerge in four to six years. In reality, the transition to EVs has taken longer than anticipated. There continues to be a niche group of consumers who are die-hard believers in the need to switch to electric vehicles, and they typically make up the bulk of electric vehicle sales. But the general population continues to have reservations about whether electric vehicles have improved enough in range, charging time, and price to give them a second look. Governments have tried to sweeten the offer by providing price subsidies to lower the cost of electric vehicles but even those are not enough for an average driver in places like the U.S. or Europe to view electric vehicles as replacements for their gasoline engine vehicles.

But winds of change are starting to form out of Europe. We see a threat on the horizon for auto manufacturers as the real electric vehicle (EV) arms race has now begun in Europe. In order for automotive original equipment manufacturers (OEMs) to meet European Union CO_2 targets in 2021, plug-in hybrid electric vehicles (PHEV) and battery electric vehicle (BEV) volumes will need to double. Plans by a top EV player to boost European capacity by about 150,000 in 2021 and 500,000 units in 2022 — equal to about 30% of European market share — will make it significantly harder for incumbent automotive OEMs to meet these CO_2 targets. This means automotive OEMs must begin to factor in either widespread fines or competitive pricing pressure particularly in the premium segment of the EV market.

For an EV manufacturer to make such a bold move into the European market is either foolhardy, or suggests it believes it has a product (i.e., battery technology) that will allow it to appeal to a broader section of the automotive market. With other disruptive players suggesting battery technology can develop significantly faster than anticipated by incumbent automotive OEMs, there is a clear risk that we are seeing a technological march on peers. In any case, with disruptive forces fully funded from a technological standpoint, the stage is set for a technological clash in the next 18 months.

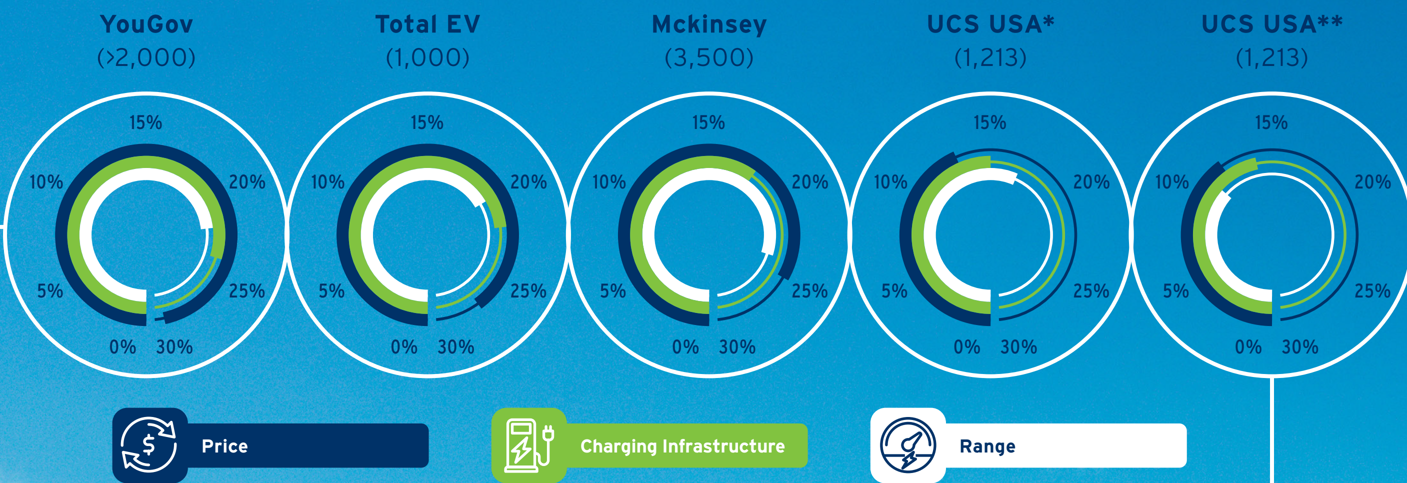
We see three main areas where automotive OEMs could be disintermediated by disruptive players in the EV market. First, a leap forward in technology could make EVs technologically and cost competitive sooner than expected — giving demand for EV uptake a regulatory push versus a consumer pull approach. Second, easy availability of credit could result in vertical integration by disruptive players as new entrants are able to gain a competitive advantage by building their own battery supply. Finally, with the prospects of EV products surpassing internal combustion engine (ICE) vehicles from a performance and consumer cost perspective, regulators will likely come under pressure to support a faster transition to lower emission technology.

Nearing a Tipping Point Driven by Supply Chain

ELECTRIC VEHICLES STILL FACE BARRIERS, BUT THEY'RE LOWER

In 2018, we noted electric vehicle adoption was being curtailed by consumer views on price, range, and charging availability. In 2020, surveys show those barriers still exist, but the gaps are closing.

Source: Citi Research, YouGov. Total EV, USC USA, McKinsey



EV RANGE HAS INCREASED STEADILY WITH EACH NEW MODEL RELEASE

While performance of EVs still lags that of conventional internal combustion engine (ICE) vehicles…

…the gap is closing quickly as new releases have significantly higher ranges.

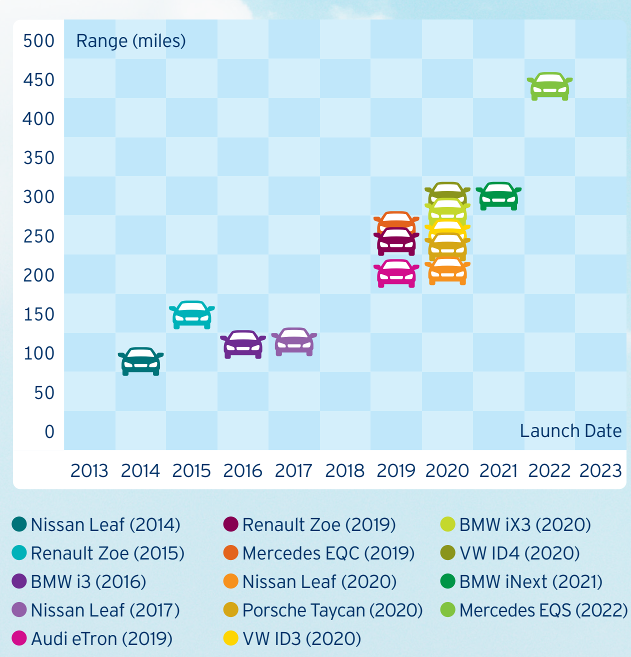
Audi ICE vs EV mileage comparison (kms)

Audi e-Tron	10891
Audi Q3	14799
Audi Q5	17684

Mercedes ICE vs EV mileage comparison (kms)

Mercedes EQC	10717
Mercedes GLC	19222

Source: Citi Research

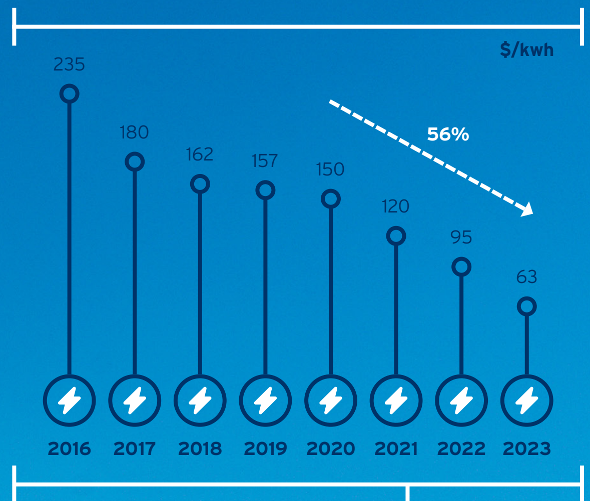


Source: Citi Research, Clear Technical, Autocar, Greencar reports, Inside Evs, elektrek

BATTERY TECHNOLOGY IS MOVING QUICKLY TO LOWER THE PRICE DIFFERENTIAL BETWEEN EVs AND ICE VEHICLES

Although battery technology makes up the majority of the cost difference between EVs and ICE vehicles, industry hopes are building for a < $100/kWh cell becoming available by 2023, which will give EVs a cost advantage and similar performance as ICE vehicles.

Components	ICE	BEV
Body	2500	2500
Wheels and tires	400	400
Braking system	400	400
Suspension	1000	1000
Axles	800	800
Steering	350	350
Interior	1500	1500
Electronics – Traditional	2000	2000
Engine	2500	-
Transmission	1500	-
Fuel System	400	-
Exhaust System	320	-
Thermal Management	499	1500
Electric Motor and Transmission	-	1400
Additional Battery	-	6550
Electronics – Additional EV	-	1500
Power electronics	-	1000



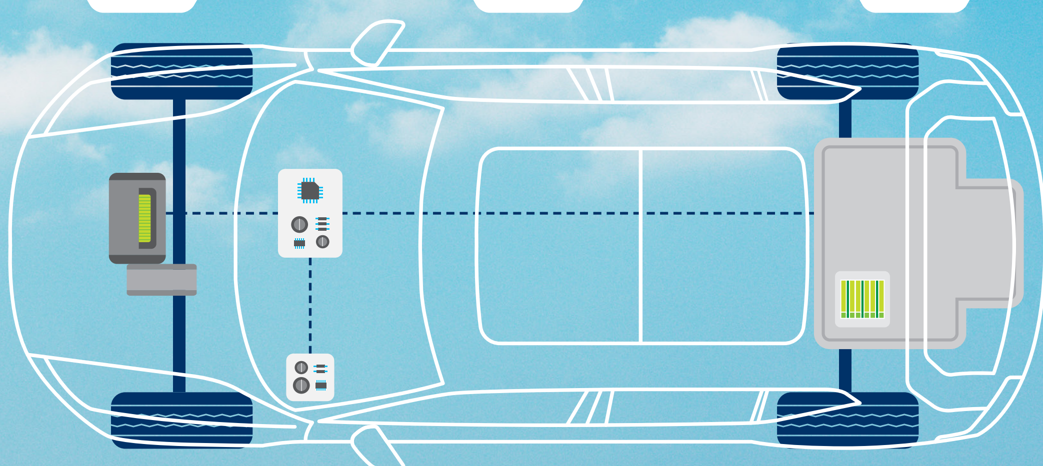
ADVANCES IN BATTERY TECHNOLOGY WILL DRIVE DISRUPTION TO AUTO ORIGINAL EQUIPMENT MANUFACTURERS (OEMs) STARTING IN 2021

The disruptive potential of EVs will become more obvious in 2021 and 2022 as technology improvements in the EV supply chain ultimately result in EVs being superior products to ICE vehicles. We see three potential scenarios:

Disruption
Disruptive EV players are likely to emerge and compete with OEMs as battery technology is improving rapidly.

Vertical Integration
OEMs could disrupt and vertically integrate into the battery supply chain, ultimately accelerating EV transition.

A Developing EV Arms Race
Competition with disruptive new players lower returns but failing to compete will likely jeopardize the long-term business outlook.



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Auto OEMs Hostages to the EV Transition

In Europe, compliance with emission regulations in 2020 has led to significant growth in electric vehicle sales and while this has been painful for profitability in the auto industry, it hasn't been fundamentally disruptive. So far the electric vehicle product on offer fails to emulate the technology of its internal combustion engine (ICE) predecessor and is being offered only to meet minimum regulatory requirements. Compliance with regulatory requirements on carbon emissions ensures auto manufactures can continue their practice of selling high-margin and high-emission sport utility vehicle (SUV) products.

Looking to 2021 and 2022 we believe the disruptive potential of EVs will become more obvious as technological improvements in the EV supply chain ultimately result in these vehicles gaining superiority over ICE vehicles. Not only will this likely result in increased consumer demand for EVs, but it will raise difficult questions for regulatory bodies who will not only be looking to lower emissions but also offer consumers cheaper transportation solutions.

From an auto original equipment manufacturer (OEM) perspective, this transition is unlikely to be good news. The return on capital generated by EV sales today is poor, even by automotive OEM standards. As technology continues evolving, we expect an arms race to develop as disruptive players commit more investment to low margin products with uncertain lifecycles.

EVs: Disruption Begins in 2021

From a consumer perspective, EVs continue to be more expensive and less effective than their existing ICE equivalents — refueling an EV takes 3-10x longer than refueling an ICE vehicle; the range in real driving conditions is roughly half the range of ICE vehicles; and the upfront cost without manufacturer or government subsidies is 10-30% higher.

What is the real issue? Battery technology is not sufficiently developed. To date, this has meant the addressable market for EVs has been confined to early adopters and for use as a secondary or short-range vehicle for consumers. At the same time, incumbent auto OEMs are reluctant to sell more EVs than what the regulators require, which in turn has seen the EV supply chain somewhat reluctant to invest in capacity and technology to improve the product.

In short, with chemicals companies and battery cell suppliers responsible for product innovation, not the auto OEMs, we believe there is significant risk the EV value chain is upended by either a step change in technology or vertical integration by a disruptive player.

How would this play out?

1. **Technological change is accelerating:** Battery technology is improving rapidly and if disruptive players can deliver their current plans it seems likely there will be a battery electric vehicle (BEV) product that is superior to ICE vehicles (in terms of cost and range) on the market before 2025. This poses a fundamental threat to incumbent auto OEMs who are working on an EV timeline that is beyond 2025.

2. **Vertical integration is also on the cards:** With capital availability dictating the speed of transition, we see vertical integration by auto OEMs into the battery supply chain as potentially disruptive. While likely lowering short-term returns, this may provide a technological edge and drive market share as well as accelerate the EV transition.

3. **EV arms race to develop:** The EV transition offers asymmetric downside for auto OEM management teams. Competing with disruptive new players will result in lower returns but failure to do so will likely jeopardize the long-term outlook for their business.

Understanding EV Consumer Demand Today

Main types of electric vehicles:

Battery Electric Vehicles (BEV): fully-electric vehicles with rechargeable batteries and no gasoline engine

Plug-in Hybrid Electric Vehicle (PHEV): can recharge battery through regenerative braking and 'plugging-in' but also have a gasoline engine

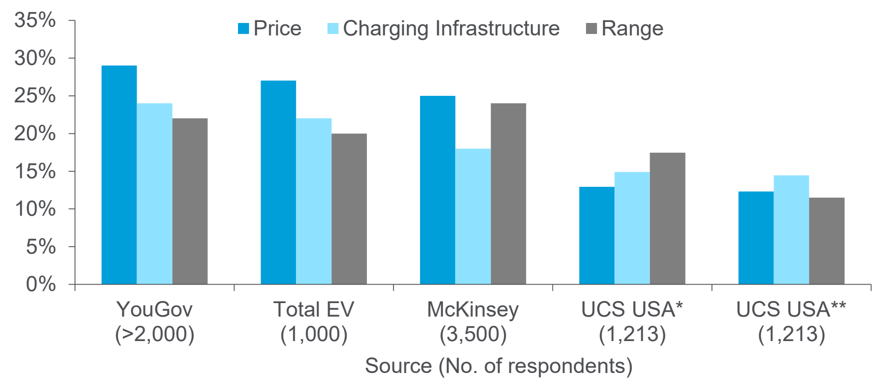
Hybrid Electric Vehicle (HEV): powered by both electricity and gasoline with battery recharging through regenerative braking

Fuel Cell Electric Vehicle (FCEV): uses a fuel cell (i.e., hydrogen) to power its onboard electric motor

New Electric Vehicle (NEV): term used in China for plug-in electric vehicles, including BEVs, PHEVs and FCEVs

A crucial component to the auto transition from ICE vehicles to EVs is consumer demand. In our 2018 Citi GPS Electric Vehicles: Ready(ing) for Adoption, we identified three barriers affecting consumer demand for electric vehicles: price, charging infrastructure, and range. While improvements in electric vehicle products and government incentives have seen the gaps between EV and internal combustion engine (ICE) vehicles narrow, there are clearly still some shortcomings in the consumer's mind when it comes to EVs.

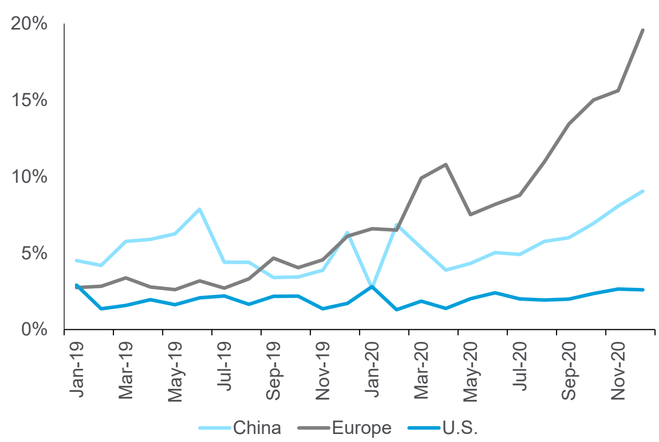
Figure 1. Survey Querying 'Main Barrier' for Higher Adoption of EVs



Note: * Respondents from California, ** Respondents from 9 Northeast U.S. states.
Source: YouGov, Total EV, ESC USA, McKinsey, Citi Research

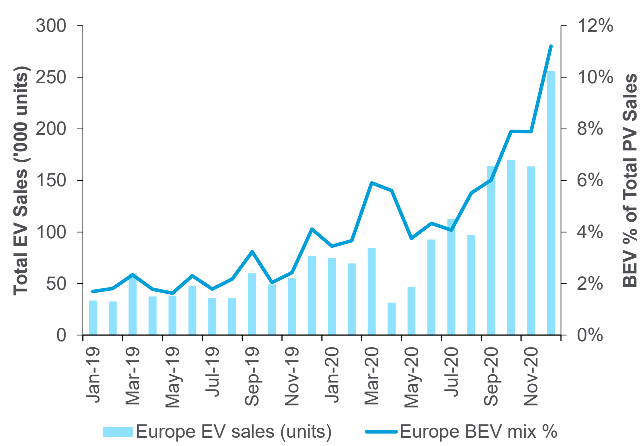
Do not be fooled by the hype surrounding the EV sales recorded in Europe in the third and fourth quarter of 2020. Despite what looks like rapid growth, this is almost entirely driven by regulation (either being pushed by an auto original equipment manufacturer, or OEM, or pulled as a result of retail incentives) with the usage data of these vehicles showing the platform is still catering to niche consumer demand.

Figure 2. Europe, China & U.S.: Proportion of EV (BEV + PHEV) Sales (2019-20)



Source: Citi Research, Anfac, Anfia, CCFA, SMMT, VDA, Motor Intelligence, CCPA

Figure 3. Europe: Total EV Sales & Proportion of BEV Sales

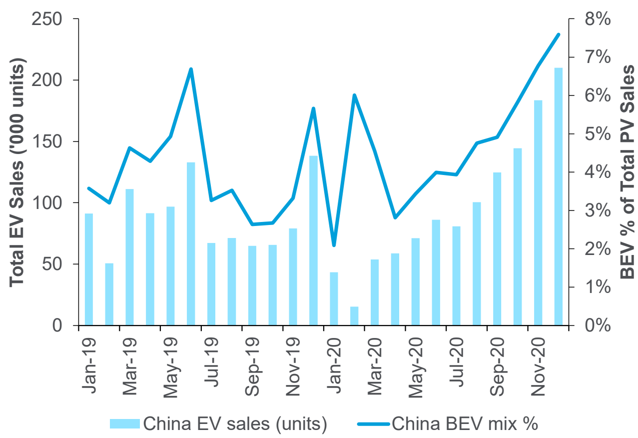


Source: Citi Research, Anfac, Anfia, CCFA, SMMT, VDA

The trends in China are more interesting because the demand for BEVs is less reliant on government regulation, which is less onerous than in Europe. Driving trends in China are more conducive to EV adoption as range anxiety and consequently re-charging issues are less significant.

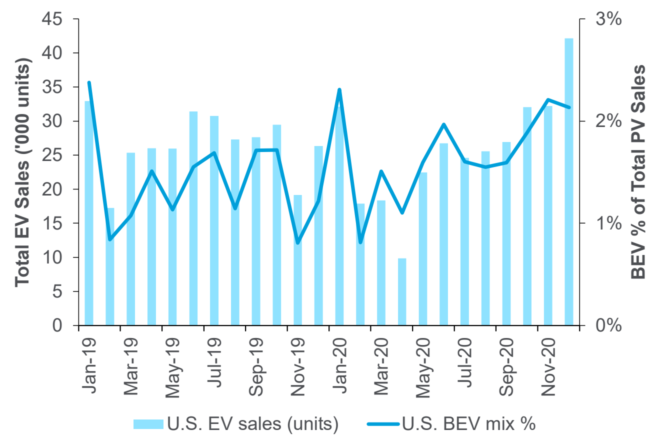
Perhaps unsurprisingly in the U.S., where range and weather extremes are greatest and government support for EVs is least, the adoption of BEVs is by far the lowest.

