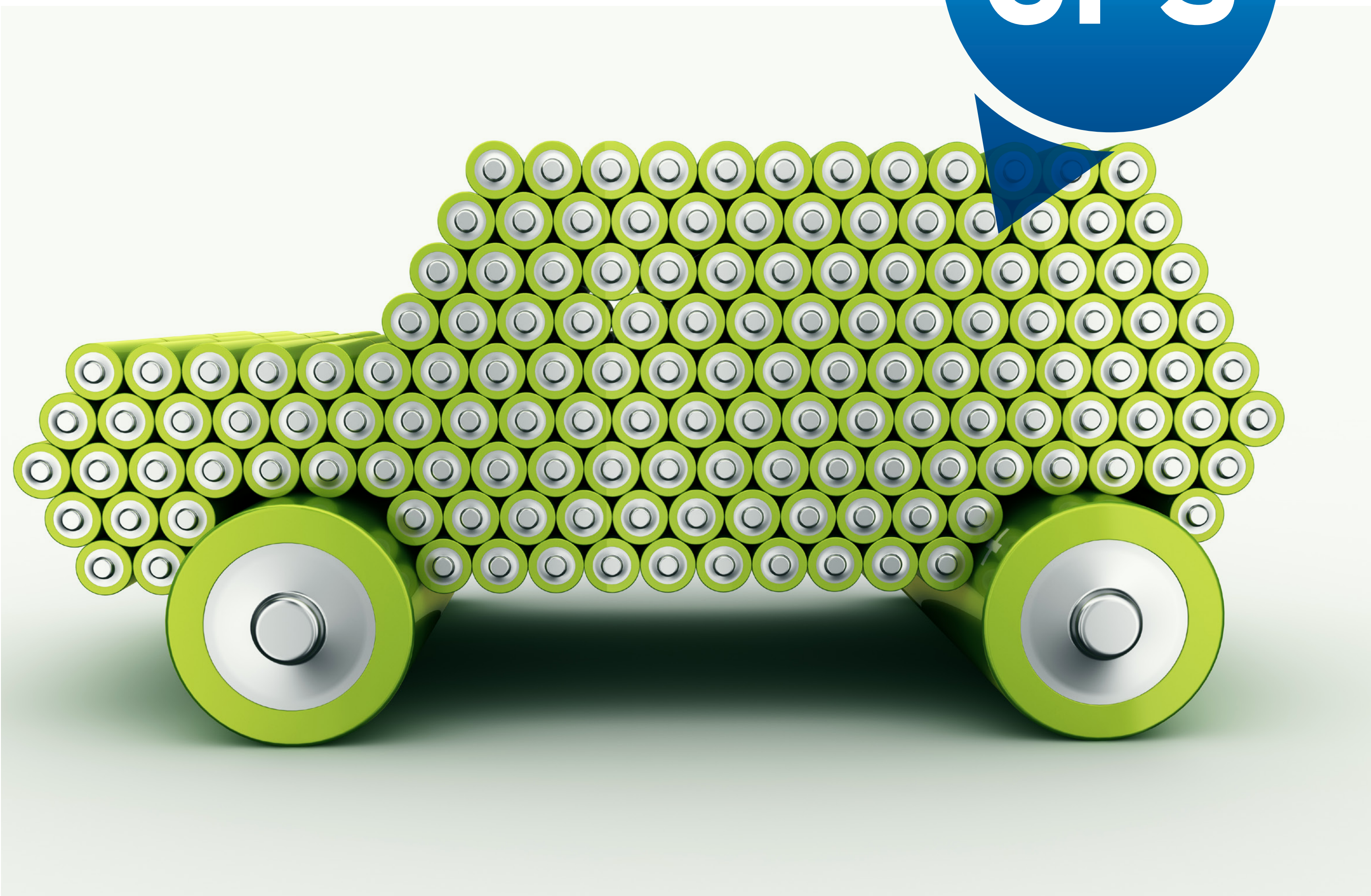

ELECTRIC VEHICLES

Ready(ing) for Adoption

Citi GPS: Global Perspectives & Solutions

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ELECTRIC VEHICLES

Ready(ing) For Adoption

Kathleen Boyle, CFA
Managing Editor, Citi GPS

What do you think of when you think of the 'Car of the Future'? The first thing that springs to mind for me is from the cartoon The Jetsons where George gets into his flying car and then folds it up and puts it in his briefcase before he gets to his desk. While that might be a bit further out in the future than is reasonable, what you consistently do not see in most futuristic stories is someone stopping on the side of the road to fill up their gas tank.

Electric vehicles as a concept have been around since the very beginning of auto invention. But it's only in the past few years that the technology has caught up with the concept. Cars that can drive for long distances without a charge are starting to be produced and demand for electric vehicles has slowly started to increase but why hasn't demand for them taken off? In the pages that follow, the authors look at where we are now in terms of battery electric vehicle adoption, where we're likely going, and how long they think it will take for us to get there.