Figure 4. China: Total EV Sales and Proportion of BEV Sales



Source: CPCA, Citi Research

Figure 5. U.S: Total EV Sales & Proportion of BEV Sales



Source: Motor Intelligence, Citi Research

In Europe the need to meet tough emission regulations in 2020 has seen auto OEMs push volumes to fleets and retail consumers, which are supported by heavy government incentives.

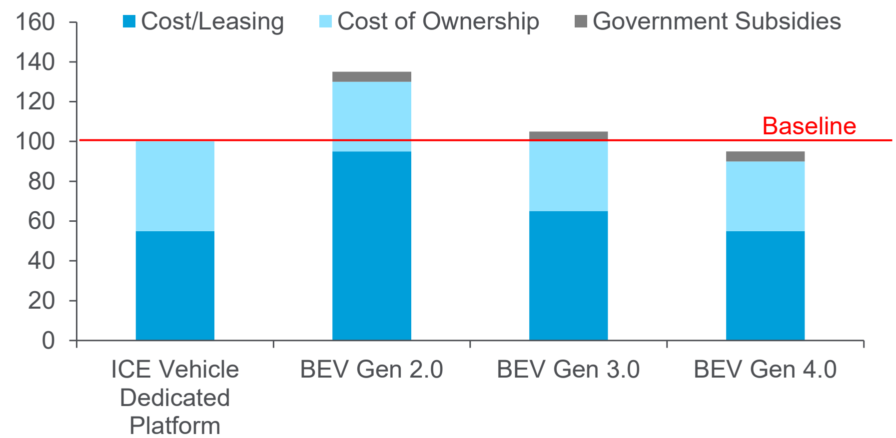
Figure 2 above demonstrates the sharp increase in the proportion of EV sales in Europe to around 20% in December (roughly evenly split between BEVs and PHEVs). The proportion of EVs has increased substantially in Europe over the course of 2020, propelled in part by existing EV subsidies and in part by the generous incentives created to stimulate passenger vehicle sales following the countrywide lockdowns and consequent economic slumps due to COVID-19.

New energy vehicle (NEV) incentives in China are also generous and have supported robust EV demand to date. China NEV sales in December reached 9% of total passenger vehicle sales, largely driven by BEV adoption (8% of total passenger vehicle sales) with plug-in hybrid electric vehicles (PHEVs) only accounting for 1% of December sales. The proportion of EVs sold in the U.S. was largely unchanged over 2020 at 2% of total passenger vehicle sales, the majority of which are BEVs.

Government Incentives Mean Price Is Less of an 'Issue'

We have seen increasingly generous government subsidies, especially in Europe, to support EV sales and the latest round of COVID-19-related subsidies have proven undoubtedly beneficial to EV sales in the short term. From a consumer perspective the current level of incentives drives the cost of an EV — in terms of total cost of ownership — more in-line with that of the equivalent ICE vehicle. However, this does not imply profitability or returns on capital for the auto OEMs are remotely near those of an ICE vehicle. It seems likely that as EV technology improves and scale benefits appear, the cost for consumers will fall below that of an ICE vehicle in the near future.

Figure 6. Total Cost of Ownership of Vehicle Model Generations vs. ICE Baseline



Source: Citi Research

The current incentives on offer from governments vary widely.

Figure 7. EV Incentives for Select Countries

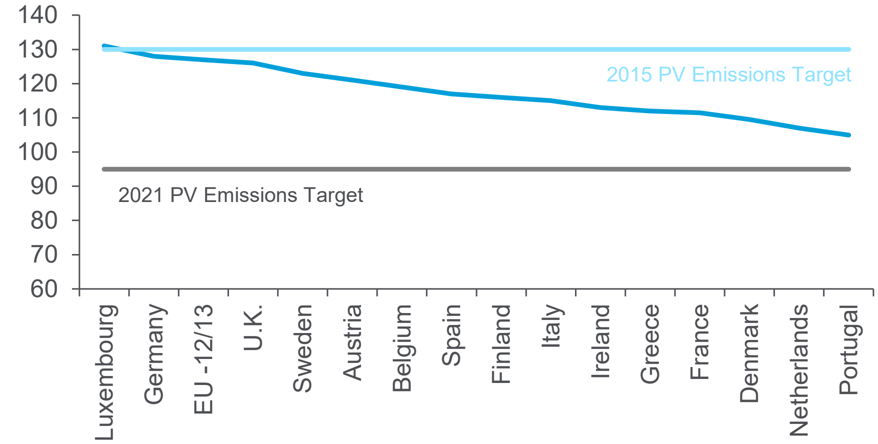
	Purchase Subsidy		Tax Incentives	Constraints
	BEV/FCEV	PHEV		
Austria	€1,500	€750		Electric range >50km, max retail price €50,000, Diesel PHEVs excluded
Sweden	SEK 60,000			Payable after 6mo of ownership, capped at 25% retail price
France	€6,000		No registration tax in many subnational regions	Maximum retail price €45,000
Germany	€3,000 €6,000 €5,000	€4,500 €3,750		Maximum retail price €60,000 Max Price <€40,000 Max Price €40,000-€65,000
Ireland	€5,000		BEVs: €5,000 tax rebate on Vehicle Registration Tax (VRT); PHEVs: €250-€2,500 tax rebate	BEVs and PHEVs < 50gCO_2/km; range >50km
Netherlands	€4,000		VAT tax rate of 4% (opposed to 22%) for vehicles <€ 50,000 (regulation due to be abolished)	Retail price range: €12,000-45,000; Min range >120km
Norway	No purchase subsidy		BEV exempt from 25% VAT and 3 purchases taxes (weight, CO_2, and NOx)	
Spain	€1,300-€5,500			Depending on range, €5,500 if range >72km. Max retail price <€40,000
United Kingdom	£3,000			Capped at 35% retail price. Max purchase price <£50,000. PHEV only applicable if <50gCO_2/km and range >112km
China	Range 300-400km: RMB 16,200 Range >=400km: RMB 22,500	Range >=50km: RMB 8,500	Purchase tax exempt	Max price <RMB 300,000
United States			Tax credits up to $7,500 (PHEV & BEV)	Battery capacity >5kWh, gradual phase out for each manufacturer after it's sold 200,000 vehicles
Korea	BEV: KRW 8,000,000; FCEV: KRW 22,500,000			
Japan	BEV: JPY 400,000; FCEV: 2,250,000	JPY 200,000		Min range PHEV >40 km. Min range BEV >400 km
Canada	C$5,000			Max price <C$45,000-C$60,000 (depending on car type)

Source: Citi Research, IEA, autovista, electrive

Push Factors: An Un-level Playing Field of ICE Vehicle Taxes in Europe

The two unspoken realities about passenger vehicle carbon dioxide emissions in Europe are first, they are not spread equally among countries and second, they have largely increased as vehicles become larger and more powerful over time.

Figure 8. Select European Countries: Passenger Vehicle (PV) Emissions, 2018 (CO_2g/km)

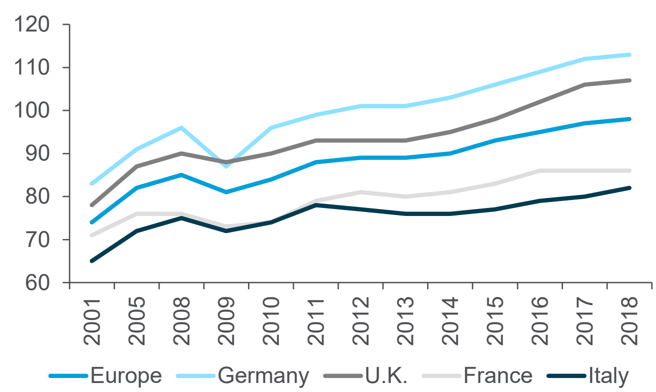


Source: European Commission

Indeed countries that have adopted punitive taxation on polluting vehicles such as France and the Netherlands have a significantly lower carbon dioxide footprint than those that do not, such as Germany and the U.K. This is reflected in consumer vehicle choices with vehicles in France typically being lighter and less powerful than those in Germany or the U.K. Notably, French auto OEMs have a much lower need to sell EVs to comply with carbon dioxide emission targets than their German counterparts.

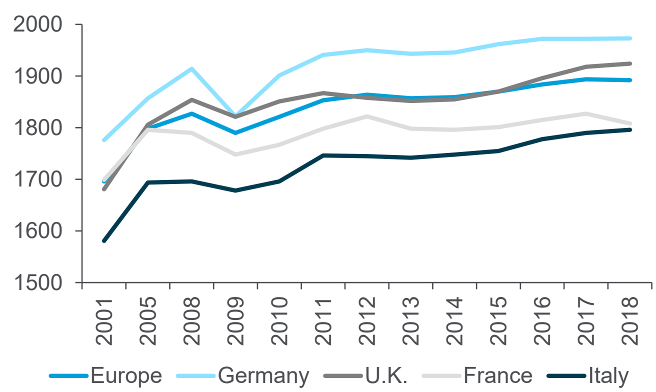
If German auto OEMs were willing to step back from the larger, more profitable vehicle categories their short-term need to sell EVs would be significantly lower.

Figure 9. Europe: Vehicle Engine Power (KW)



Source: ICCT, Citi Research

Figure 10. Europe: Gross Vehicle Weight (kg)

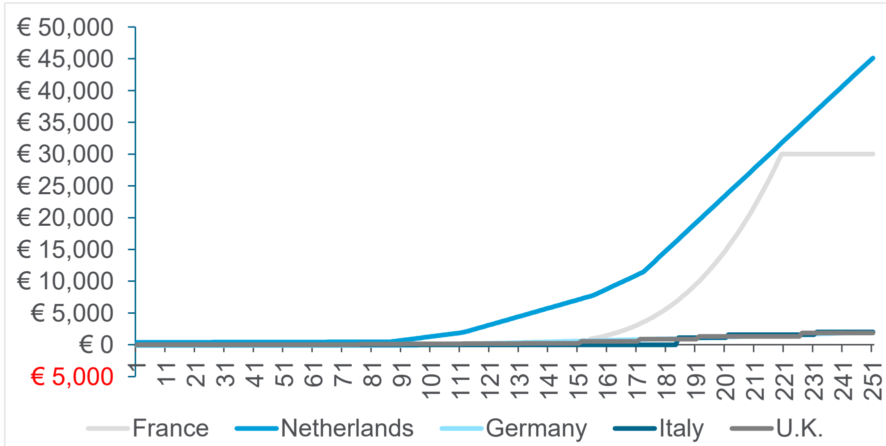


Source: ICCT, Citi Research

There is increasing pressure to raise taxes on polluting vehicles with France set to raise the purchase tax on vehicles producing more than 218gCO_2/km to around €29,000. The Netherlands also operates a strict tax regime on polluting vehicles and even countries such as Germany and the U.K. began tightening regulations slightly at the beginning of 2021.

Historically, a purchase tax rate of between 10% and 15% of the total vehicle purchase price has been sufficient to persuade consumers to shift to a less-polluting vehicle.

Figure 11. Vehicle Purchase Tax by CO_2 g/km in Respective European Countries, 2021



Note: Germany annual CO_2 tax rate capitalized in 4x multiplier, Italy converted from NEDC
Source: ICCT, Citi Research

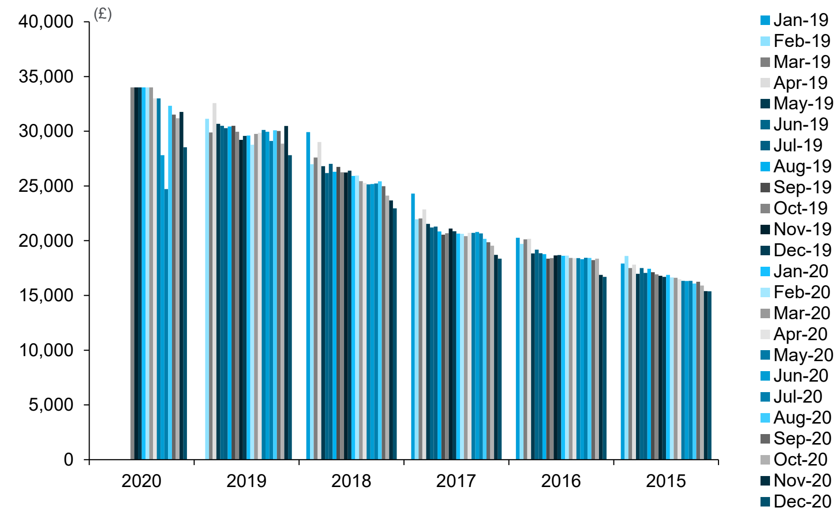
Residual Value Trends Remain Remarkably Strong

One positive aspect in the development of the EV market has been the solid nature of residual values. Typically, the auto industry sees falling prices for new vehicles and improving product performance tends to lead to a sharp depreciation in used vehicle pricing. To date with EVs this has not been the case. Residual values have been helped by the gradual nature of technology improvements in the EV market.

Looking at a model such as the BMW i3 — one of the longer-serving BEV vehicles on the market — we can see a fairly consistent depreciation profile. We attribute this consistency to the vehicle being a relatively niche product, meaning shortcomings in its range or charging capabilities are not a concern for customers who bought it either new or used. Its residual value is also helped by the gradual nature of technological improvements.

However, should performance improve more rapidly, should EV uptake increase to the point that EVs look to become more mainstream, or the speed of technology improvements starts to increase, we believe residual values will start to decline.

Figure 12. BMW i3 Used Pricing by Model Year by Month

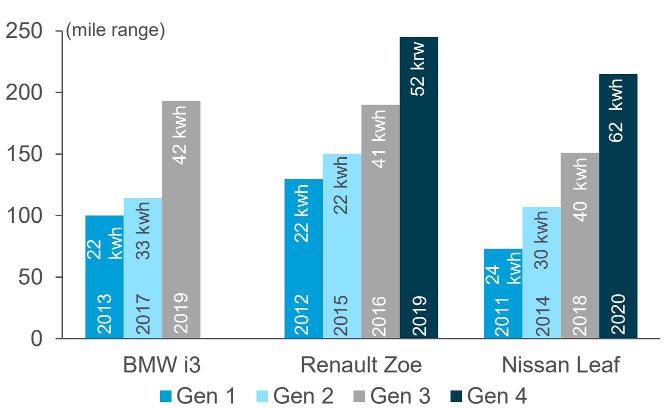


Source: Citi Research

EV Range Is Improving but Still Lags ICE Vehicles

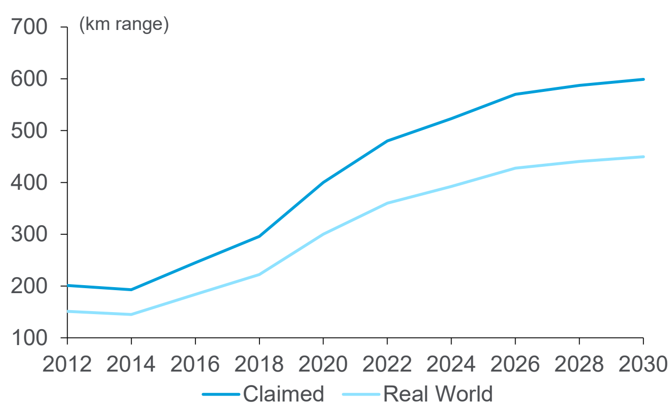
From a consumer perspective, EV performance has improved significantly over the last decade. For example, the most recent Renault Zoe (2019) model can travel 245 miles (395km) before needing to recharge versus the 90 mile range offered in its 2012 model. Larger and denser battery technology is the chief driver of this improvement. Nonetheless, its range is still well below the range achievable with an ICE Renault Clio, which has about a 400 mile range.

Figure 13. Battery Range in Successive BEV Model Generations



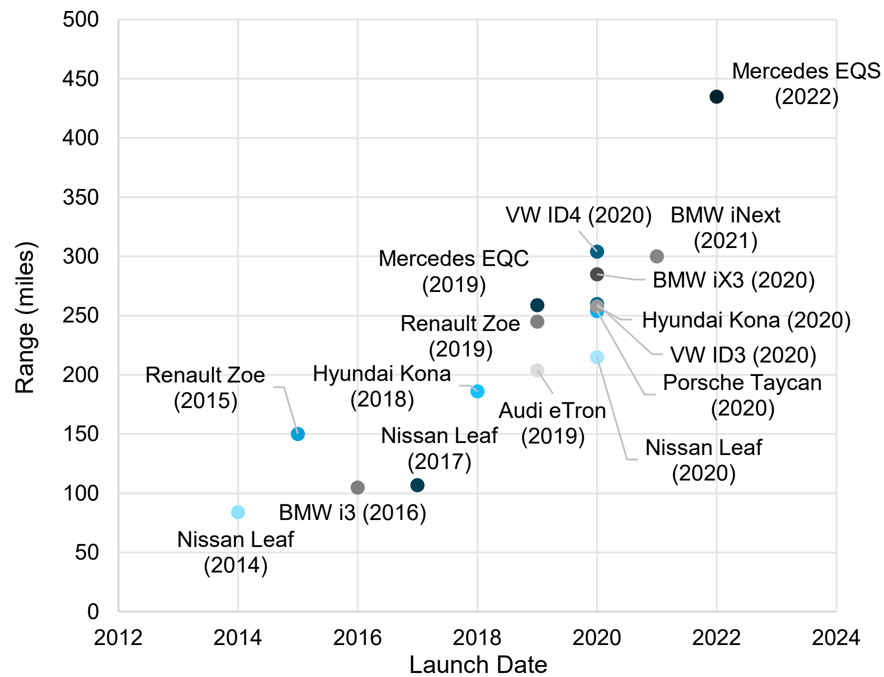
Source: Citi Research, Clean technical, Autocar, Greencare reports, Inside EVs, Company Data

Figure 14. Average BEV Range Evolution – Claimed and Real-World



Source: Citi Research LMC

Figure 15. Newer Model Launches Improve Significantly on Range



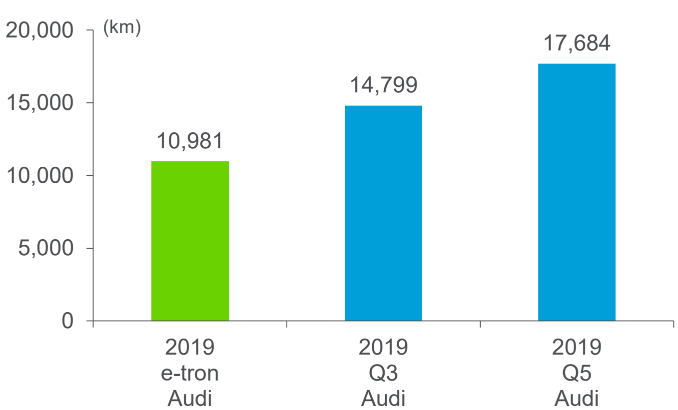
Source: Citi Research, Clean Technical, Autocar, Greencar reports, Inside EVs, electrek

Interestingly, the pace of change in battery technology is accelerating and reaching a point where a range of 400 miles is achievable on a single charge in some vehicles (i.e., Mercedes EQS). What this means is that we are reaching a tipping point where BEVs can begin to look to address the entire vehicle market rather than just act as expensive short-range vehicles.

Mileage Shows the Limited Utility of EVs

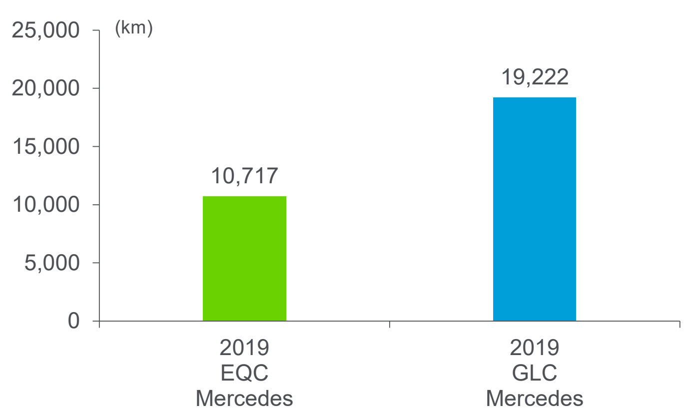
The clearest insight into the consumer view of BEVs is found by looking at current mileage and usage of BEV vehicles compared to all registered vehicles. The most significant gulf between a BEV and its equivalent ICE is seen with the Audi e-tron and Q3/5, and the Mercedes EQC and GLC. Figure 16 and Figure 17 below show the utility of these SUVs is very limited compared with their ICE counterparts.