There are four main barriers to adoption for consumers to fully embrace battery electric vehicles — range, infrastructure, battery degradation, and cost. Basically consumers want to know if the car will get them to where they want to go, can they plug it in when they need to recharge it, will the battery last long enough and is it cheaper than a regular gas/diesel passenger car. On most of these fronts, we find that we're getting closer to 'yes', but just aren't quite there yet.

So why are people buying battery electric vehicles at all? When we look at current demand, we find that we're still in the early stages of EV adoption with just 1% of battery electric vehicles and plug-in hybrids making up just 1% of new car sales globally. Demand up until now has been driven primarily by 'push' factors such as government support through the use of taxes and incentives. Regulations on emissions are used to make electric vehicles cheaper and traditional internal combustion engines more expensive to meet emission targets.

In order for penetration of battery electric vehicles to truly increase, demand 'pull' factors will need to take over. Consumers need to believe that the utility of a battery electric vehicle is higher than for a conventional engine vehicle. For this to happen, the price of batteries has to come down enough so that cost parity with traditional vehicles is reached. Lower battery costs will also extend the range of battery electric vehicles and newer technologies will solve the problem of battery degradation. Finally, a network of charging stations will need to be installed to alleviate the 'plug-in' fear.

The timing and scale of electric vehicle adoption is open to debate and the range of estimates for penetration in 2030 is pretty wide. Our forecasts are based largely on push demand in the sense that we make no assumption around consumers actively pursuing battery electric vehicles over and above traditional vehicles. Our base case scenario is for 10% battery electric vehicle penetration by 2030 with Europe and China remaining the largest EV markets. Our bull case scenario lifts penetration to 18% in 2030 and assumes both European emissions targets will be met and China new energy vehicle targets will be reached. Our bear case at 5% penetration sees a more significant miss on both targets.

We firmly believe the future is electric. The question today, as it was in the past, remains when.

The Future is Electric, the Question is When

THERE IS A LOT OF TALK AND INTEREST AROUND ELECTRIC VEHICLES (EVs) BUT EVs ARE STILL A MINOR PROPORTION OF AUTO SALES

Battery Electric Vehicles is now the **#1 ISSUE** on Automobile Executives minds, up from *#10* in 2014...

(Source: KPMG Global Automobile Executive Survey)

...but battery electric vehicles still make up **<1%** of global new car sales...

2017		2014
0.8%	vs.	0.2%

(Source: Citi Research, LMC)

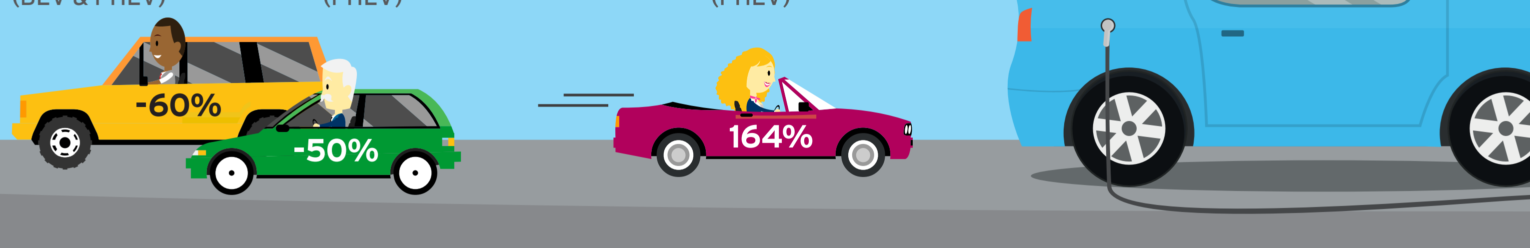
CURRENT DEMAND FOR EVs IS DRIVEN PRIMARILY BY 'PUSH' (I.E. INCENTIVES) VERSUS 'PULL FACTORS' (I.E. CONSUMER DEMAND)