Figure 16. Audi ICE vs. EV Mileage Comparison (km)



Source: Citi Research

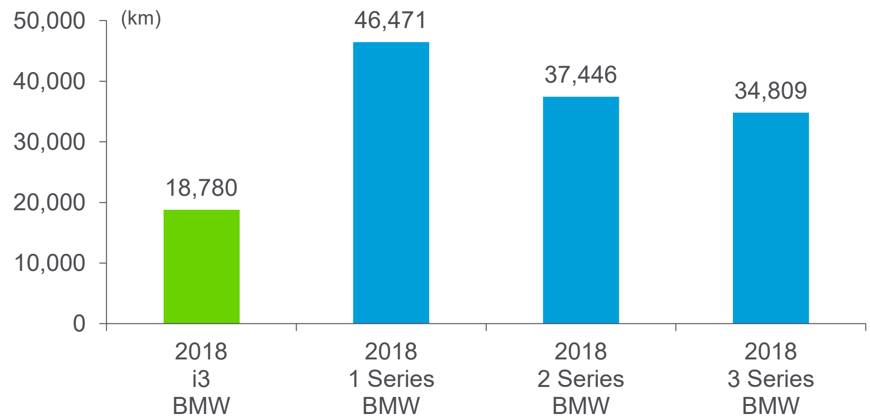
Figure 17. Mercedes ICE vs. EV Mileage Comparison (km)



Source: Citi Research

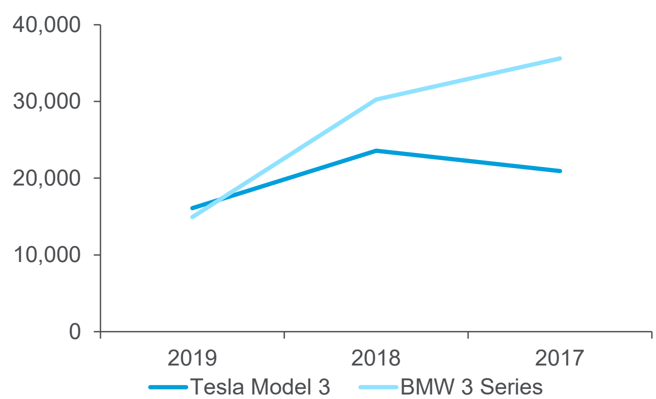
The BMW i3, which has a longer history, shows a similar lower usage pattern when compared with other BMW models of the same model year. Turning to Tesla in the U.S, we can again see far more limited mileage in its models versus comparable ICE vehicles.

Figure 18. BMW ICE vs. EV Mileage Comparison (km)



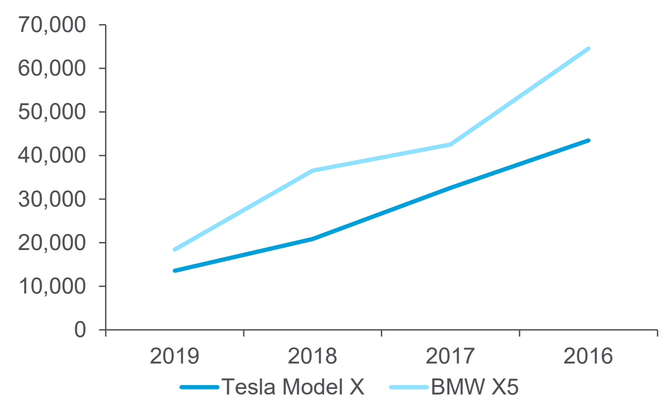
Source: Citi Research

Figure 19. U.S. Vehicle Mileage by Model Year (miles)



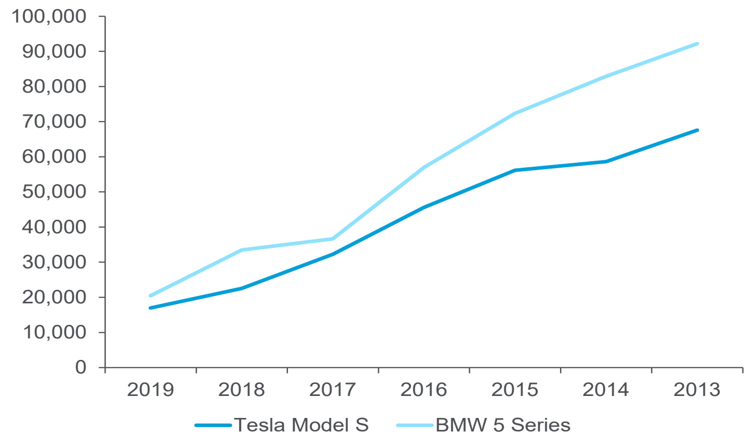
Source: Citi Research

Figure 20. U.S. Vehicle Mileage by Model Year (miles)



Source: Citi Research

Figure 21. U.S. Vehicle Mileage by Model Year (miles)



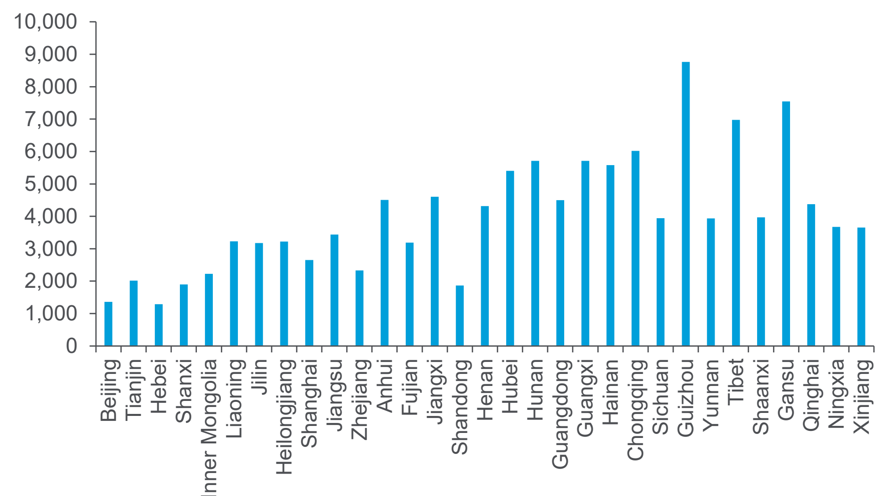
Source: Citi Research

Regional Differences in EV Adoption Highlight Range as an Issue

Given the range challenges for the electric vehicle product currently on the market we posit that sales of EVs to date are largely focused on a specific niche in the market, which has the charging capability and does not have a daily need for range beyond around 150 miles.

Taking a regional perspective we see significant supporting evidence for this view, particularly in China. Looking at the different vehicle usage trends in China, most regions have annual passenger kilometers of less than 6,000. Compared to Western markets where the U.S. has about 4x the mileage requirement of China and Europe has about 3x, it seems obvious EV adoption would happen sooner in China if pricing with ICE vehicles was comparable.

Figure 22. Annual Passenger Kilometers by Region in China



Source: National Bureau of Statistics of China, Citi Research

Given the majority of electric vehicle products on offer today have a range below 200 miles, this is clearly an impediment to EVs becoming the main household vehicle in Europe or the U.S. The lower overall mileage requirements from drivers in China means range is less of an impediment to EV adoption than in other markets and we believe this is a key driver for strong EV sales in the premium segment. In contrast, we have seen strong demand in Europe for PHEVs and the BEV sales focused on the smaller A/B vehicle segment (Renault Zoe, Nissan Leaf, BMW i3), which are typically used for shorter journeys, while sales of premium vehicles (Audi e-tron, Mercedes GLC and Tesla Model S) have been more underwhelming.

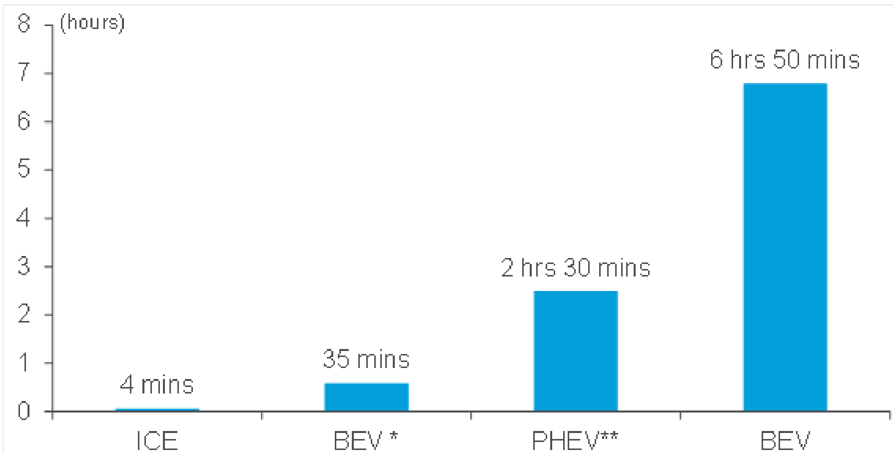
In China the development of batteries has also been interesting with much of the market (including the premium players) willing to embrace the cheaper but lower performance lithium iron phosphate (LFP) cells.

Gradual Improvements in Charging Time

Another issue faced by EVs is their slower refueling time compared to ICE vehicles. While rapid charging to 80% may provide a level of comparability between EV and ICE vehicles, few things compare to the convenience of a petrol/gas station as a means of transferring energy into a vehicle. While recharging times have been improving, it seems unlikely EV refueling will ever reach complete parity with ICE refueling times.

That said, a rapid charging time of around 30 minutes seems palatable for consumers, particularly with the recent improvements in charging density and range of vehicles. While the major use of EVs is still predominantly urban travel it's also worth considering that such shorter distances will most likely be reliant on home overnight charging, diminishing the time required of a consumer to visit a petrol/gas station on a regular basis as with ICE vehicles.

Figure 23. Average Refueling Time — ICE Is the Clear Winner



Note: * Rapid charging to 80%; ** Time taken to charge battery, refueling combustion engine in ~4 minutes also available

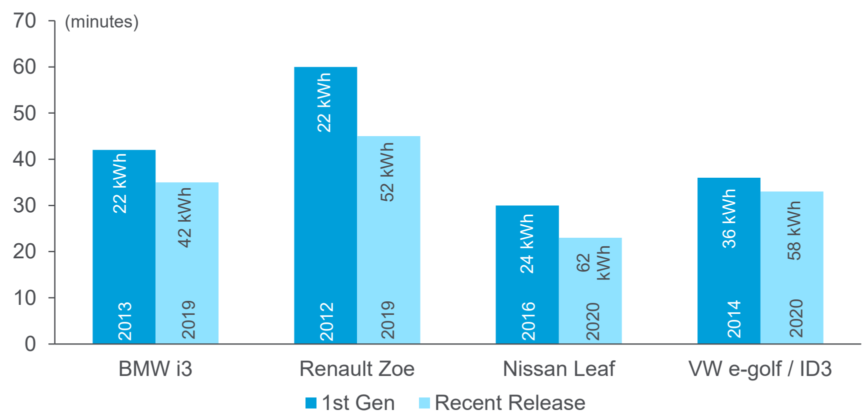
Source: Zap Map, Pod Point, Smart EV, Citi Research

An ideal battery is one with a long life-span, high energy and power densities (enabling long ranges), and a quick recharging time. In reality, the physics of each of these requirements offsets the other. Fast charging can generally be achieved in between 30 and 90 minutes depending on the temperature with an average of about 40 minutes. Typically, these fast charging rates are only achievable up to about an 80% level due to both safety limitations and decreasing charge speeds past that level.

There are four main components affecting charging speed:

- **Battery Pack Capacity:** Generally, a larger battery pack can be charged faster. PHEVs, which have small battery packs, typically have slower charging speeds.
- **State of Charge (SOC):** The charge speed of a battery drops as it reaches its full charge, therefore the speed of charging starts to drop when the SOC reaches 80-90%. This is why rapid charging is usually limited to 80% SOC.
- **Battery Temperature:** The temperature of the cells is perhaps the biggest determinant of performance. Most factors that influence a cell's recharge time also influence its temperature. Cells operate most effectively between 20-25 degrees Celsius. When the temperature of a battery is outside of this range, the current is reduced to protect the health of the cells.
- **Battery Chemistry & Form:** Battery manufacturers have to make compromises between weight, size, cost, life, and performance of the battery. Premium-priced vehicles can have cooling systems installed to better regulate temperature and improve recharging speeds. Cell formation also affects the recharge speed of a battery, mainly affecting how the cell handles temperature.

Figure 24. Charging Time Has Only Improved Marginally (Rapid Charge to 80%)



Source: Zap Map, Pod Point, electrek, EV database, inside EVs, Citi Research

Charging Infrastructure is Expanding

Electric vehicle charging networks are critical to the adoption of EVs. The number of global charging points has accelerated into 2019 with 862,118 publically available charging points (598,000 publicly accessible slow chargers; 264,000 publically available fast chargers). That said, in 2019, private chargers accounted for about 90% (6.5 million) of the worldwide light-duty vehicle chargers, as private charging remains the most convenient and cost effective for private individuals and companies. Additionally, country-specific support policies (such as preferential rates, equipment purchase incentives, and rebates) support the growth in private charging infrastructure.

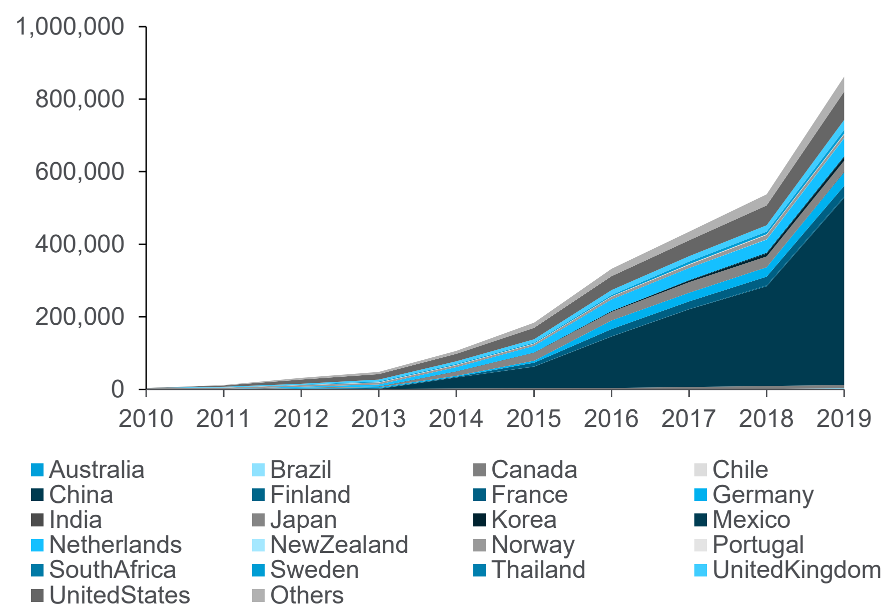
Figure 25. European Charging Infrastructure Policy Initiatives and Incentives

Country	Infrastructure Incentives
United Kingdom	Electric Vehicle Home Charge Scheme subsidizes <75% of purchase & installation costs (capped at £500, including VAT).
Ireland	Up to €600 for installation of Electric Vehicles Supply Equipment (EVSE) at home.
France	The ADVENIR program covers the costs of supply and installation of charging points <40% for companies and <50% for apartment blocks. €300 is also available in tax credit (<75% of charging point cost) for newly private residence installed chargers.
Germany	The federal government plans to invest €500 million in private charging points. Private individuals can receive <50% (max €1,000) per charging point. Public chargers are also eligible for a <50% grant (max €5,000) per charging point.
Italy	Tax credit granted to individuals, companies, and condominiums of <50% for the purchase and installation costs of EV chargers (max €3,000).
Spain	Under the Moves II plan, private individuals and businesses can receive grants between 30-40% (max €100,000) of the purchase and installation cost of public or private chargers.
Norway	Over most of Norway a <20% grant for purchase and installation is available (max NOK 5,000 (€450)) per charging point (the grant allowance is greater for housing associations).
Sweden	The 'Klimatklivet' program provides a grant that covers <50% of both public and private charging stations for businesses and public associations. For individuals, the 'Charge at Home' program provides grants <50% (max SEK 10,000 (€960)) for purchase and installation costs of home chargers.

Source: EAFO, ESB, EV Fleet World, Wallbox, Citi Research

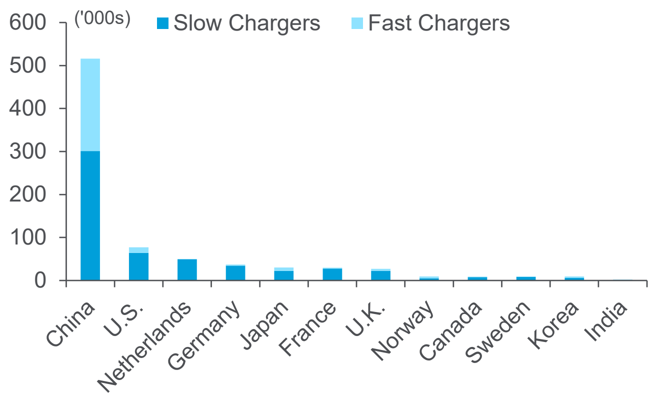
On publically available charging infrastructure, China leads the way with over 301,000 slow charging and 215,000 fast charging ports across the country. In Europe, the Netherlands leads in public charging infrastructure density with 50,000 charging points (2.8 per 1,000 population), supported by the government's focus on increasing publically available charging infrastructure as opposed to the private subsidies for building out home charging infrastructure seen in other European countries.

Figure 26. Number of Global Public Charging Points Accelerating (2010-2019)



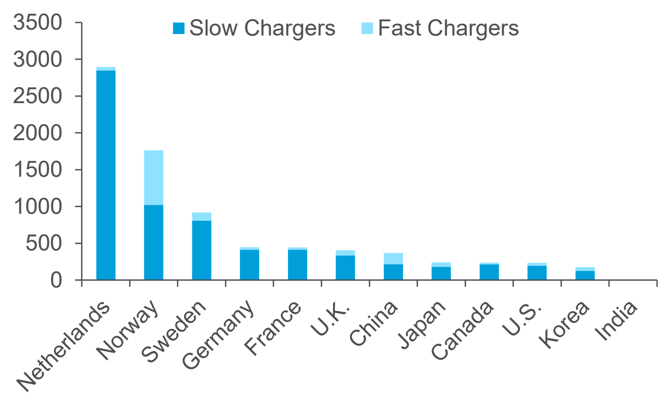
Source: IEA Global EV Outlook 2020, Citi Research

Figure 27. Publicly Available Charging Points per Country



Source: IEA Global EV Outlook 2020, Citi Research

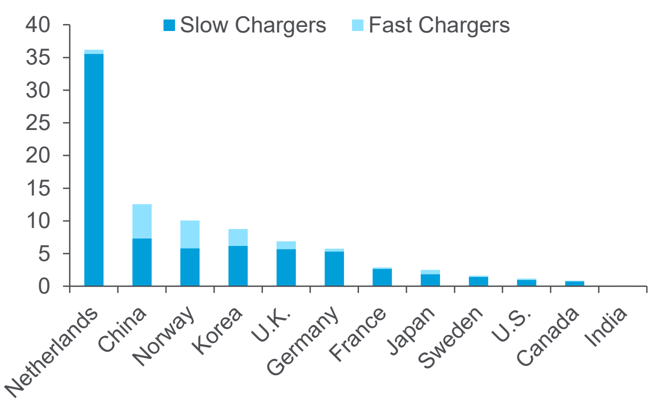
Figure 28. Publicly Available Charging Points per Million Population



Source: IEA Global EV Outlook 2020, World Bank, Citi Research

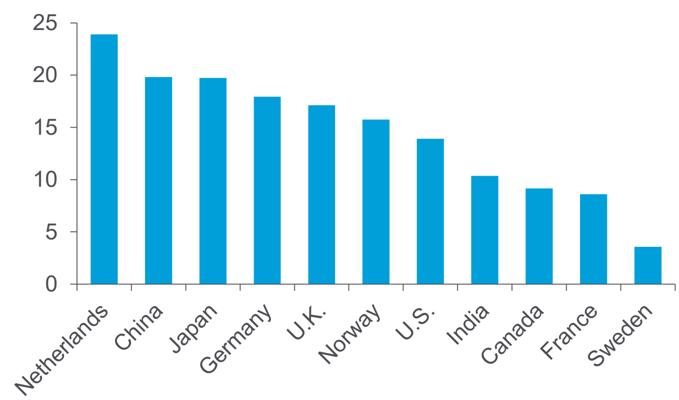
The Netherlands' push for publically accessible charging points has improved infrastructure to the extent that there are more charging points than gas pumps per 100km of road (36 chargers vs 23 gas pumps per 100km). All other countries have a larger gas pump density to charging infrastructure — at least when it comes to public charging — but the gap is gradually closing with governments pushing to make charging infrastructure widely available.