EV's highly sensitive to changes to incentives: Push factors

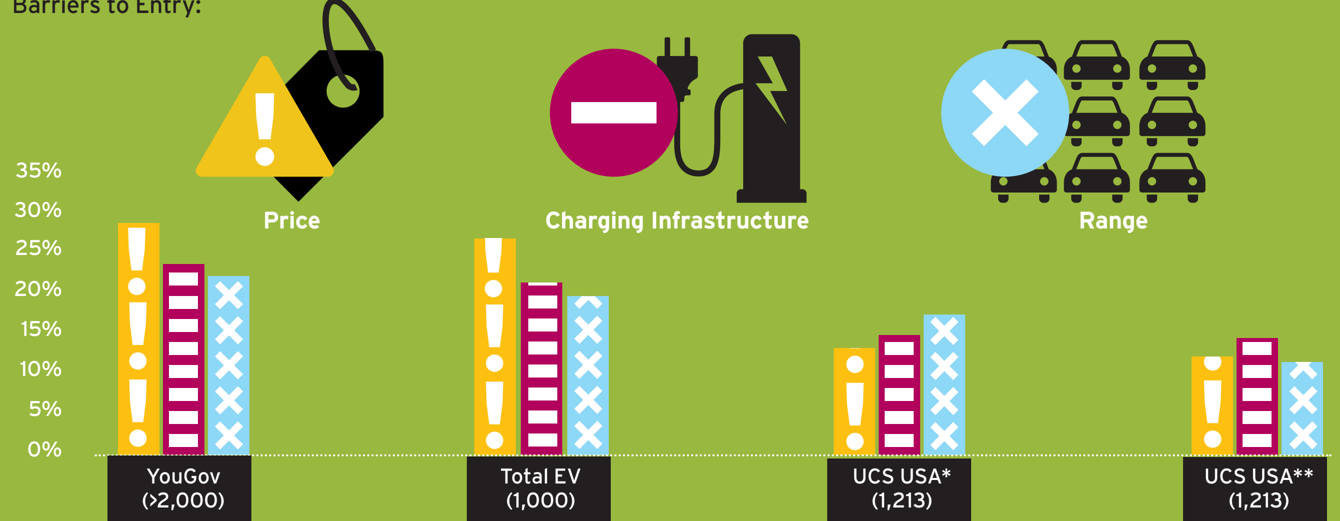
2016 Sales impact from:

Incentive Decrease: Denmark (BEV & PHEV); Netherlands (PHEV)

Incentive Increase: Norway (PHEV)



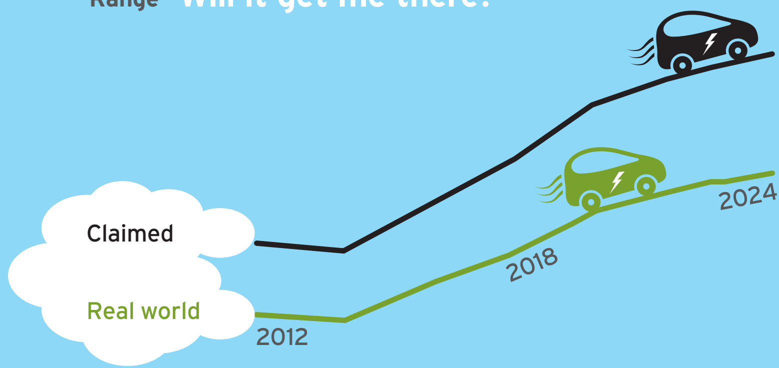
What are the main reasons that you would NOT buy an EV?
Barriers to Entry:



Source (Number of respondents)

THERE ARE STILL SIGNIFICANT BARRIERS TO MASS ADOPTION FOR EVS

Range - Will it get me there?



Total Cost of Operating – They cost more

(Source: Company data, Whatcar)

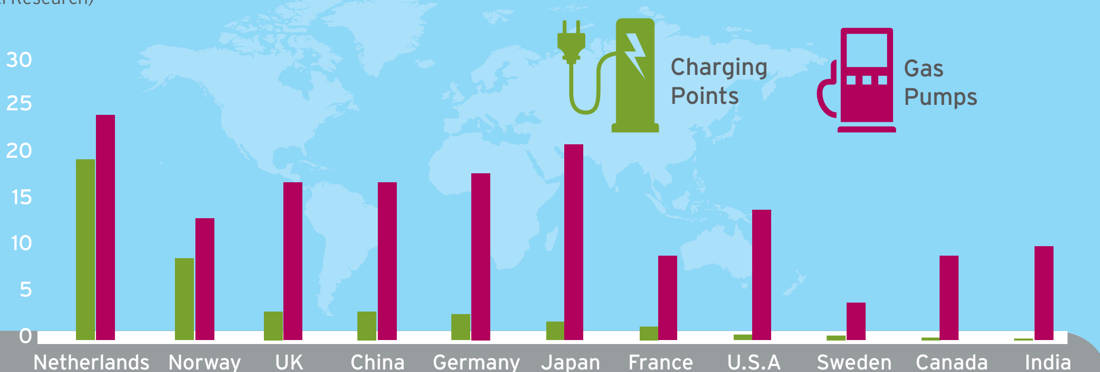
Cost of Battery Electric Vehicle (BEV)

100% vs. **63%**

Average cost of equivalent Internal Combustion Engine (ICE) model

Infrastructure - It's hard to find a place to plug in

Based on an average sample of 10 countries, there are 3.7 gas pumps per 100km of road for each charging station (Source: IEA, CIA, Fuels Europe, Petrol Plaza, U.S. Census data, Global News, Statista, Citi Research)

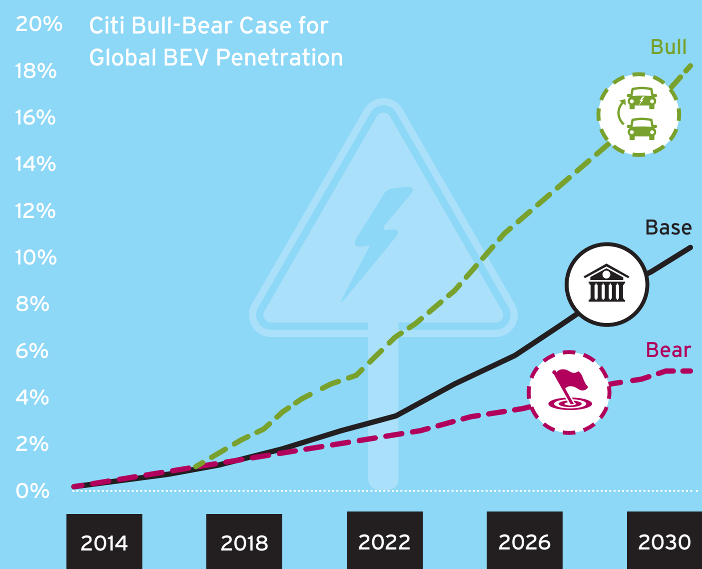


OUR FORECASTS FOR EV PENETRATION ARE

A function of both the production plans at OEMs and what we believe carmakers will need to achieve in terms of BEV and PHEV volumes to be compliant in a regulatory context.

(Source: Citi Estimates)

- **Assumes consumers actively pursue EV's over and above ICE vehicles**
- **Demand driven by government support**
- **Regulatory targets are missed in EU and China**

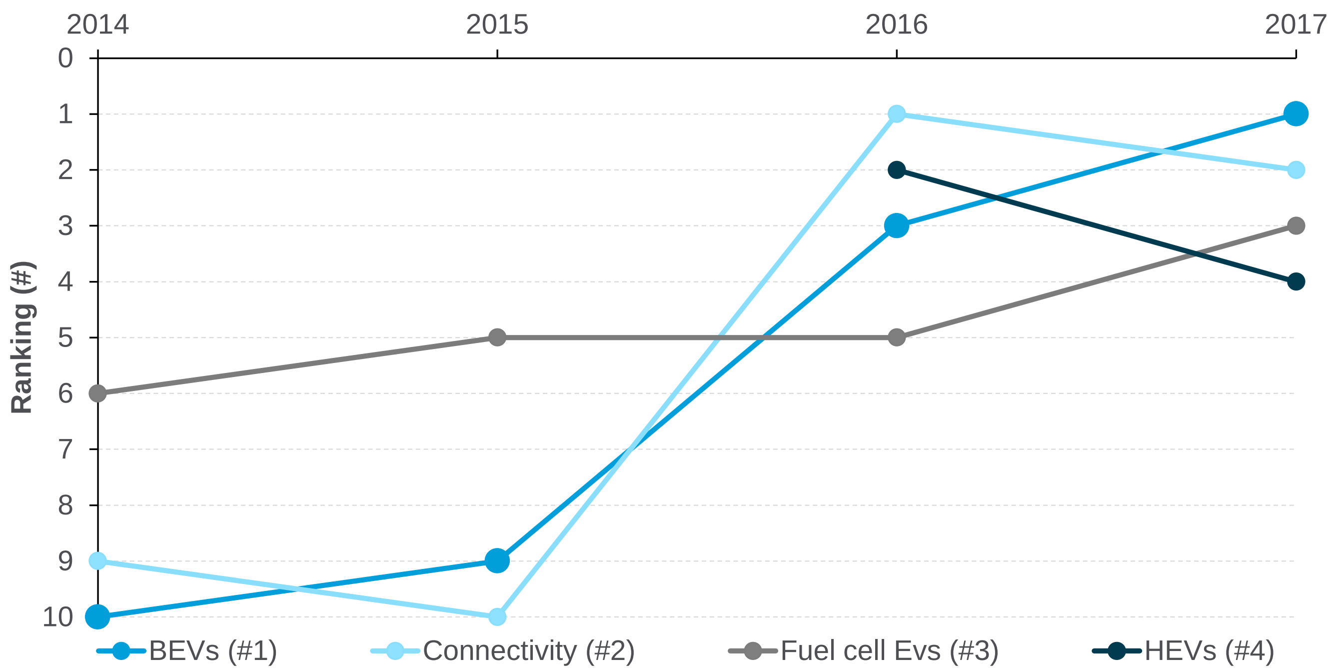


Contents

Introduction

Electric vehicles (EVs) are all the rage. Politicians, senior executives (from inside and outside the automotive industry), investors, journalists, and Joe Public all have something to say about them. It is no surprise that the number one topic on the minds of automotive executives is battery electric vehicles (BEVs), having been just 10th on the list in 2014 (see Figure 1). In this report, we tackle the key issues relevant in the decision-making process, from a car manufacturer's perspective, for electric vehicles, and we explore what needs to happen to break down the great wall of barriers to adoption.