Figure 29. Charging Points per 100km of Road



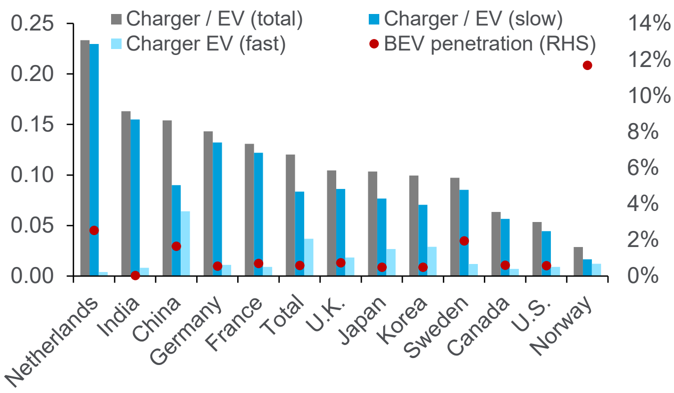
Source: IEA Global EV Outlook 2020, CIA, Citi Research

Figure 30. Gas Pumps per 100km of Road



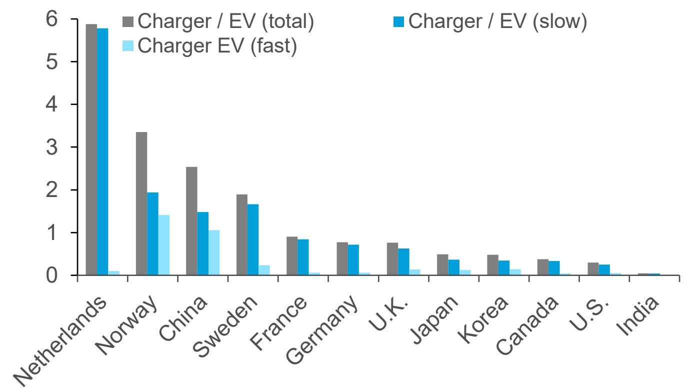
Source: IEA Global EV Outlook 2020, Fuels Europe, Petrol Plaza, U.S. Census Data, Global News, Statista, Citi Research

Figure 31. Ratio of Publicly Available Charging Infrastructure to Registered EV Vehicles (2019)



Source: IEA Global EV Outlook 2020, LMC, Citi Research

Figure 32. Ratio of Publicly Available Charging Infrastructure to Total Registered EV Vehicles (2019, '000 units)

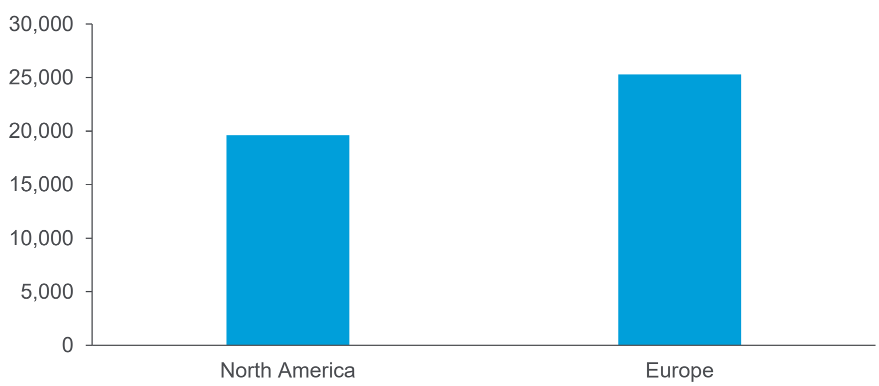


Source: IEA Global EV Outlook 2018, Citi Research

AC (alternating current) charging is the simplest type of charging available, providing power to the on-board charger of the vehicle where the charge is then converted to DC (direct current). AC charging can take anywhere from 5 hours to >12 hours to charge. By contrast DC fast charging bypasses the limitations of the on-board charger and required conversion, providing DC power directly to the battery, thereby increasing charging speed dramatically. A fast charge can only charge the battery to 80% (any more would result in significantly longer charging times) generally in average timeframes of about 40 minutes.

The number of fast charging points has grown significantly over the past few years, approaching to nearly 20,000 in North America and over 25,000 in Europe.

Figure 33. Number of Fast Charging Points in North America and Europe



Source: Alternative Fuels Data Center, EAFO, Citi Research

In addition to different operating models, charging network providers also price their services differently. Some automatically recognize a car upon plugging in while others require a card/membership/application/credit card, which make them slightly less convenient to use.

OEMs Assume Regulation-Driven EV Demand

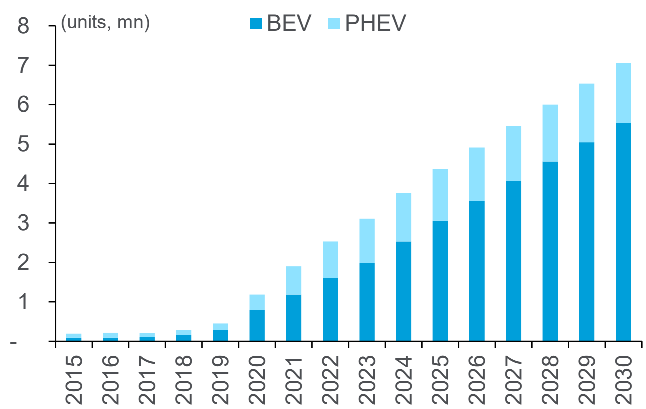
Europe: 2050 Carbon Neutrality Driving Emissions Targets

The European push towards electrification is largely driven by the Paris Climate Agreement, which calls for carbon dioxide neutrality by 2050. In Europe, autos are currently the largest contributor to carbon dioxide emissions, making it a clear focus area for governments committed to meeting climate change targets. From 2021, phased in from 2020, the European Union (EU) fleet-wide average emission target for new cars is 95gCO_2/km and applies to 100% of the new EU fleet (up from 95% in 2020).

This is a significant jump from the previous 130gCO_2/km target; consequently, we look for a substantial increase in the sale of battery electric vehicles (BEV) or plug-in-hybrids (PHEV) engines as a proportion of total vehicle sales. Notably, the former not only releases zero carbon dioxide emissions but also gains significant credits in the fleet emission scoring calculations. The sharp emissions target change in 2020/21 results in a step-change in our forecasts from 2019 levels, causing a shift in the forecast EV penetration pathway (the sale of electric vehicles as a percentage of total vehicle sales) in Europe.

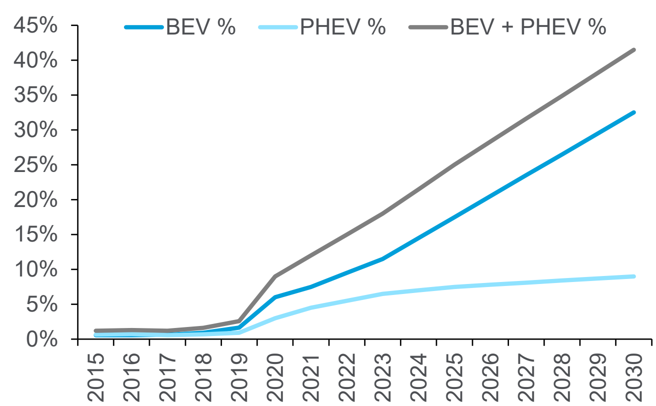
Furthermore, Regulation (EU) 2019/631 sets new EU fleet-wide carbon dioxide emission targets for the years 2025 and 2030 (dated April 17, 2019). For passenger vehicles, these targets are defined as a 15% reduction from the 2021 starting point by 2025 and a 37.5% reduction by 2030. These targets form part of the European Commission's plan to reduce EU greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels, aiding to the pathway to climate neutrality by 2050.

Figure 34. Europe: EV Sales Forecast to 7.1 Million by 2030



Source: Citi Research

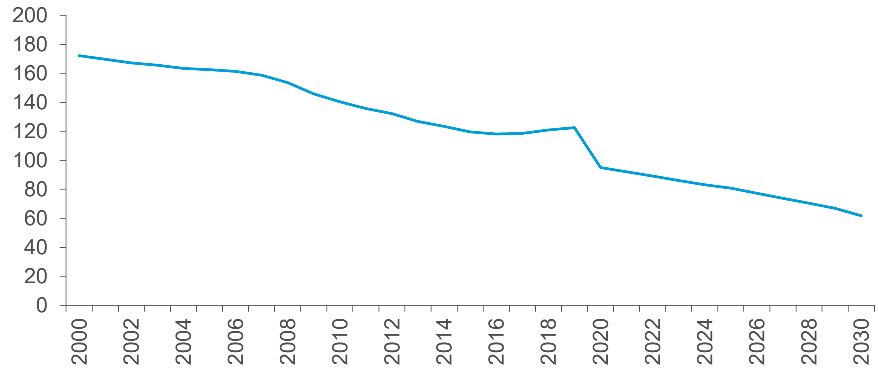
Figure 35. Europe: EV Penetration Forecast to 42% by 2030



Source: Citi Research

Given the reliance of BEV sales on government incentives, low levels of profitability, and the limitations of the product developed to date, the approach from the incumbent European auto OEM is one of targeting regulatory compliance and no more.

Figure 36. European Union CO_2 Emissions for Average Passenger Cars (CO_2 g/km)



Source: EEA, Citi Research

BEVs can be an important part of profit maximization within the regulatory requirements as they can allow auto OEMs to continue to sell high margin and higher emission vehicles. However, should a BEV product substitute for a high margin ICE vehicle product, the result for profits would be unavoidably negative. Below we outline some basic scenarios for a hypothetical European auto OEM.

Figure 37. 2019 Status Quo Gross Profit and CO_2 Performance

Status-Quo	D/E ICE	A/B ICE	Group
Price (EUR)	80,000	23,000	
Number of units	400,000	400,000	800,000
Gross Revenue(EUR)	32,000,000,000	9,200,000,000	41,200,000,000
Net revenue (EUR)	25,600,000,000	7,360,000,000	32,960,000,000
Gross profit margin (%)	35%	15%	
Gross profit (EUR)	8,960,000,000	1,104,000,000	10,064,000,000
CO_2/km (g)	140	95	118

Source: Citi Research

Assuming an auto OEM made no technological improvement in 2020 compared to 2019 and sold no BEV products, its only option for meeting compliance is through mix dilution. This results in the most negative impact on profits.

Figure 38. 2020/21 CO_2 Compliance through Mix Dilution (43% Decline in Gross Profits)

Compliance through Mix Dilution	D/E ICE	A/B ICE	Group
Price (EUR)	80,000	23,000	
Number of units	180,000	620,000	800,000
Gross Revenue(EUR)	14,400,000,000	14,260,000,000	28,660,000,000
Net revenue (EUR)	11,520,000,000	11,408,000,000	22,928,000,000
Gross profit margin (%)	35%	15%	
Gross profit (EUR)	4,032,000,000	1,711,200,000	5,743,200,000
CO_2/km (g)	140	95	105

Source: Citi Research

Should the auto OEM look to launch a small number of EVs to aid in carbon dioxide compliance this would allow a higher number of sales of high margin, higher pollution products. This offers the most positive outcome of the scenarios.

Figure 39. 2020/21 CO_2 Compliance through EV Sales (35% Increase in Gross Profits)

Compliance through BEV	D/E ICE	A/B BEV	Group
Price (EUR)	80,000	34,000	
Number of units	600,000	200,000	800,000
Gross Revenue(EUR)	48,000,000,000	6,800,000,000	54,800,000,000
Net revenue (EUR)	38,400,000,000	5,440,000,000	43,840,000,000
Gross profit margin (%)	35%	2%	
Gross profit (EUR)	13,440,000,000	108,800,000	13,548,800,000
CO_2/km (g)	140	0	105

Source: Citi Research

Over compliance clearly results in profit dilution although this assumes credits are not sold to competitors.

Figure 40. 2020/21 Over Compliance through EV Sales (9% Decline in Gross Profits)

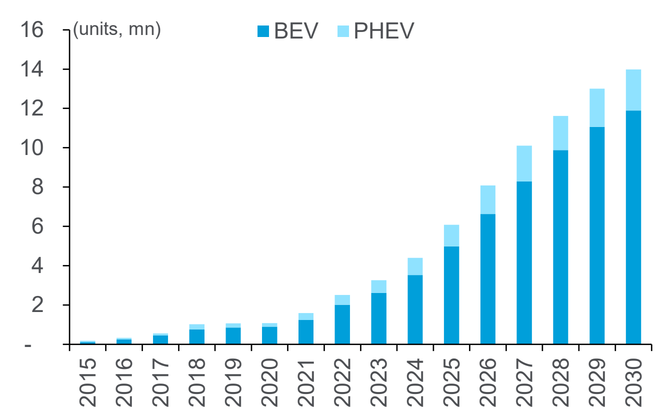
Over Compliance	D/E ICE	A/B BEV	Group
Price (EUR)	80,000	34,000	
Number of units	400,000	400,000	800,000
Gross Revenue(EUR)	32,000,000,000	13,600,000,000	45,600,000,000
Net revenue (EUR)	25,600,000,000	10,880,000,000	36,480,000,000
Gross profit margin	35%	2%	
Gross profit (EUR)	8,960,000,000	217,600,000	9,177,600,000
CO_2/km (g)	140	0	70

Source: Citi Research

China: Emission Targets 7 Million NEVs by 2025

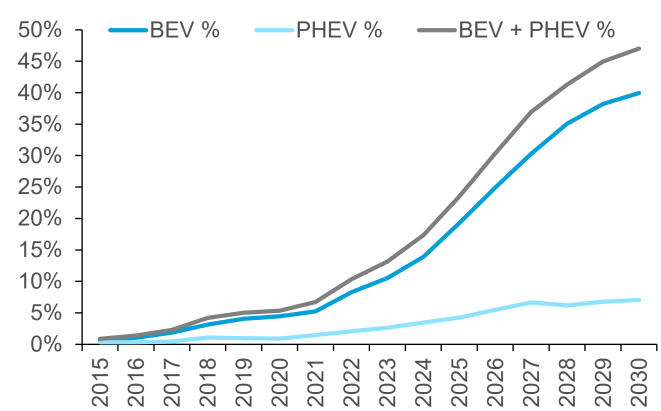
In China, the short-term New Energy Vehicle (NEV) penetration targets drive our forecasts to ~14 million units by 2030 (47% penetration). The Chinese government has made it clear they want to be global leaders in electric vehicles, and they have set ambitious targets for the number of NEVs they want to sell in 2020 and 2025: with the aim of 20% penetration in 2025. To encourage supply of NEVs the Ministry of Industry and Information Technology (MIIT), China's regulatory body, set an 'NEV target score' for manufacturers. The recently updated scheme (June 2020) works to regulate the average fuel consumption of new passenger cars at 4 liters/100km by 2025, down from 5.5 liters/100km in 2019.

Figure 41. China: EV Sales Forecast to ~14 Million Units by 2030



Source: Citi Research

Figure 42. China: EV Penetration Forecast to 47% by 2030



Source: Citi Research

The updated methodology for calculating the NEV target score is as follows:

- A) In 2020, the percentage requirement is 12%, increasing to 14%, 16%, and 18% for 2021/22/23, respectively.
- B) The percentage (A) is applied to the total ICE passenger car production for the corresponding year = 'NEV target score'.
- C) The actual NEV score is determined by applying a multiple to the volume of NEVs produced/ imported. [Note: BEVs with a driving range in excess of 100km have a higher multiple than plug-in-hybrids.]

In addition to the NEV targets, the MIIT has also set a target to reduce the overall fleet's fuel consumption by ~28% by 2020 (to 5L/100km vs 6.9L/100km in 2015); this is referred to as Corporate Average Fuel Consumption (CAFC). Each auto OEM has a specific target, and like in Europe, the more fuel-efficient vehicles benefit from super-credits.

Figure 43. Dual Credit Management System

Regulatory authority	Ministry of Industry and Information Technology (MIIT)	
Two parallel system	Corporate Average Fuel Consumption (CAFC) credit	New Energy Vehicle (NEV) credit
Calculation method	CAFC credit = (Target CAFC - Actual CAFC) x # of vehicles BEV with R>50km has multiplier impact of 5x/3x/2x in 2021/22/23 when calculating CAFC PHEV with fuel consumption < 2.8L/100km has multiplier impact of 3.5x/2.5x/1.5x in 2016-17/2018-19/2020 when calculating CAFC	NEV credit = NEV point / vehicle x # of vehicles NEV point per BEV = R x 0.006 + 0.8 (cap at 5) NEV point per PHEV = 1.6 NEV point per FCEV = 0.08
Management method	- CAFC negative credit can be offset by CAFC positive credit earned from previous year, transferred from related corporates, or by NEV positive credit - CAFC credit is allowed to be carried forward for at most 3 years (with a 90% conversion ratio from 2019 onwards) and can be transferred within related corporates (shareholding at or more than 25%)	- NEV negative credit can only be offset by NEV positive points via purchases from other manufacturers - NEV credit can trade freely on MIIT's platform, but cannot be re-sold - The NEV points in 2019 can be carried forward in equal amounts for to 2020, while the points in 2020 can only be carried forward by 50%
Assessment companies	All passenger vehicle OEMs selling in China (including import)	All passenger vehicle OEMs with annual production volume or import volume greater than 30,000 units in China
Assessment criteria	A positive balance under GB 27999-2014	2019/2020 NEV point to # of non-NEV vehicles ratio at 10%/12%
Penalty measures	Suspend application of car models that do not meet GB27999 standard and suspend partial production of high fuel consumption models	Suspend partial production of gasoline models

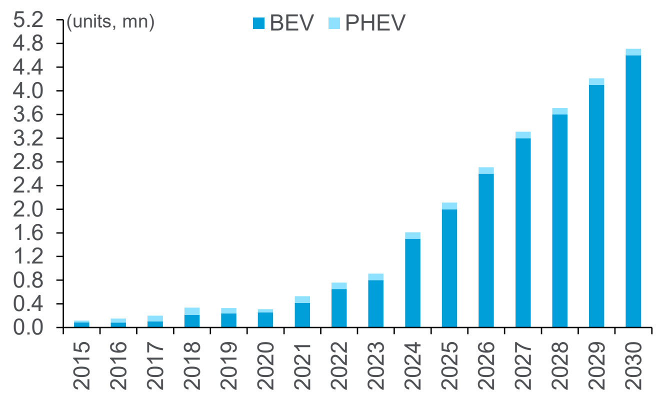
Source: MIIT, Citi Research

United States: Scope for More Regulatory Pressure

Unlike in Europe and China, EV penetration in the U.S. market is driven predominantly by consumer pull rather than regulatory push factors, particularly following the rollback of fuel efficiency targets by the Trump administration. In stepping away from the 54mpg 2025 target set by the Obama administration, the Trump administration set a new target of 40mpg. Based on this new lower target, fuel economy standards would have to rise by about 1.5% a year, compared to the 5% annual increase required by the Obama rule, thereby easing the regulatory pressure on U.S. automakers. For reference, despite the weakened regulation, the U.S. auto industry recently achieved an average annual increase in fuel economy of 2.4%.

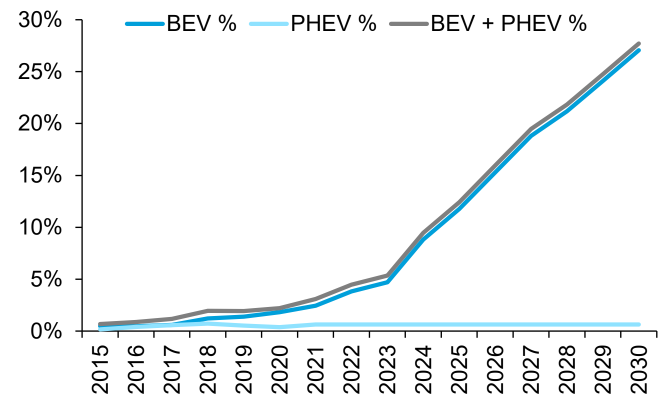
Consequently, in the U.S. there has been less of the regulatory pressure we see driving EV investment in Europe. Auto OEMs are still spending on electrification (one U.S. OEM for example announced plans to spend $11 billion on EVs by 2022), but the regulatory pressure to increase EV penetration, potentially at the expense of profitability, is less prevalent. Demand for electric vehicles also remains concentrated in California, which despite the Trump administrations rollback on emissions targets, decided to uphold the Obama targets. Earlier in 2020, California's government announced plans to ban the sale of new gasoline-powered cars statewide by 2035.