Figure 1. Battery Electric Vehicles Are at the Forefront of the Minds of Automotive Executives



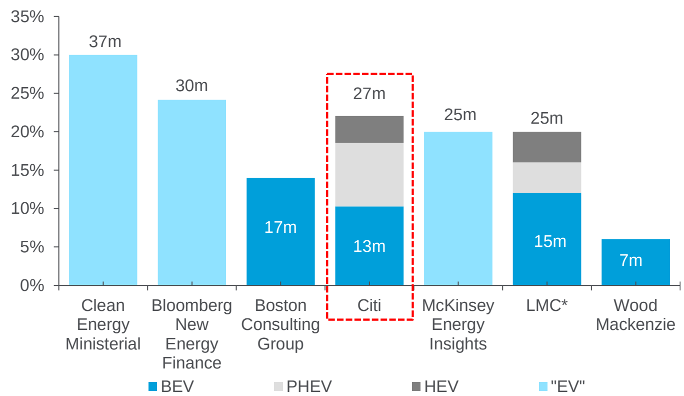
Source: KPMG Global Automotive Executive Survey (2017), Citi Research

While their rise has been gradual, global penetration of battery electric vehicles is still at a low level. Until now, regulation has been the primary driver of supply, as it has influenced the actions of car makers. Consumers are coming to grips with the technology, and while generous incentives help, there are still several barriers that need to be overcome (see Figure 2). Like with any new technology this will take time. The most optimistic forecast we have seen for BEV penetration is 14% (from BCG) in 2030, and in our base case we assume it will reach 10% (see Figure 3).

Figure 2. EVs – The State of Play as It Stands Today

Source: Citi Research

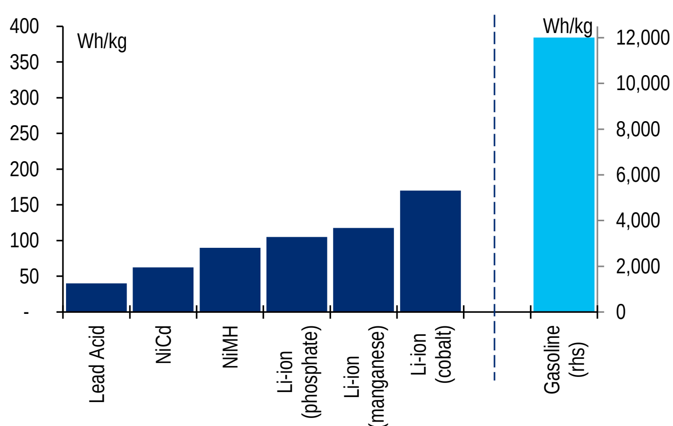
Figure 3. Forecast EV Penetration (% New Car Sales) in 2030



"EV" is defined as BEV, PHEV, and Full Hybrid, *LMC forecasts for 2027
Note: Data labels show the number of units that are expected to be "EV" and BEV
Source: Citi Research, Company reports

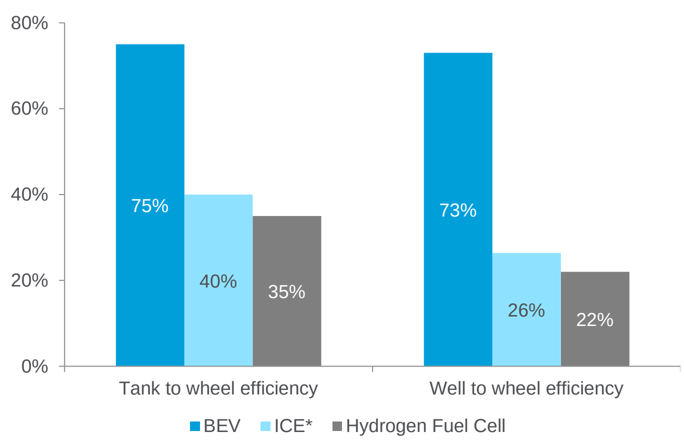
The future is electric, but when has always been the question. The battle between internal combustion engines (ICEs) and electric vehicles (EVs) is not new. The car as we know it (gasoline/diesel internal combustion engine) was invented in ~1870, and, depending on which account of history you read, by either Siegfried Marcus or Karl Benz. They were not, however, the first to make a motorized vehicle – that honor goes to Frenchman François Isaac de Rivaz, who in 1808 invented a hydrogen-powered vehicle. What's perhaps more interesting is that electric vehicles started appearing some 30 years prior to internal combustion vehicles, so arguably the "disruption" that many believe is imminent has been a long time coming. We think the reasons why one technology succeeded while the other remained niche are the same today as they were almost 180 years ago: energy density (i.e., amount of energy stored in a given system or region of space per unit volume) and its relationship to cost/convenience, but this looks set to change.