Figure 44. United States: EV Sales Forecast to ~4.7 Million by 2030



Source: Citi Research

Figure 45. United States: EV Penetration Forecast to 28% by 2030



Source: Citi Research

Once announced, the Biden administration's direction on emissions targets will most likely see a re-tightening of restrictions, perhaps returning to the Obama rule of 54mpg by 2025, or echoing Californian rules, which would shift the path for EV adoption in the U.S. If the new administration chooses not to implement tougher emissions targets, the country may also face global backlash, perhaps extending to sanctions later into the decade.

Japan: Strengthening Electrification Strategy; HEVs Continue to Dominate

Prime Minister Yoshihide Suga announced in October 2020 that Japan would aim to be carbon-neutral by 2050, and the government followed up on December 25th by announcing a "Green Growth Strategy" aimed at meeting the target. The relevant detail for autos involve the following:

1. Vehicle electrification is to proceed toward a goal of EVs accounting for 100% of new passenger vehicle sales by the mid-2030s. Included in this are BEVs, PHEVs, Fuel Cell Electric Vehicles (FCEVs), and Hybrid Electric Vehicles (HEVs). Specific initiatives include leveraging fuel-economy regulations, promoting public-sector procurement of EVs, building out the charging infrastructure, and offering government assistance and subsidies for EV adoption and replacement of ICE vehicles.

2. BEV adoption is to be strengthened over the next 10 years, with Japan building a world-leading supply chain for batteries and other components. Special focus is being given to electrification of mini-vehicles and commercial vehicles.

3. Automotive production, usage, and disposal is to be carbon zero by 2050.

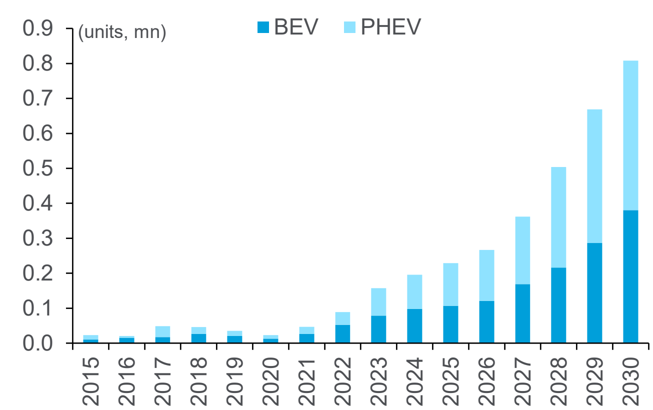
4. Synthetic fuels that contribute to carbon neutrality are to be priced lower than gasoline by 2050.

5. The cost of an automotive battery pack is to be decreased to ¥10,000/kWh ($95/kWh) as soon as possible before 2030 to make EVs as economical as gasoline-powered vehicles (we estimate a current cost of around ¥15,000/kWh ($143/kWh)). Next-generation batteries are also to be developed from 2030, beginning with full-scale commercialization of all-solid lithium-ion batteries followed by commercialization of innovative batteries (e.g., fluoride, zinc anode, etc.) from around 2035.

In addition to the above, the Ministry of Economy, Trade & Industry (METI) announced new fuel economy standards in March 2020 requiring a minimum of 25.4km/liter in year to March 2030, marking a 32.4% improvement on 2016's 19.2km/liter. Fuel economy for BEVs and PHEVs is to be assessed using the 'well-to-wheel' approach, which goes beyond the power supplied to the vehicle by gas or electricity to include energy consumption efficiency further upstream.

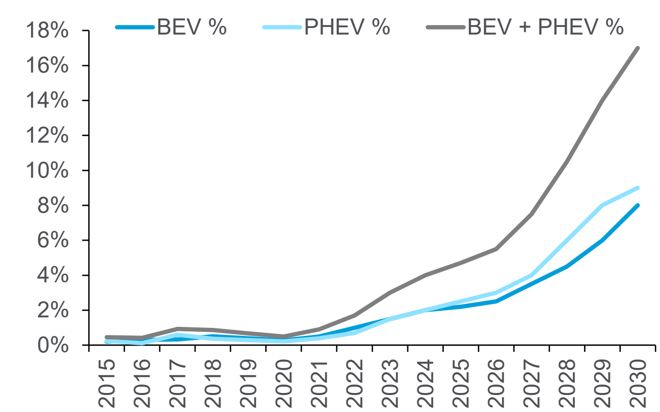
In view of these rules, we expect Japan's powertrain mix to remain tilted toward HEVs for now. HEVs are included in the Green Growth Strategy's EV definition and are also a technology where Japanese auto OEMs have the expertise to easily meet the government's new 2030 fuel-economy standards. Toyota's Yaris EV, for example, gets 36km/liter (in WLTC or Worldwide Harmonized Light Vehicles Test mode), which is far above the 2030 minimum. Japan's use of the well-to-wheel concept will also make it difficult for BEVs or PHEVs to gain an edge in Japan's current power supply mix. BEVs thus look likely to see slower take-up in Japan than in other developed markets, but the fact that Japan accounts for just 20% of Japanese auto OEMs' overall sales volume suggests that they will follow overseas peers in shifting to BEVs in other markets as regulations there are tightened. BEVs could also eventually become more popular in Japan premised on increased use of renewable energy that would have them faring better in the well-to-wheel assessment.

Figure 46. Japan: EV Sales Forecast to ~0.81 Million by 2030



Source: Marklines, Citi Research

Figure 47. Japan: EV Penetration Forecast to 17% by 2030



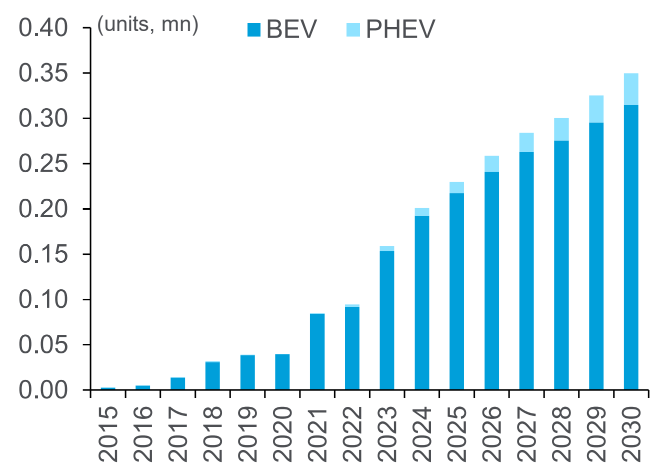
Source: Marklines, Citi Research

Korean Autos: Electrification Inflection into 2021

We believe that Korean automakers could emerge as one of the industry leaders in the upcoming vehicle-electrification megatrend — from being 'fast-followers' in their 40-year history — delivering attractive product offerings such as industry-leading efficiency (driving range) and charging-times, which, in our view, are two major criteria for consumer decisions on mass-market EV models.

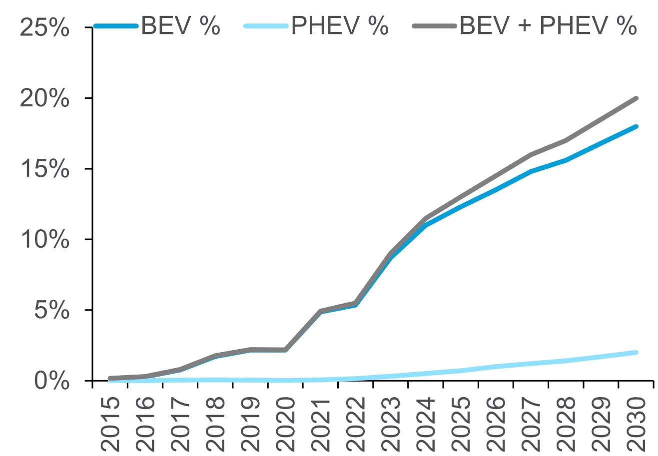
Moreover, earlier adoption of EV-dedicated platform (mass production from 2021, the second-earliest among mass-market auto OEMs in 2020), and a higher ratio of 'in-house' key component production, could lead to Korean auto OEMs having among the fastest ramp-ups in EV business profitability. Battery cell costs and how governments deal with subsidies could work as key swing factors for margins, but our analysis on the EV cost structure indicates Korean auto OEMs will likely deliver similar-or-above profitability from their EV businesses compared to their ICE businesses by 2025, driven by their dedicated platform strategy and higher in-house production rates.

Figure 48. Korea: EV Sales Forecast to ~0.35 Million by 2030



Source: Citi Research

Figure 49. Korea: EV Penetration Forecast to 20% by 2030



Source: Citi Research

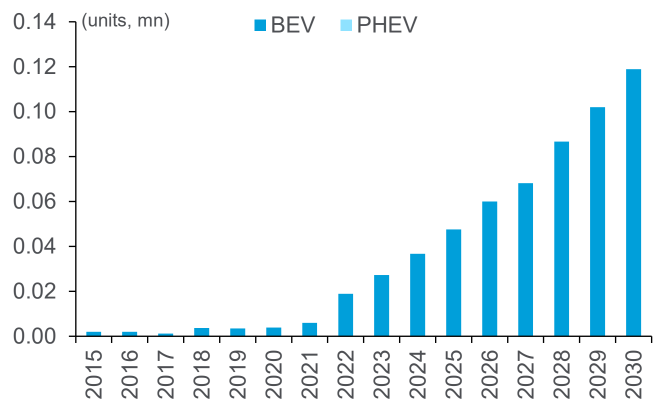
India: Electrification with a Two Wheel Focus

The penetration rate of EVs in India is still limited with many of the challenges previously outlined (high upfront costs, limited infrastructure, and product shortcomings) particularly acute in the region. However, there are nascent signs of increased regulatory pressure to de-carbonize, which will drive the transition to electric.

In short, we think the push for EVs in India is driven by: (1) a concern for reducing pollution; (2) improved performance and lower operating costs for EVs; (3) a gradual reduction in imported crude oil dependence; and (4) compliance with the more stringent CAFE (Corporate Average Fuel Economy) norms.

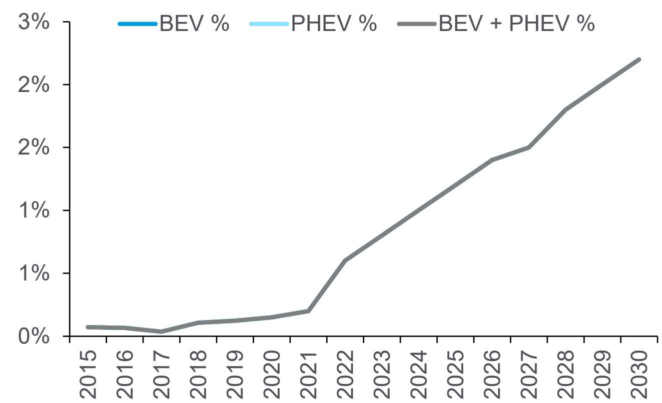
We believe the emergence of lithium cells and battery manufacturing in India is likely to be the key driver for a step-up in Indian EV penetration. However, given cost and infrastructure challenges, we also believe the development of electrified transportation in India is likely to be more heavily focused on two-wheel vehicles rather and four-wheel in the near term.

Figure 50. India: EV Sales Forecast to ~0.12 Million by 2030



Source: Citi Research

Figure 51. India: EV Penetration Forecast to 2% by 2030



Source: Citi Research

Government Policies Targeted at EV Proliferation

The NITI Aayog (a government policy think tank) proposed converting all 3-wheel vehicles (3Ws) to EVs by 2023 and all two-wheel vehicles (2Ws) below 150cc to EVs by 2025.[1] We are uncertain if the government will adopt this recommendation but if it does, we could see a more substantial shift to EVs in these two segments. Over 2020, 2Ws <150cc accounted for over 90% of all 2Ws sold.

Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME)

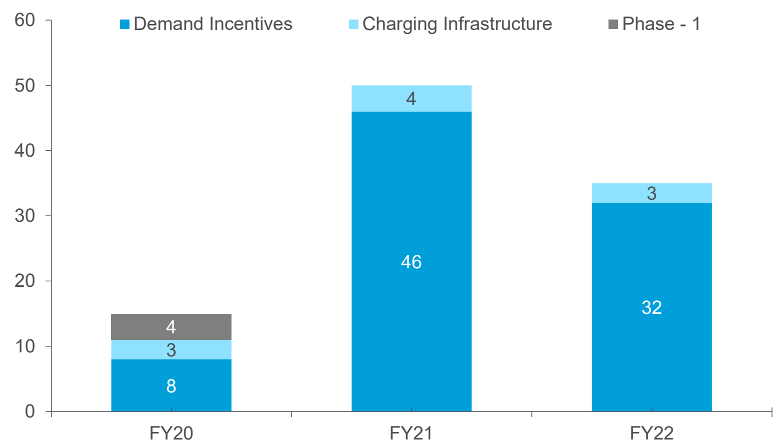
The FAME scheme (launched in two phases) aims to encourage the uptake of reliable, affordable, and efficient electric and hybrid vehicles (xEV).

1. **FAME I** was launched initially for a period of two years, commencing from April 2015 with subsequent extensions approved through March 2019. Under the scheme, total incentives of ~Rs3.6 billion ($49m) for around 280,000 vehicles were disbursed with expected fuel savings of 50 million liters.

2. **FAME II** was launched April 2019, with an initial outlay of ~Rs100 billion ($1.4bn) for a period of three years (FY20-22). Of the total budgetary support, ~86% was allocated to incentives to increase demand for efficient electric and hybrid vehicles in the country. The target is to support 7,000 electric buses (e-buses), 500,000 electric three-wheelers (e-3W), 55,000 electric four-wheeler passenger cars, including strong hybrid (e-4W), and 1 million electric two-wheelers (e-2W). For four-wheelers (including passenger vehicles), the incentives are only for commercial usage and not for private use.

[1] Petroleum Conservation Research Association, “Energy News: July 2019”, http://www.pcra.org/pcra_adm/writereaddata/upload/files/JULYeBOOK2019.pdf.

Figure 52. Break-up of Fund Allocation Under FAME II (Rs bn)



Source: Department of Heavy Industries, Citi Research

Figure 53. Vehicle Segment-Wise Incentives in FAME II

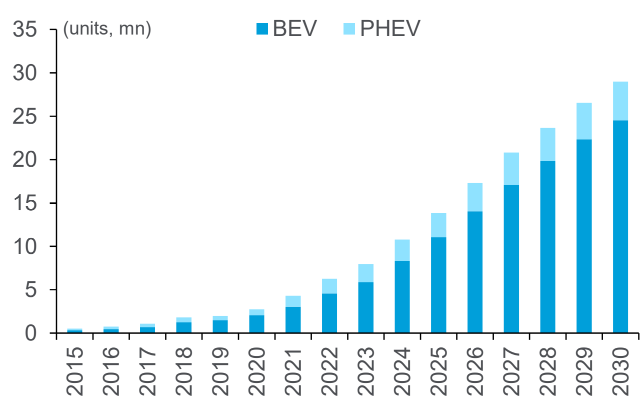
S No	Vehicle Segment	Max number of vehicles to be supported	Approximate size of battery in kWh	Total incentive @ RS10,000/kWh for all vehicles and Rs20,000/kWh for buses and trucks	Max ex-factory price to avail of incentive	Total fund support from Department of Heavy Industries
1	Registered e-2 Wheelers	1,000,000	2kWh	Rs20,000	Rs150,000	Rs20 billion
2	Registered e-3 Wheelers (incl. e-rickshaws)	500,000	5kWh	Rs50,000	Rs500,000	Rs25 billion
3	e-4Wheelers	35,000	15kWh	Rs150,000	Rs1,500,000	Rs5.25 billion
4	4W Strong Hybrid Vehicles	20,000	1.3kWh	Rs13,000	Rs1,500,000	Rs260 million
5	e-Buses	7,090	250kWh	Rs5,000,000	Rs20,000,000	Rs35.45 billion
	Total Demand Incentive			.	.	**Rs85.96 billon**

Source: Department of Heavy Industries, Citi Research

The Last ICE Vehicle in Europe Around 2040

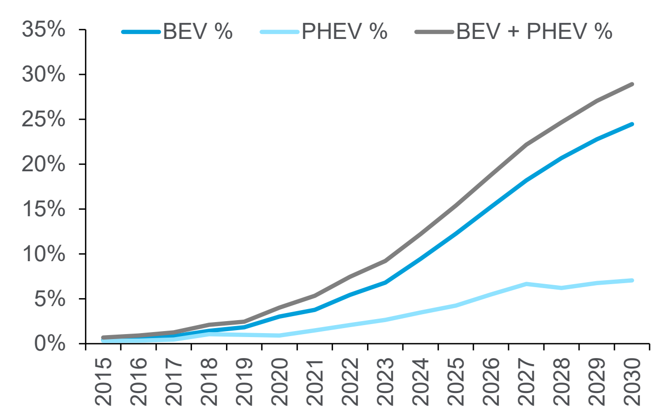
Where we believe the market is yet to fully focus on is around the reality that with EVs approaching cost crossover with ICE powertrains and carbon dioxide targets of net zero in 2050, ICE powertrains are now in structural decline. We have seen a few announcements from governments, such as France and the U.K., about banning new ICE vehicle sales by 2040 and 2035, respectively, but generally these appear to have been overlooked.

Figure 54. Global: EV Sales Forecast to 29 Million by 2030



Source: Citi Research

Figure 55. Global: EV Penetration Forecast to 29% by 2030



Source: Citi Research

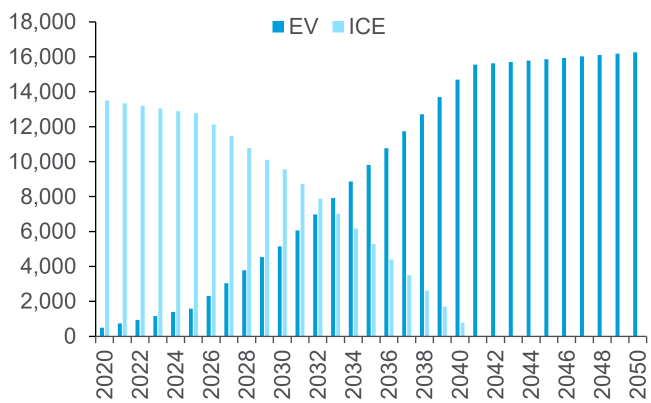
Figure 56. Announced and Proposed Bans for Emitting Vehicles

Country	Data announced	Date ban to be enacted	Type	Scope
Canada	2017	2040	Emitting vehicles	New car sales
Costa Rica	2019	2050	ICE	New car sales
France	2017	2040	ICE	New car sales
Iceland	2018	2030	ICE	New car sales
Ireland	2018	2030 (Draft)	ICE	New car sales
Israel	2018	2030	ICE	New car sales
Netherlands	2017	2030	ICE	All cars
Norway	2017	2025 (tax and usage incentives)	ICE	All cars
Singapore	2020	2040	ICE	All cars
Slovenia	2017	2030 (50g/km CO2 limit)	ICE	New car sales
Sri Lanka	2017	2040	ICE	New car sales
Sweden	2018	2030	ICE	New car sales
United Kingdom	2020	2035	Non-electric	New car sales

Source: Citi Research

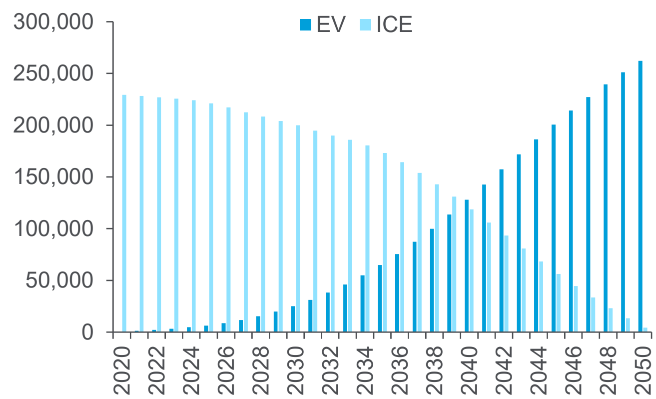
We believe these targets dates for ICE bans are likely to become widely held as governments aim to comply with net zero carbon targets in 2050. With passenger cars having a useful life of about 20 years and the current European fleet having an average life of about 12 years, we estimate the last new ICE car can be sold in 2040 at the very latest (and even then will have a significantly truncated life) if the European passenger vehicle fleet is to reach net zero carbon by 2050. On our forecasts, even if the last ICE passenger vehicle retires in 2050, we estimate the industry will have contributed almost 8,000 metric tonnes (MT) in CO_2 between 2020 and 2050 — around 20% of the EU's entire carbon budget.