Figure 4. Energy Density by Chemistry: Gasoline Wins Easily



Source: Citi Research, epectec

Figure 5. Energy Transfer Efficiency Using Renewable Energy: EV Wins



*Based on latest Toyota 2.0 litre gasoline engine
Source: Transport & Environment, Toyota, Citi Research

Regulatory pressures are reducing EV's cost disadvantage. Transportation is ultimately about getting from one place to another, and therefore utility in the context of transport is largely a function of speed and convenience. We think other factors are secondary. Comparatively poor energy density (see Figure 4) has been the Achilles heel of EVs in terms of range, refueling, and cost. It might be improving, but it is unlikely to ever do so sufficiently so as to result in a threat to fossil fuels. However, if you broaden the definition of cost to include air quality, then energy density could improve. Authorities are acutely aware of the increasingly urban nature of populations and are pushing for zero in-use tailpipe emissions as a result. Using taxation and incentives rather than outright bans (thus far), authorities are driving up the cost of conventional ICE vehicles, while growing EV volumes are providing the scale for both higher levels of research and lower costs of production. Cost equivalence between EVs and ICE is now within sight.[1]

Vehicle Types

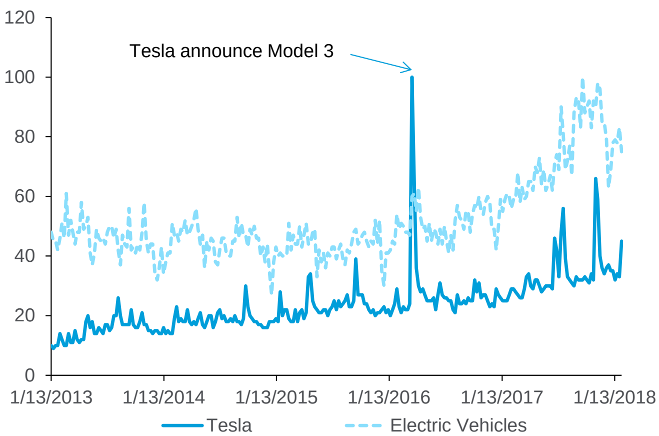
Electric vehicles can broadly be split into four categories. Hybrid Electric Vehicles (HEVs), Plug In Hybrid Electric Vehicles (PHEV), and Electric Range Extended Vehicles (E-REV) all include internal combustion engines that are supplemented (usually at low speeds, in urban areas) by electric batteries. Battery Electric Vehicles (BEVs), however, are entirely powered by electricity from the grid. The distinction between HEVs and PHEVs is that the batteries for the HEVs are charged from energy recuperation, while PHEVs, like BEVs, are charged from the mains.

[1] When Will Electric Vehicles be Cheaper than Conventional Vehicles?, BNEF, 12-Apr-17

Where Are We Now?

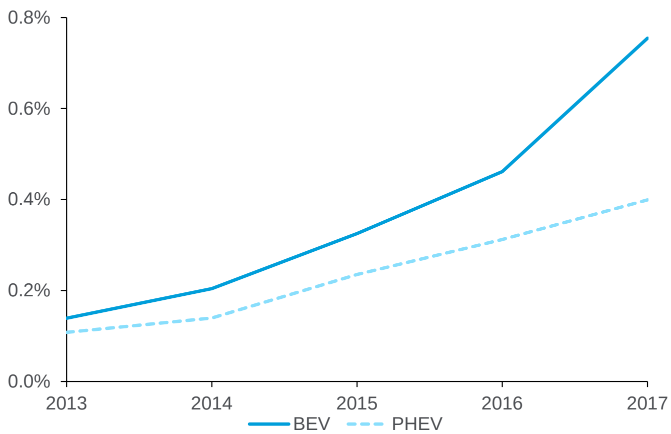
EVs are still a minor proportion of auto production. Contrary to media hyperbole and the large tomes of commentary written about the rise of EVs and the demise of the internal combustion engine, in reality the volumes of electric vehicles (PHEVs and BEVs) produced and sold globally are still relatively minor in the context of global vehicle production (see Figure 7). We think there are good reasons for this, not least because the incumbent carmakers have been somewhat reticent to put the full weight of their R&D and marketing force behind EVs. Ultimately, however, we think the weak demand for EV stems from the shortcomings of current battery technology.

Figure 6. Google Search Interest for "Tesla" and "Electric Vehicles"



Source: Citi Research, Google Trends

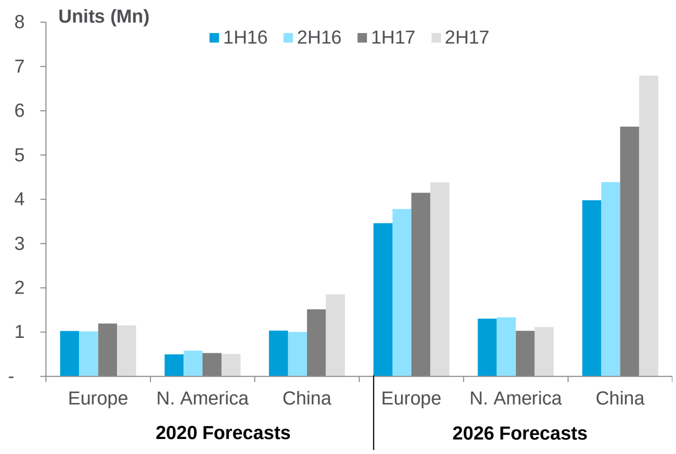
Figure 7 Global New Car Sales Penetration for PHEV and BEV



Source: Citi Research, LMC

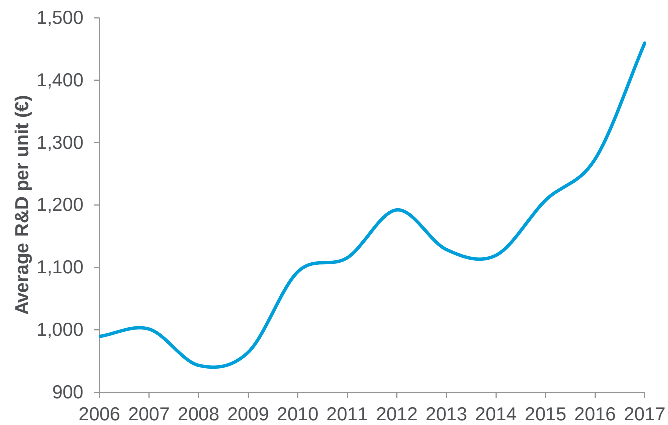
The OEMs are readying themselves for a shift away from ICE. We believe that the mass adoption of an alternative, cleaner powertrain is inevitable, and if the commentary and intentions from the car manufacturers are to believed it would appear they agree. In Figure 9 we show how the average research & development (R&D) spend per vehicle sold among global original equipment manufacturers (OEMs) has evolved over the past 12 years. It shows clearly that it has risen by 40%. There could be a number of factors driving this increase, but we would argue R&D in relation to electrification is the primary contributor. In Figure 8 we show how LMC's BEV and PHEV forecasts have evolved for the past two years, it shows rising forecasts in China and Europe, but falling in North America.

Figure 8. Evolution of LMC's BEV and PHEV Forecasts



Source: Citi Research, LMC

Figure 9. Average R&D per Vehicle for Global OEMs Trending Upwards



Source: Citi Research, Company Data (BMW, Daimler, FCA, Ford, GM, Honda, Renault, PSA, Toyota, Volkswagen)

What Does an EV Look Like Today?

Smaller range, longer refueling, and higher price – not a very compelling pitch. As Figure 10 and Figure 11 illustrate, the current generation of EVs (both BEV and PHEV) compares poorly to conventional ICE vehicles. This might be considered an unfair comparison as the fueling and maintenance costs of an EV are considered to be substantially lower. For example, at prevailing energy prices a Nissan Leaf costs €0.04 per mile whereas a 1.6L diesel VW Golf costs €0.08 per mile. We challenge this analysis, however, as embedded in the overall running costs of an EV is the depreciation of its battery, and, as we detail later, this adds a significant burden to the running costs of an EV. Based on the metrics we have chosen, it is hard to conclude that today's EVs are well placed to displace ICEs in a meaningful way.

Figure 10. Characteristics of an EV: Lower Emissions, but Lower Utility

Model	Range (electric only) (km)	Rapid Charge (min)	Standard Charge (hour)	Average Price ($)	Direct CO_2 Emissions
Tesla Model S	489	40	11	79,445	0
Nissan Leaf	249	30	5	29,608	0
VW e-Golf	299	35	5	39,082	0
Renault Zoe ZE	402	60	6	22,658	0
Chevrolet Bolt	238	60	6	37,707	0
BMW i3	314	35	5	49,487	0
Average BEV	332	43	6	42,998	0
Toyota Prius	1328 (39)	N/A	3	27,445	91
Mitsubishi Outlander	873 (33)	25	4	36,064	96
Chevrolet Volt	676 (53)	N/A	4	34,688	29
BMW 330e	882 (25)	N/A	2	37,275	44
Volkswagen Passat	1063 (31)	N/A	3	36,165	40
Average PHEV	964 (36)	N/A	3	33,868	65