Figure 57. European Passenger Vehicle Sales by Powertrain



Source: ACEA, Citi Research

Figure 58. European Passenger Vehicle Fleet by Powertrain



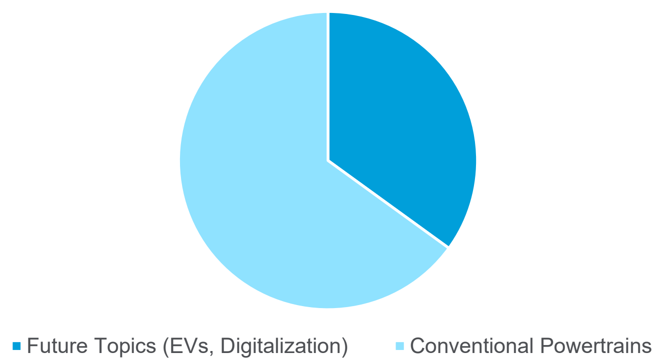
Source: ACEA, Citi Research

Managing a Declining Cost Base: Permanent Restructuring Costs

Thinking about this situation from a purely auto OEM perspective, we see the challenge now evolving from being one of funding the more expensive new technology to managing the cost and capital invested in a rapidly declining legacy technology.

Auto OEMs depreciate land and buildings over a 20-year period and power train investments over 10 to 12 years. While plants can be converted from one technology to another, any investment in a new ICE plant from 2020 onwards is likely to be impaired at some point, and we suspect the increased focus on distinct vehicle platforms will make restructuring plants more difficult. Similarly, any ICE powertrain investment from 2025 onwards is clearly at risk of the same outcome. While auto OEM capital expenditure (capex) guidance is always slightly opaque given the clear limitations to ICE investments, we are concerned that the majority of investment is still directed towards this area, even for the most forward looking of auto OEMs.

Figure 59. OEM Investment Spending on New & Legacy Technology (% of investment 2020-25)



Source: Company Reports, Citi Research

The most concerning aspect, in our view, is the employee base. Employees at European auto OEMs have an average age of around 45 years and their work is overwhelmingly focused on ICE powertrains. In a hypothetical scenario of no new hiring and assuming a retirement age of 65, roughly half of the ICE workforce would leave naturally by 2040. However, this means that roughly half the workforce will need to be repurposed as EV engineers. Given the differences in technology, not to mention the need for fewer employees with less complicated EV vehicles, this is likely to prove a challenging task. Besides, one needs to consider the involvement of the unions who will look to protect member interests. If we were to look to the entire automotive value chain, this issue could impact up to 6% of total European employment and rise as high as 20% in Germany, based on our estimates.

The EV Battery Supply Chain

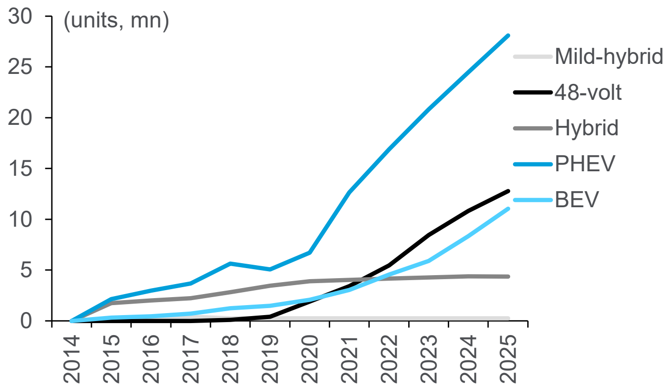
The major difference between the supply chains for internal combustion engine (ICE) and EV vehicles is the battery and associated electronics. The supply and development of the battery cell is vital to the establishment of the EV industry.

Figure 60. ICE vs. BEV Vehicle Manufacturer Suggested Retail Price (MSRP) by Component (€)

Source: Citi Research

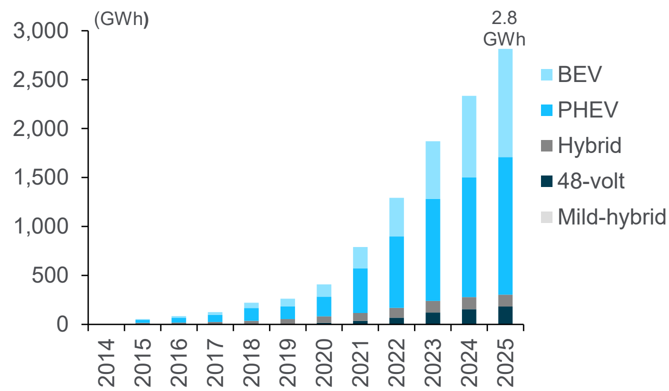
Reflecting the expectation of regulatory-driven demand for EVs, we have seen developments in the battery supply chain. On the demand side, we see global EV cell demand growing to around 2,800 GWh in 2025 and a simplistic analysis of cell supply shows the industry broadly keeping pace. Ignoring short-term friction in building plants in specific regions, we see relatively comfortable levels of cell supply for the market in 2021 and 2022.

Figure 61. EV Global Demand Forecasts (units, mn)



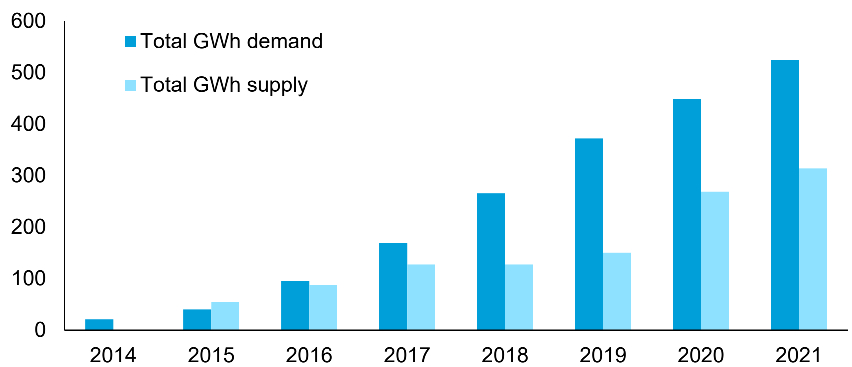
Source: HIS, LMC, Citi Research

Figure 62. Global Cell Demand Forecast (GWh)



Source: HIS, LMC, Citi Research

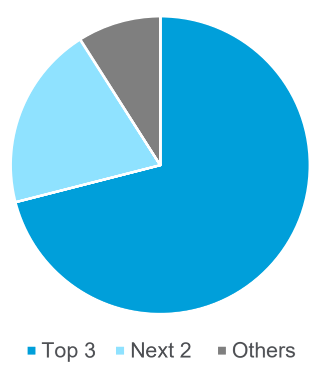
Figure 63. Global Cell Supply/Demand Balance (GWh)



Source: Citi Research

Significant economies of scale in production of battery cells means the sector has been largely dominated by a handful of large players. China's incentives on EVs have also been driving cell capacity supply in the region.

Figure 64. Battery Cell Market Share by Shipment is Dominated by Top 3 Producers (2019)



Source: SNE, Citi Research

Types of Lithium-ion Batteries:

Lithium Cobalt Oxide (LCO): most popular choice for mobile phones, laptops, and digital cameras.

Lithium Manganese Oxide (LMO): used in power tools, medical instruments, and hybrid and electric vehicles.

Lithium Nickel Manganese Cobalt Oxide (NMC): used in power tools, e-bikes and other electric powertrains.

Lithium Iron Phosphate (LFP): used to replace lead acid starter batteries

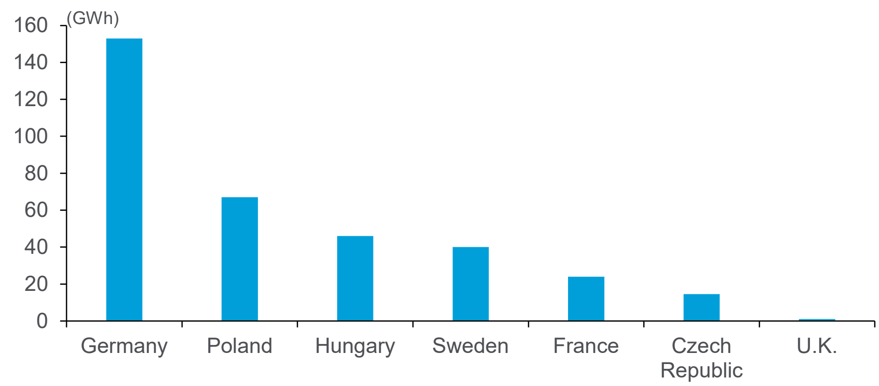
Lithium Nickel Cobalt Aluminum Oxide (NCA): used in EV powertrains

Globally, there are 186 battery cell megafactories in the development pipeline to 2030 (of which 140 are in China), according to Benchmark Mineral Intelligence (BMI). If each plant can produce even 16 GWh of capacity, this indicates over 3,000 GWh of additional capacity could be in the pipeline to 2030. Cell production in Europe is expected to ramp up significantly in the next few years driven by heavy investment from Asian and European manufacturers. Expectations are that European capacity will form around 25% of total global capacity by 2030.

In Europe, there are 17 gigafactories in the pipeline to 2030 (in France, Germany, Hungary, Poland, Slovakia, Czech Republic, Norway, the U.K., and Sweden), which could power at least 6 million EVs, according to the European Commission. At least seven operators are looking at increasing capacity in Germany over the next 10 years. According to BMI estimates, more than 150 GWh could become available to Germany by 2025.

In Poland there is an extensive ramp-up of capacity to almost 70 GWh (reportedly costing €2.5 billion, including €480 million of aid from the European Investment Bank (EIB) and €95 million in aid from the Polish government). The expansion is slated for completion in 2022, two to three years after construction began. It seems likely the new expansion will service cylindrical cells, potentially even putting the new 'form factor' cylindrical cells into production with 5x higher energy density and 6x greater power. In Hungary, two battery cell providers are looking to build out capacity over the next few years, bringing the country’s total battery production capacity to 46 GWh. One battery cell operator in Hungary is expected to begin production of 5th generation technology — with a density of at least 600Wh/L offering 370 miles (600km) of charge. The cells will reportedly be NMC (lithium nickel manganese cobalt oxide) cells in a prismatic-form, with a new cathode material that has a nickel content of >80%, although other reports suggest the operator will start to apply an NCA (Lithium Nickel Cobalt Aluminum Oxide) type of cathode material in Hungary to increase the energy density of its batteries.

Figure 65. European Battery Capacity Pipeline by 2030



Source: BMI, Citi Research

Figure 66. Snapshot of European Battery Plant Investment

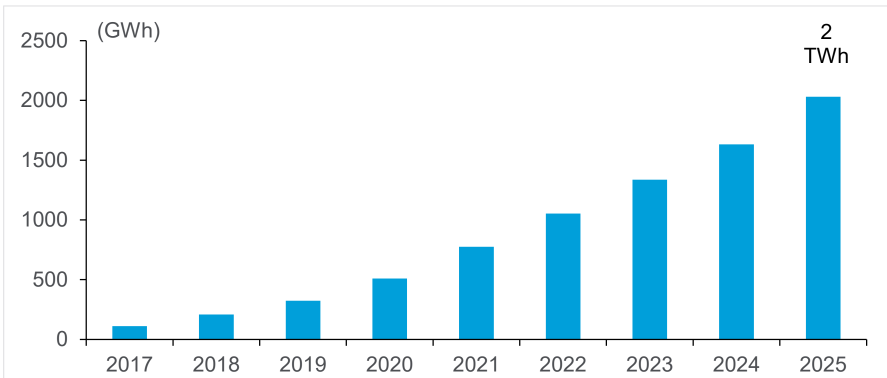
Location	Capital Expenditure ($ mn)	GWh	$/kWh	Operating from	Construction timeframe
Hungary	1,558	10	156	2018 (Plant 1) / 2021 (Plant 2)	2 years / 1.5 years
Hungary	1,621	16.5	98	2020 (Plant 1) / 2022 (Plant 2)	2 years / 2-3 years
Poland	3,034	50	87	2022	2-3 years
Sweden & Germany	4,700	32	147	2024	5 years
Germany	1,951	14	139	2022	2-3 years

Note: Only covers incremental capacity.
Source: Company Websites, automotive-iq, Citi Research

In China, a $1.15 billion expansion is under way in battery production operations along with a plant expansion in Chongqing, which is expected to deliver an additional 20 GWh of cell capacity at a cost of around $1.5 billion with a planned opening date in 2021. In the U.S., there have been announcements of intentions to grow output by an additional 90 GWh by 2022 and to a total of 3,000 GWh by 2030. A capacity rollout of this size and speed — which amounts to a 360 GWh fixed capacity annual increase from 2022-2030 — is unheard of in an industry with a total of only around 285 GWh of global capacity in 2019.

In forecasting battery cell capacity, we take into account industry expansion plans across all regions (with some moderation) and arrive at our global battery cell capacity estimate of ~2 TWh by 2025.

Figure 67. Citi Battery Cell Supply Forecast to 2TWh by 2025



Source: Citi Research

The Consensus View on Battery Development

By 2025, the consensus expectation is (1) for battery potential to reach a maximum energy density of 500 Wh/kg; (2) for battery pack costs to fall to less than $100/kWh (the breakeven point with combustion engines); and (3) for batteries to offer a maximum potential range of over 450 miles. Between now and 2025, consensus anticipates the graphite anode on battery cells will be replaced with a silicon-based anode — leading to a 20-30% increase in energy density while improving both range and recharge speed. Most cells will also likely be cobalt-free, which will help drive down the cost of the battery cell.

By 2030, expectations are for batteries to reach an energy density of 700 Wh/kg. This will be based on solid-state chemistry (polymer-/ceramic-based), which will increase the energy density of the cell. The resultant cell is expected to offer improved range and recharge performance at a lower weight and cost.

Figure 68. Consensus Cell Development Expectations, 2020-2030

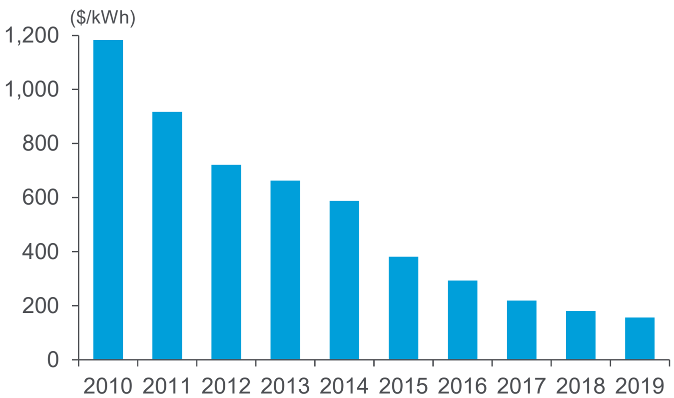
	Stage 1 2015-2020 Generation 2 Battery	Stage 2 2020-2022 Generation 3 Battery	Stage 3 2023-2024 Generation 4 Battery	Stage 4 2025-2030 Generation 5 Battery
Anode	Graphite-based	Silicon-based		Li-metal
Electrolyte	Liquid (e.g., LiPF6)			Solid (e.g. Polymer-/Ceramic-based)
Cathode	Nickel- & Cobalt-based	>90% Nickel	Cobalt free	
Max Energy Density (Wh/kg) (Citi est.)	200-300	300-350	350-500	500-700
Max Range Potential (Citi est.)	250-350 miles	350-450 miles	➢ >450 miles	

Source: Company Reports, BCG, Citi Research

How Quickly Have Things Developed in the Past?

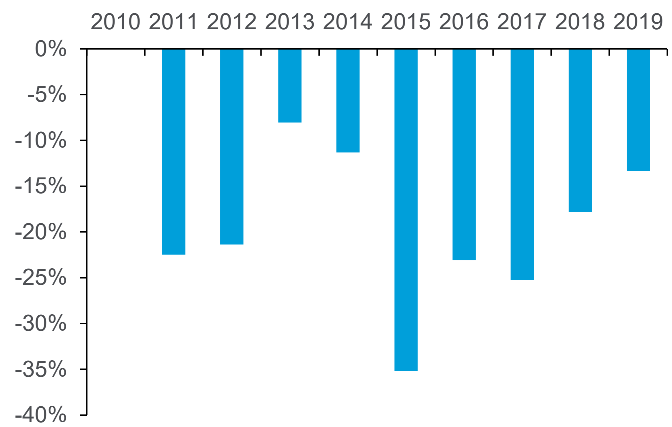
Battery pack cost reductions are predominantly due to increasing energy density in cells as new cell technology is incorporated. Increasing order size and growth in battery electric vehicle sales have also supported cost reductions at the battery pack level. Additionally, the adoption of new pack designs and diminishing manufacturing costs will drive prices down in the near-to-medium term. In order to hit the breakeven point between EV with ICE vehicles, the cost of battery packs need to fall to $100/kWh. With 2019 battery pack costs at $156/kWh, the path to delivering $100/kWh by 2024 looks promising.

Figure 69. Battery Pack Cost ~$156/kWh in 2019



Source: Citi Research

Figure 70. Battery Pack Year-on-Year Cost Reduction (%)



Source: Citi Research

Most electric cars run on lithium-ion batteries designed as an assembly of individual connected battery cells, monitored by a dedicated electronic circuit. The battery systems in most cars are flat and located between the axles in the vehicle's underbody (in the shape of a skateboard). The number of cells, the size of each cell, and the cell arrangement determine the voltage delivered by the battery, its capacity, and its density — all of which affect the performance of an electric vehicle.

The EV Revolution Will be Supply Driven

With consumer and auto OEM demand for BEVs reliant on incentives, the development of the industry is reliant upon the supply chain to find cost efficiencies and technological improvements. This in theory means battery cell suppliers and chemical companies should generate higher returns than the auto OEMs by either refusing to innovate or by gaining volume commitments for products with uncertain profitability profiles.

The reliance on the battery supply chain for technological development leaves the auto OEMs susceptible to disintermediation.

We see three main risks:

- **Faster technological development:** A leap forward in technology meaning BEV products become cost and technologically competitive sooner than expected (demand moves from a regulatory push to consumer pull approach) and old technology becomes obsolete sooner than expected.
- **Irrational is rational:** Easy availability of capital results in vertical integration by disruptive players (new entrants are able to gain a competitive advantage by building their own battery supply even if this is dilutive for short-term shareholder returns).
- **Political curve ball:** With the prospect of EV products surpassing ICE vehicles from a performance and consumer cost perspective, regulators will likely come under pressure to support a faster transition to lower-emission technology.

1. Faster Technological Development

Improving technology can only serve to accelerate the adoption of EVs. With costs already approaching parity with ICE vehicles and likely to fall further, range and charging speed are also improving. The key risk for incumbents seems to be the potential for this technological development to occur faster than expected.

In this scenario, the costs of restructuring the legacy ICE cost base will prove a greater burden while the negative mix effect of selling lower-margin EVs, especially if these increasingly substitute for high-margin large SUVs, will prove painful.

EVs Upending the ICE Value Chain

The automotive ICE value chain is characterized by high levels of competition among the auto OEMs who dictate the returns within the industry as they look to balance scale, fixed cost utilization and pricing power. No other aspect of the value chain has seen returns exceed the auto OEMs sustainably.

Figure 71. ICE Value Chain – Return on Invested Capital (ROIC)

Source: Company Reports, Datastream, Citi Research

Figure 72. EV Value Chain – Return on Invested Capital (ROIC)

Source: Company Reports, Datastream, Citi Research

The EV value chain shows some dramatic differences. Namely the auto OEMs are likely to make a negative return on capital (thin profit margins and likely shorter-than-expected lifecycles on products and R&D investments) while cell manufacturers and chemical companies have superior returns on capital (even if these are now falling). Crucially this dynamic provides limited incentive for the incumbent players to accelerate technological development. The auto OEM has no wish to sell more return-dilutive products than necessary and the supply chain does not want to develop technology faster than planned as it will make current investments obsolete far sooner than expected.

The Incumbent Plans for EV Technology

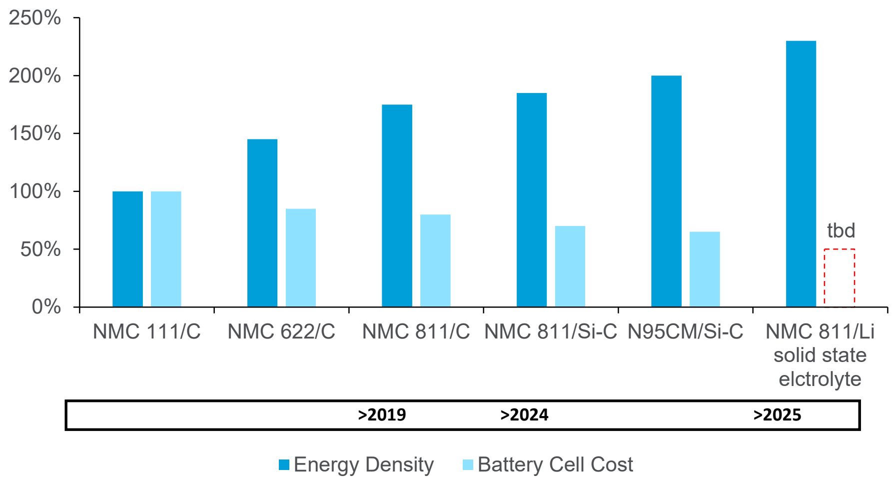
Current industry planning is based around the broad assumption that BEV vehicles remain inferior to ICE vehicles until around 2025 on either a cost or performance basis. This rate of change means that auto OEMs are not planning for regulatory-driven demand until after 2025. This gradual adoption and improvement in technology will allow auto OEMs to slowly manage down their ICE powertrain businesses and match the duration of capital expenditure with depreciation and new model cycles.

BloombergNEF forecasts average battery cell costs were around $156/kWh in 2019, moving to $100/kWh by 2023, an expected reduction of 36% over 4 years.

Looking at future cell progression, one of the large European auto OEMs aims to have the following cell technology in their EV batteries:

- NMC 811/C cell between now and 2024;
- NMC 811/Si-C cell by 2024, with the Si-C (silicon carbon composite) anode in final development;
- N95CM/Si-C battery cell in the lead up to 2025, with > 90% Nickel cathode in final development; and
- NMC 811/Li solid-state electrolyte by 2025.

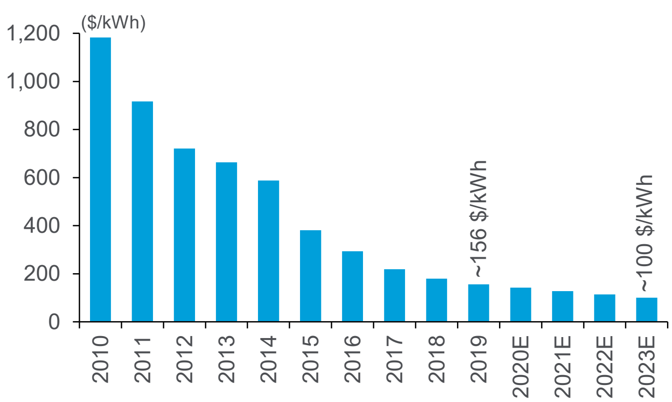
Figure 73. Battery Cell Chemistry Development



Source: Company Reports, Citi Research

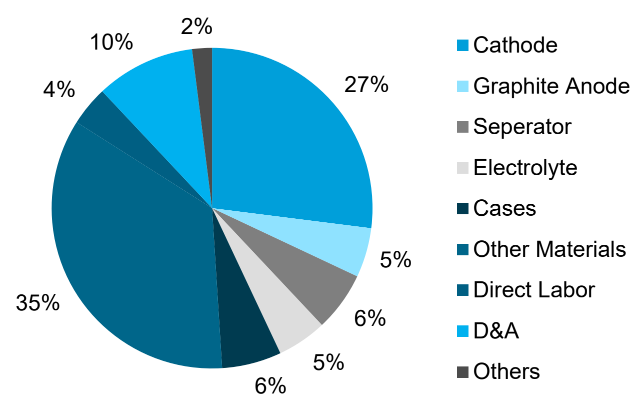
The capital expenditure required for a 10 GWh plant is anywhere from $500 million to $1.6 billion. This shows the variance in cell costs per producer.

Figure 74. Battery Pack Costs Forecast to Fall to $100/kWh



Source: Citi Research

Figure 75. Sample Battery Manufacturer Cost of Goods Sold Breakdown (2017)

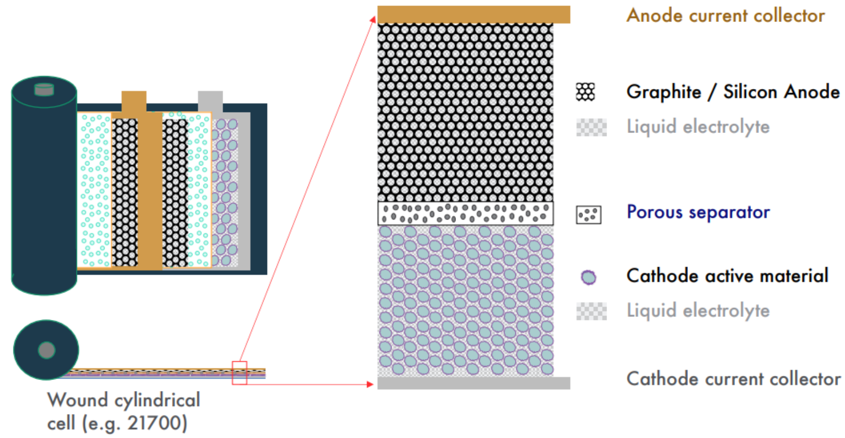


Note: Other Materials includes copper foil, packs, BMS, etc.
Source: Citi Research

What Drives Battery Performance?

The key characteristics for a battery include its capacity, voltage, output power density (acceleration), and battery energy density (endurance). Battery capacity (maximum energy exertion in kWh) affects range, top speed, and acceleration. Higher voltages lead to lighter-weight batteries, smaller motors and interconnectors, greater efficiency, less heat, and faster charging.

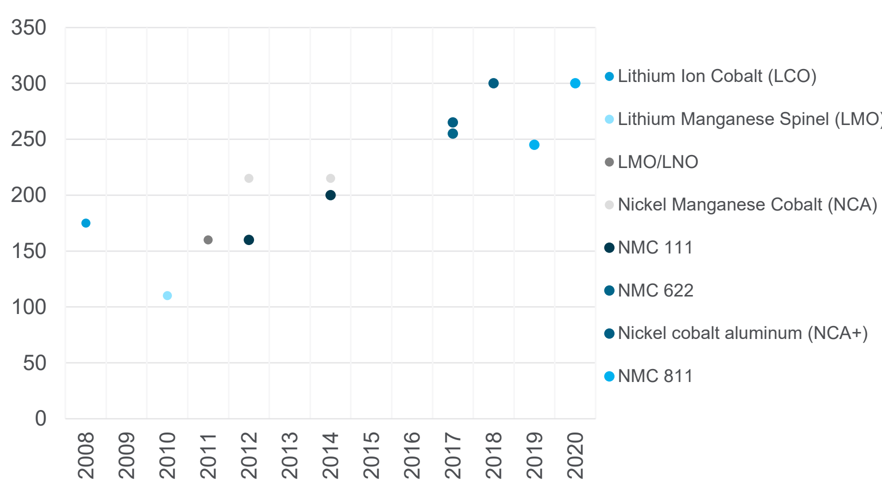
Figure 76. Lithium Ion Battery Cell Chemistry (e.g., 21700 cell)



Source: Company Reports, Quantum Scape, Citi Research

Energy density is the amount of energy that can be stored in a battery pack relative to its weight. An increase in energy density means more efficient energy extraction from a battery pack of the same weight, which translates directly into vehicle range. The chart below shows the improvement of lithium-ion battery cell densities over the past decade. At present lithium-ion technology represents the best compromise between capacity, volume, and mass in EVs, offering high voltage, straightforward recharging, and durability. Battery energy density helps explain why a Tesla Model-S battery pack weighs 2x the Nissan Leaf battery pack, yet delivers 3x more driving range.

Figure 77. Battery Cell Density Progression, 2008-2020 (Wh/kg)



Source: Citi Research, BNEF

How Quickly Will Things Develop in the Future?

The next decade will bring about rapid change in EV batteries. At present, EV battery packs are not completely commoditized, with different batteries from different producers offering different specifications and performance. We expect the long-term development of the battery industry to move towards a more concentrated and standardized process. There are two key drivers for battery performance and cost: the cell chemistry make-up and cell design.

Cell chemistry developments:

Figure 78. Energy Capacity from Graphite Anode to Silicon-based Anode

	Capacity (mAh/g)
Graphite	360
Graphite +SiOx	500-600
Si - C Composite	1200

Source: Citi Research, Company Reports

- **Silicon anode cells** are expected to deliver a 20-30% jump in energy density, improving both range and recharge speed. Many lithium-ion batteries today use graphite anodes, which have hit their limitations for power and energy density. By contrast, silicon anode batteries can fast charge to over 80% of their capacity in 5-10 minutes, without physically damaging the battery. Cost remains a hindrance to increasing the silicon composition in the anode as it mostly cannot be used in its natural occurring state (because of its expansion properties); however, some manufacturers are working to use naturally-occurring silicon (as opposed to synthetic silicon), which is estimated to reduce costs by 5% and increase battery range by 20%. Leading up to 2025, we expect continued increases in the silicon content in batteries to the extent where developments will enable silicon-dominant anodes.

Figure 79. Energy Capacity from Nickel Cobalt Cathodes to a >90% Nickel Cathode

	Capacity (mAh/g)
NMC 111	150
NMC 532/622	180
NMC 811	210
>90% Ni	230

Source: Citi Research, Company Reports

- **Cobalt-free cathodes** are expected to replace current nickel and cobalt cathodes. Eliminating cobalt from the cell will work to drive down cost, as cobalt is an expensive and controversial mined resource. Conversely, nickel, which already forms part of the cathode, is relatively cheap while achieving a higher energy density. Aside from cost, this change will incrementally drive performance, potentially extending vehicle ranges >400 miles between charges, and enable batteries to last as long as 1 million miles. Estimates have been made that high nickel cathode (0% cobalt) development will lead to a 15% reduction in $/kWh at the cathode level. Cobalt-free battery production is expected to begin in June 2021, likely the world's first mass-produced cobalt-free battery.

- **Solid-state batteries** have a greater energy density than today's lithium-ion batteries, enabling longer ranges. They are also lighter, more economical, and have faster recharge times. Consensus is that large-scale industrial production is likely to be about 10 years away, however some proponents suggest this may be achievable sooner. The solid-state technology should offer improved vehicle performance by reducing the size (~40%) and cost (~20%) of the cell.

Cell Design Developments:

Cell design and structure are prominent features in overall cell cost and performance. At present, there is no universally-accepted cell design; however, most automakers making electric vehicles are using pouch cells.

- **Cylindrical cell** advantages are that is has high specific energy, is mechanically stable, and has a relatively straightforward production process in automated manufacturing. Most importantly, the cylindrical cell design has a low cost, and offers a longer useful life but it does not deliver on energy density (and is heavier) compared to other cell designs. Compared to other cell types, cylindrical cells can be produced much faster so more kWh per cell can be produced every day equaling lower $ per kWh.

- **Prismatic cell** is space-efficient — either jelly-rolled or stacked — but it can be more expensive to manufacture than the cylindrical cell. Prismatic cells are also less efficient in thermal management and have shorter life cycles than the cylindrical design.

- **Pouch cell** offers a simple, flexible and lightweight solution to battery design, using laminated architecture in a bag — which is both light and cost-effective — but can shorten the battery life span if exposed to humidity and high temperatures. Pouch cells operate optimally with light loading and moderate charge times.

Improvements in technology gives prismatic and pouch cells the potential for greater capacity than the cylindrical format. Flat-cell designs are getting price competitive and battery experts predict a shift towards these cell formats, especially if the same performance criteria of the cylindrical cell are achievable.

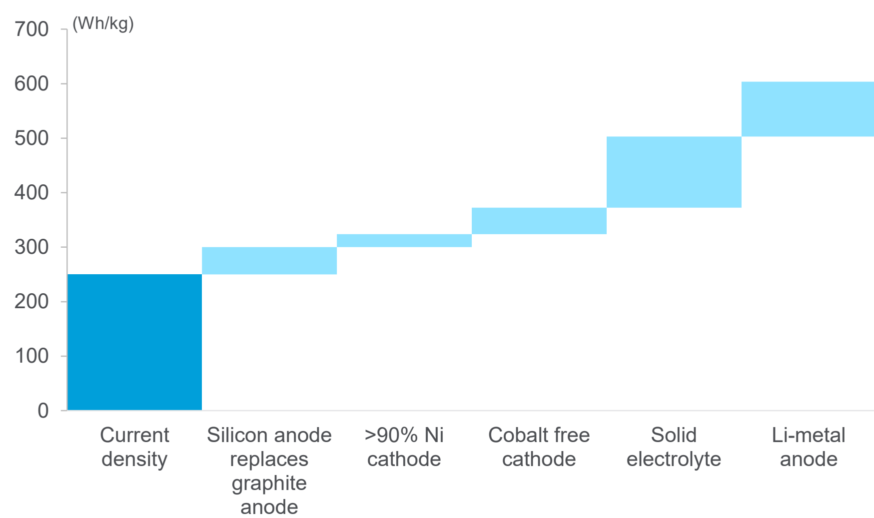
Cell Production Process/Assembly:

The cell production process and assembly also drives cost at a battery pack level. Over time, pack assembly is expected to benefit from increased volume and standardization of components. Battery cell producers have announced design plans that bring production benefits: the materials can be handled through continuous roll processing by laser-patterning the anode and cathode for direct connection, rather than attaching separate tabs, delivering substantial gains in production speed. There are also design plans for a new dry electrode coating process to replace the wet process, which would lead to a 10x reduction in required plant footprint and a 10x reduction in energy consumption. But this dry mix technology is still in a very early stage. Some European auto OEMs are setting up plants to assemble packs after purchasing the cells from an external supplier, giving them direct oversight and flexibility with cell assembly.

How Quickly Are Cells Changing?

New EV battery chemistries are being adopted faster than in the past. On average, a significant jump in energy density has occurred every three to five years. NMC 811 (80% nickel, 10% manganese, and 10% cobalt) has the highest energy density in mass-produced cells to date (300Wh/kg), producing almost 2x the energy density of the NMC 111 cell.

Figure 80. Citi Forecast Changes to Cell Energy Density, 2020-2030



Source: Citi Research, Company Reports, BNEF

The second wave of NMC 811 batteries will see silicon added to the graphite anode and the next step in LFP (lithium iron phosphate), which despite having a lower energy density compared to NMC, are safer and offer a better cycle life than NMC batteries.

Crucially, the NMC 811 is an improvement of existing technology on the market, rather than a distinct, novel chemistry. Upcoming changes in cell chemistry (silicon anode cells, lithium-iron-phosphate cathodes, and solid-state cells) will require a greater shake-up of battery production. Developments in cell design also threaten existing battery production infrastructure. While EVs continue to be produced with different battery and cell make-ups, with technological improvements occurring across cell designs, technological jumps threaten the use-case for existing battery production technology.

Changes in battery cell chemistry and design have been relatively quick to date and it seems this pace may increase further on the brink of significant breakthroughs in cell technology. One manufacturer gives a battery development timeframe showing it took six years to move from first generation battery technology but only four years to move to third generation from second generation technology.

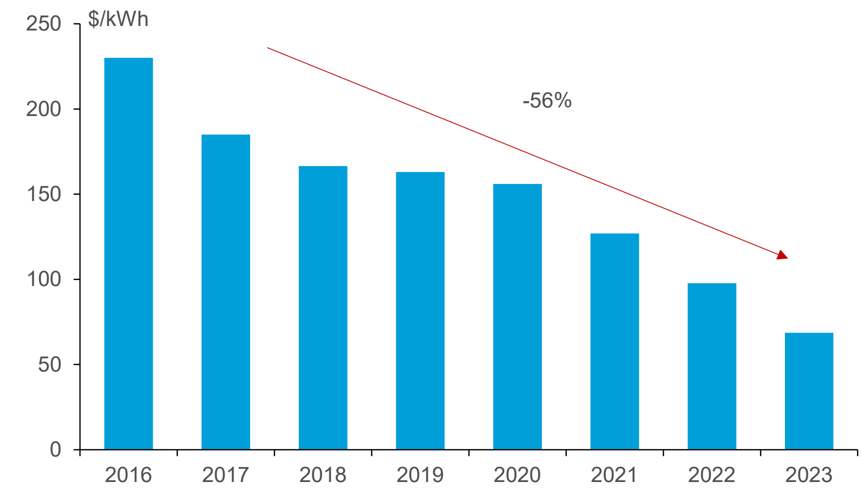
Modeling out the upcoming changes in battery technology we anticipate Battery Gen 3 is already under way, with cell chemistry in the anode moving from graphite to silicon and some cells offering a very small cobalt percentage. Recent changes in cell design combined with the chemistry alterations will likely lead to a step-change in density of 300-350kWh. We anticipate this rate of change will likely increase; we already see LFP (no cobalt) cell designs enter production. Consequently, we anticipate cobalt-free cells be commonplace from 2023/2024, indicating fourth generation of battery technology is likely two to three years away (refer to Figure 68).

What if Disruption Happens Sooner?

We believe one of the major threats to the incumbents within this framework is for a disruptive innovator to accelerate the technological change. With capital widely available for long duration technology companies, we have seen an increased focus on investments that could see battery technology develop more rapidly than expected.

Indeed some auto OEMs at the forefront of the EV market believe that by investing along the value chain to accelerate cell chemistry development and increasing scale, cell costs can be reduced significantly faster than the forecasts outlined above.

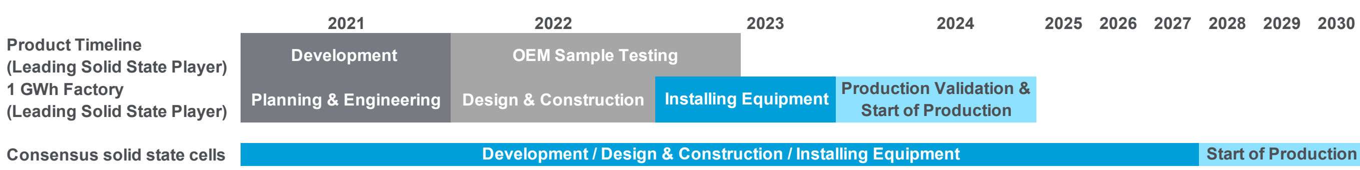
Figure 81. Aggressive EV Cell Forecasts



Source: Citi Research

Another area of potential disruption comes from the development of solid-state batteries. To date the consensus view on solid-state batteries is that widely commercialized technology will only become available from 2030 onwards, with most R&D still grappling with scaling the cells and finding a cell chemistry that works at room temperature. However, recent capital raisings have highlighted a number of new entrants, suggesting these companies are fully financed to deliver commercial solid-state cells starting in 2024. This increases the probability new technology will be delivered sooner than expected.

Figure 82. Disruptive Solid-State Production Timeline



Source: Citi Research, Company Reports

2. Does Irrational Behavior Become Rational in an EV World?

The rapid development of EV technology opens the door for disruption of the existing automotive landscape. We see this occurring in two main areas:

- **Competition for EV market share:** The highest margin EV products are the ones that allow the sale of credits to other auto OEMs. At the same time, the most margin dilutive and brand damaging action an auto OEM can take is to be fined for failing to sell enough EVs. On this basis we believe an EV price war/arms race is likely to erupt as auto OEMs use new technology and competitive pricing to attempt to win market share.

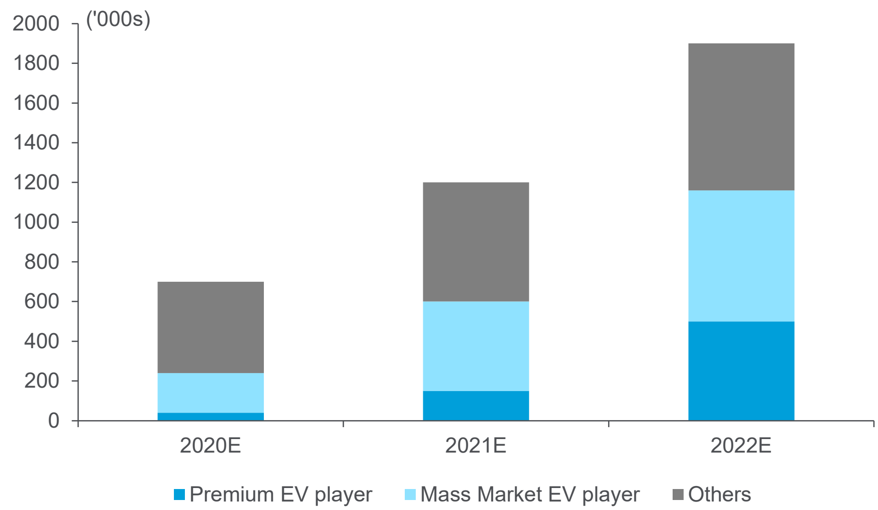
- **Vertical integration:** With technological development dictated by the supply chain, we can see a clear incentive to deploy capital in vertical integration as a means of gaining a technological edge.

A Battle for EV Market Share

Historically, the largest producer of BEV vehicles globally has failed to sustainably make a profit on its product offering despite its premium positioning. While this is partly explained by investment it also suggests a willingness to forsake short-term profitability to aid the faster development of the EV market. On this basis the greatest threat we see to its competitors is its willingness to continue investing in market share gains through price competition.

Looking at current production plans disclosed by auto OEMs and comparing them to our cell production capacity forecasts, we have identified a developing disconnect. Based on announced plans, we estimate two auto OEMs are targeting around two-thirds of the European BEV market between them in in 2022. With eight other auto OEMs all offering BEV products, either expectations for consumer adoption are significantly too low or a price war will ensue.

Figure 83. Top 2 Players to Account for 2/3rds of European BEVs by 2022E



Source: Citi Research

The Return of Model Cycles

While the phenomena of model cycles has weakened in recent years, historically auto OEMs have seen significant market share gains and losses around the launch of new models. Model cycle impact has diminished as ICE products are increasingly commoditized. However, in an EV world it seems likely technological improvements, particularly at the battery level, will result in the re-emergence of the model cycle.

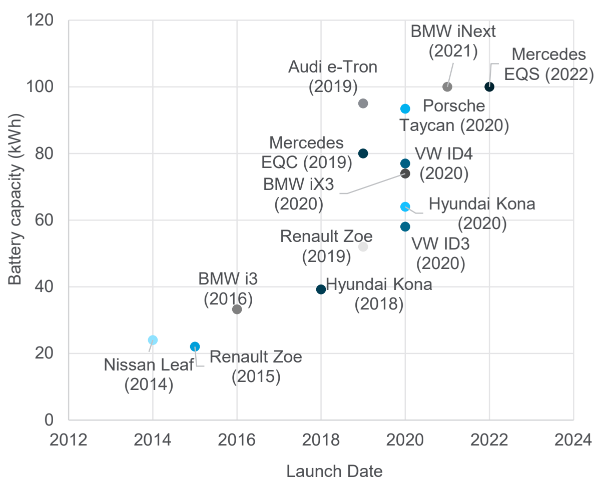
An added complication of a model cycle for EVs in Europe is the existence of supercredits, which are incentives given to auto OEMs for putting zero- and low-emission vehicles on the market. Supercredits from EVs can be used to offset the sale of higher margin ICE vehicles. However, if the supercredit at an auto OEM is exhausted, any significant EV market share losses are likely to result in fines relating to failure to comply with CO_2 emission targets. These fines equate to €95 per g/km for each unit the auto OEM falls short of its average new vehicle sales CO_2 target.

How Performance Has Evolved

From a technological standpoint we have seen the performance of BEV vehicles improve almost sixfold since 2014. While this is a slightly unfair comparison given the huge advances in technology, it is worth noting the 2021 BMW iX is expected to have 50% more range than the 2019 Audi e-tron while the 2021/2022 Mercedes EQS will have 80% more range than the 2019 EQC. Perhaps most interesting is the Tesla Model S reboot which is suggested to have a further 15% more range than the EQS.

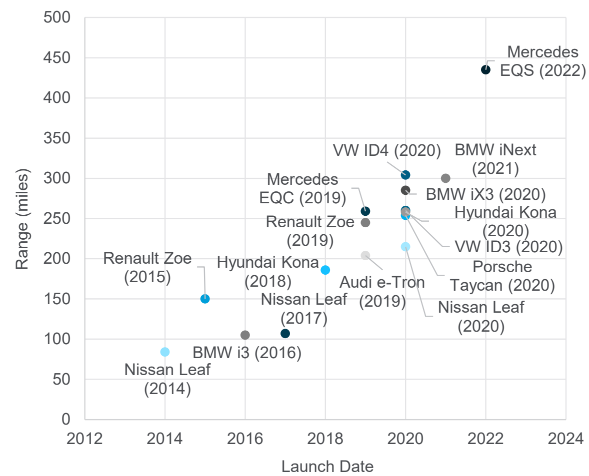
In the charts below we have excluded Tesla which has been an outlier in terms of performance with its models achieving ranges in excess of 250 miles since 2012/13 with the launch of the Model-S. However, it is worth noting these vehicles were targeted at a different price segment to the competing models in the market. This range is now expected to exceed 420 miles with the 2020 Model-S Plaid, highlighting Tesla's continuing technological advantage over the incumbents even as their EVs targeting the premium segment come to market.

Figure 84. Vehicle Battery Capacity by Model Launch Date



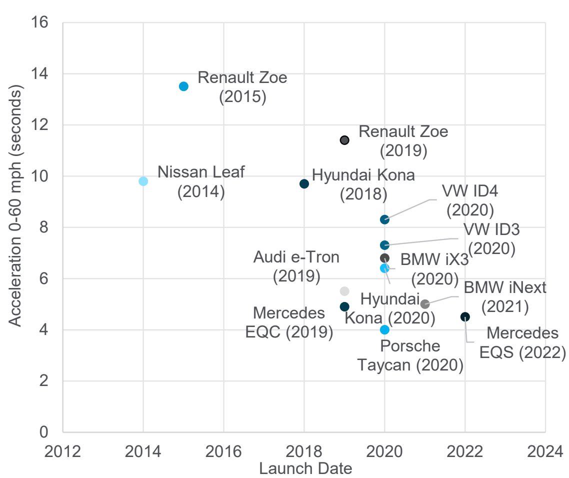
Source: Citi Research, electrek, EV-database.org, car magazine, carwow, The Week, cleantechnica

Figure 85. Vehicle Battery Range by Model Launch Date



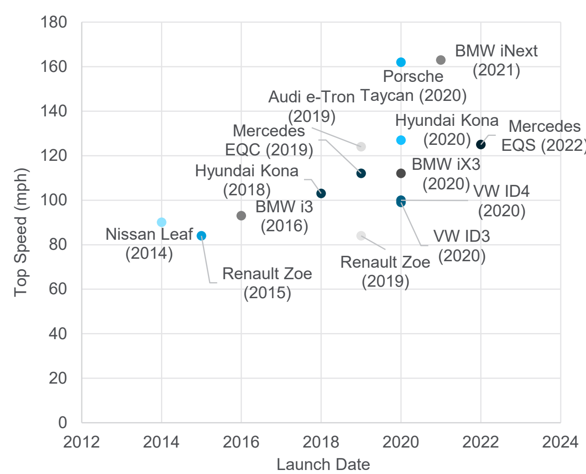
Source: Citi Research, electrek, EV-database.org, car magazine, carwow, The Week, cleantechnica

Figure 86. Vehicle Acceleration (0-60mph) by Model Launch Date



Source: Citi Research

Figure 87. Vehicle Top Speed by Model Launch Date



Source: Citi Research

The Case for Vertical Integration

When we look at the historic technological development of battery cells it is notable that much of it relies upon the anode and cathode development, which is driven by the chemical companies rather than the cell OEMs. Indeed, looking at the new disruptive players in this market, it is their separator and anode technology which is key to their technological leadership.

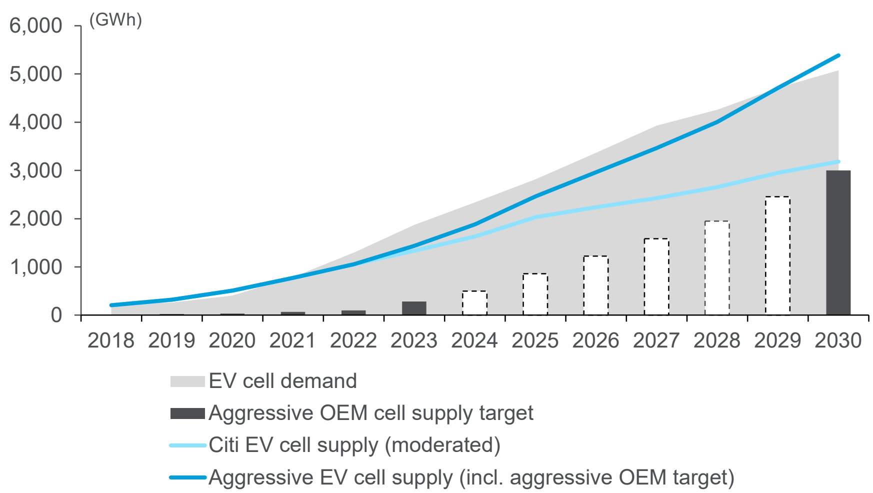
From a consumer and automotive OEM perspective this technological development of the EV supply chain is key to product differentiation. In this regard the auto OEMs are wholly reliant on the supply chain for the pace of change and the capacity to support consumer demand. Looking at recent announcements by disruptive players the potential benefits from greater control over the supply chain is obvious.

Building Sufficient Battery Supply

A major challenge facing the EV world is delivering a sufficient supply of cells to meet demand. This challenge will become even more acute if improving technology results in consumer demand that is greater than expected.

To date it, the cost of a new battery cell plant costs is about €100 million per gigawatt hour of cell capacity, using the costs for the most recent plant in Poland as an example. This plant has taken around two years to be constructed. Expectations are that going forward this timeline can be reduced slightly but one to two years seems like a reasonable construction timeframe. Given that cell producers expect the useful life for the machinery within their plants to be four to five years, it seems reasonable that the technology they are offering could be as much as seven years old.

Figure 88. Cell Supply Forecasts Include Aggressive OEM Targeted Full/Moderated Capacity Expansion



Source: Citi Research, Company Reports, MBI, BNEF

This likely means there will likely be an S-curve in battery capacity growth as plants offering early cell forms become comparatively obsolete and new cell capacity is only just now being constructed to meet mainstream demand. Capacity forecasts by manufacturers are clearly well ahead of expectations for the wider industry and for these expectations to be fulfilled it seems likely there will be significantly higher levels of capital expenditure deployed to cell capacity than currently forecast.

The Technological Advantage of Vertical Integration

Beyond a potential capacity need there is also a potential technological edge that can be gleaned from vertical integration. With the auto OEMs highly reliant upon the battery supply chain for technological development there seems limited scope for differentiation in products. However, early access to a step-change in technology through vertical integration may provide a product edge either through cost or performance.

In this regard it is worth contrasting what the disruptive players in the industry are suggesting versus the incumbents. With most incumbent cell suppliers operating on a four to five year depreciation cycle, it seems likely that it will be 2025 before 4th generation battery technology will become widely available even before considering the time taken to ramp up production capacity.

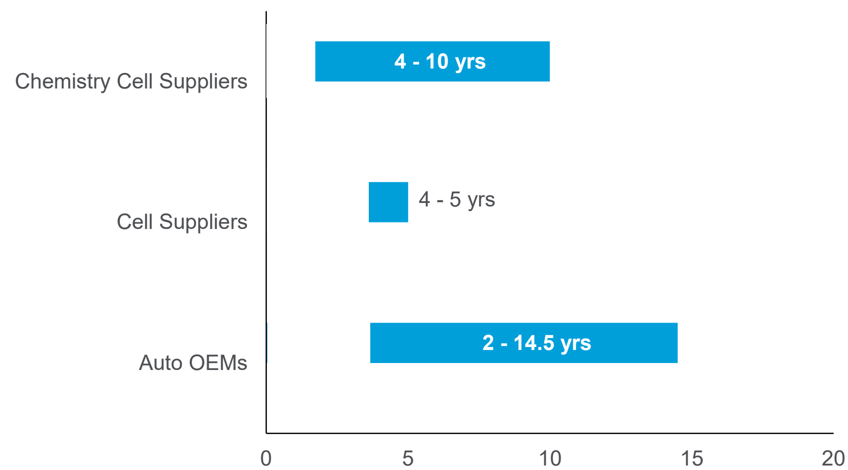
Figure 89. Example of Evolving Battery Development Timeline

	2010	2016	2020
	1st Gen	2nd Gen	3rd Gen
Range (miles)	<125	125-315	>315
Rapid charging (80%)	60mins	40mins	30mins

Source: Citi Research, Company Reports

In this regard it is worth remembering that cell suppliers are highly reliant upon the chemical companies designing anodes and cathodes who also operate on a four to 10 year useful life policy for investment.

Figure 90. Machinery Depreciation Policy: OEMs, Cell Suppliers & Cell Chemistry Suppliers



Source: Citi Research, Company Reports

Turning to the disruptive players, some have indicated they can have a commercial solid-state battery in production by 2022, which would be readily scalable should capital be available at this point. The same players also indicate they believe battery cell costs will be reduced significantly before 2023 and deliver significantly higher range. Should these plans be delivered there is scope for several of the existing cell suppliers to be disrupted and for OEMs to offer a differentiated product in the market in terms of price or performance.

Who has the Capital and Will to Vertically Integrate?

Vertical integration obviously comes with risks of diluting returns and uncertain technological life-cycles. While this might pressure short-term financial performance it clearly raises larger downside risks for the OEMs unwilling to be involved in this practice.

3. Political Curve Ball?

The greatest unknown and hardest to predict change is regulation and the politicization of the EV transition. From a regulatory standpoint the incumbents in the automotive industry seem to be running counter to the prevailing zeitgeist. Over the last decade the auto industry profit pools have become almost directly correlated with selling larger and more powerful vehicles which is becoming politically less palatable.

We outlined the difference in CO_2 emissions and tax levels across Europe in Figure 8 and Figure 11 earlier in the report. While the punitive taxation on large vehicles in France and the Netherlands has captured headlines, the short-term impact is likely limited as few large polluting vehicles are sold in these countries. Looking to the rest of Europe, particularly Germany and the U.K., we see two options for lowering CO_2 emissions: (1) raising taxes for high margin polluting vehicles or (2) increasing incentives for low margin and low emission BEVs. Neither scenario will be accretive for profits at the incumbent auto OEMs.

The German government has already raised purchase taxes on larger vehicles (at the margin) and despite this, the Green party is still polling strongly ahead of the upcoming September elections. In the U.K. we expect to see proposals for higher taxation accompanying the 2021 budget statement in early March.

From a tax perspective one of the challenges facing European governments in particular in the transition to low emission transportation will be the loss of fuel duty. In the U.K., fuel duty amounted to around £30 billion in tax receipts and represented almost 4% of government expenditure.

Figure 91. Fuel Duty by Country (2019)

Country	Petrol		Diesel	
	Per Liter in EUR	Per Gallon in USD	Per Liter in EUR	Per Gallon in USD
Austria	€ 0.48	$2.14	€ 0.40	$1.79
Belgium	€ 0.60	$2.68	€ 0.60	$2.68
Bulgaria	€ 0.36	$1.61	€ 0.33	$1.47
Croatia	€ 0.52	$2.32	€ 0.41	$1.83
Cyprus	€ 0.43	$1.92	€ 0.40	$1.79
Czech Republic	€ 0.50	$2.23	€ 0.42	$1.87
Denmark	€ 0.63	$2.81	€ 0.43	$1.92
Estonia	€ 0.56	$2.50	€ 0.49	$2.19
Finland	€ 0.70	$3.12	€ 0.53	$2.37
France	€ 0.68	$3.04	€ 0.59	$2.63
Germany	€ 0.65	$2.90	€ 0.47	$2.10
Greece	€ 0.70	$3.12	€ 0.41	$1.83
Ireland	€ 0.59	$2.63	€ 0.48	$2.14
Italy	€ 0.73	$3.26	€ 0.62	$2.77
Latvia	€ 0.48	$2.14	€ 0.37	$1.65
Lithuania	€ 0.43	$1.92	€ 0.35	$1.56
Luxembourg	€ 0.46	$2.05	€ 0.34	$1.52
Malta	€ 0.55	$2.46	€ 0.47	$2.10
Netherlands	€ 0.79	$3.53	€ 0.50	$2.23
Poland	€ 0.39	$1.74	€ 0.34	$1.52
Portugal	€ 0.64	$2.86	€ 0.49	$2.19
Romania	€ 0.44	$1.96	€ 0.41	$1.83
Slovakia	€ 0.51	$2.28	€ 0.37	$1.65
Slovenia	€ 0.55	$2.46	€ 0.47	$2.10
Spain	€ 0.50	$2.23	€ 0.38	$1.70
Sweden	€ 0.65	$2.90	€ 0.46	$2.05
United Kingdom	€ 0.65	$2.90	€ 0.65	$2.90
Average	€ 0.56	$2.48	€ 0.45	$2.00

Source: Tax Foundation, Citi Research

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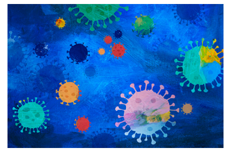

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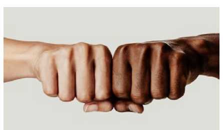

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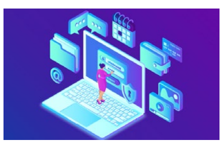

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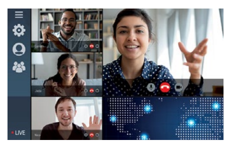

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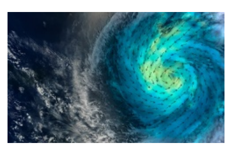

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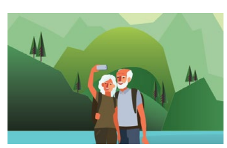

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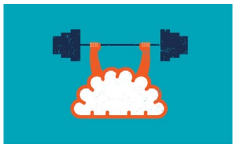

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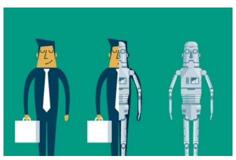

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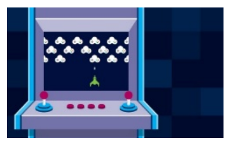

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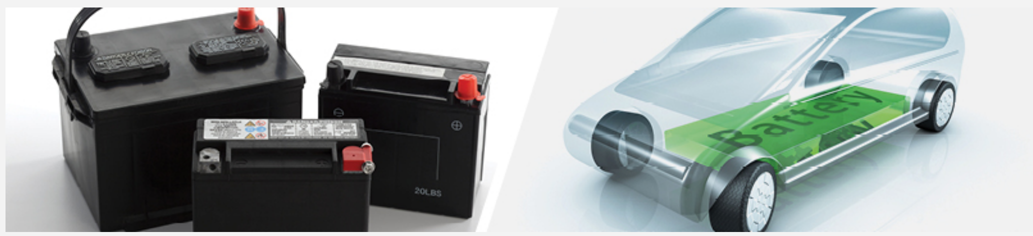
Key Insights regarding the future of Electric Vehicles

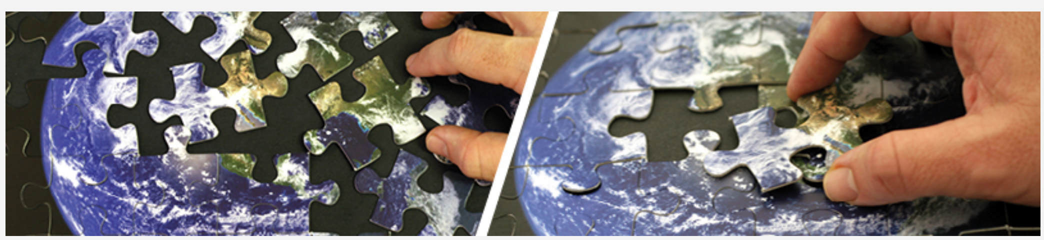
INNOVATION

Advancements in battery technology are lowering costs and improving the performance of EVs. Disruptive players are vertically integrating in the EV supply chain, helping accelerate technological development. / The industry expects solid-state batteries – the most advanced cell technology – to be commercially available from 2030, but disruptive players that are fully funded may deliver starting in 2024.



REGULATION

The Paris Climate Agreement is a major driver behind Europe's push to lower carbon emissions in the auto sector. The EU is aiming for a fleet-wide average emission target of 95gCO_2/km (up from 130gCO_2/km), applicable to 95% of new EU fleet in 2020 and 100% in 2021. / The EU is also targeting a 15% reduction in fleet-wide carbon dioxide emissions for passenger vehicles by 2025 and 37.5% by 2030.



SPENDING POWER

Government subsidies have made EV pricing more competitive with those of internal combustion engine (ICE) vehicles, but performance limitations have largely confined EVs to a niche market for short-range vehicles. / A race among auto manufacturers for a technological edge over competitors could enable EVs to surpass ICEs as a superior product sooner than expected, leading to a shift from regulatory-driven to consumer-led demand.