Source: Citi Research, LMC, Journal of Industrial Ecology, Edmunds, AutoHaus, Voiture-Neuve, Broadspeed, Zap Map, Smart EV, Pod Point

Figure 11. Characteristics of an ICE: Easier and Cheaper, but Dirtier

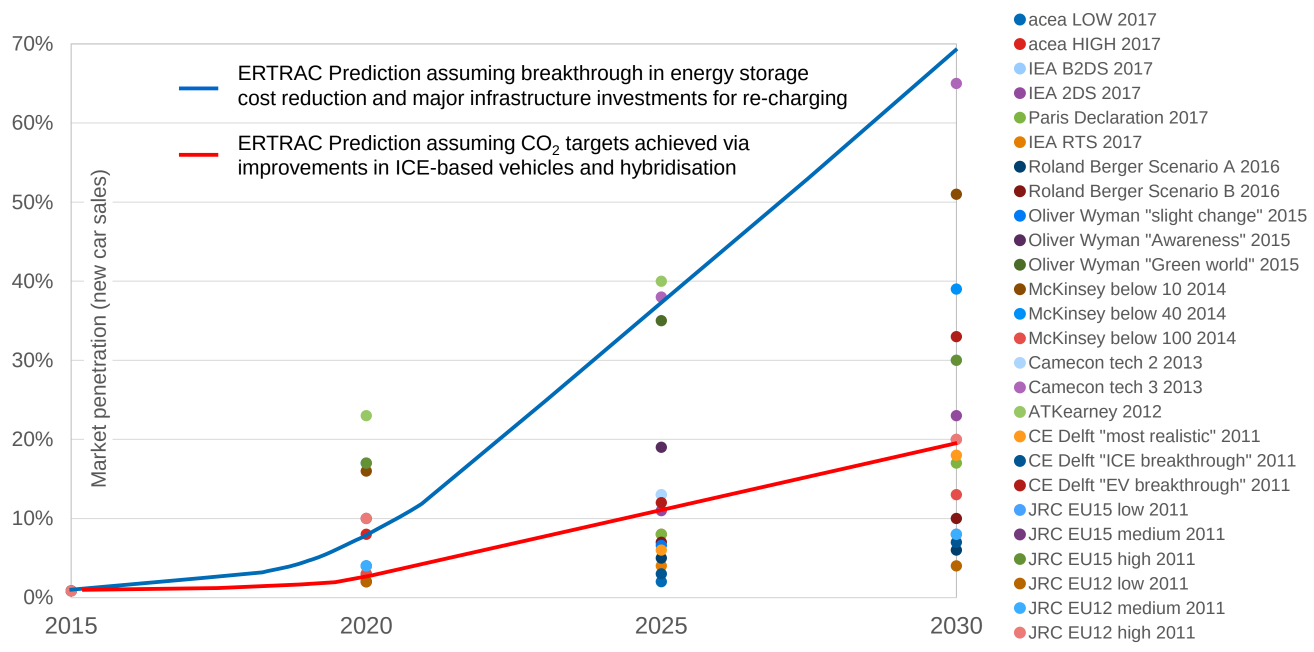
Model	Range (km)	Re-fueling Time (mins)	Average Price ($)	Direct CO_2 Emissions (g/km)
Toyota Corolla	989	3.7	23,666	168
Ford Focus	1,377	3.7	21,351	120
Volkswagen Golf	1,065	3.3	24,017	148
Toyota RAV4	1,410	4.0	33,312	126
Honda Civic	1,175	3.3	28,330	129
Volkswagen Polo	1,006	3.0	16,458	137
Honda CR-V	1,220	3.9	27,897	148
BMW 3-series	891	3.4	40,159	178
Renault Megane	1,255	3.1	25,791	112
Mercedes E-Class	1,728	4.4	60,501	122
Average ICE	1,212	3.6	30,148	139

Source: Citi Research, LMC, Car-Emissions.com, CarAraC.com, AutoHaus, Voiture-Neuve, Broadspeed

Where Are We Going To?

The timing and scale of a potential EV disruption are open to debate. It may well be that the future is electric, but the timing and scale of that epiphany is not clear. As we detail below (Figure 12), courtesy of data collected by industry consultant Ricardo, there is a broad array of EV penetration forecasts in the public domain, and the further out we look the greater the variance in estimates. This is problematic for both manufacturers and investors: Investing for 40% penetration in 2025 is clearly a very different prospect than sub-10% penetration in the same timeframe. It is interesting to note that the more recent forecasts are less optimistic than prior years. It may be that the initial hysteria around EVs is calming down.

Figure 12. New Car Market Penetration Predictions for BEV & PHEV



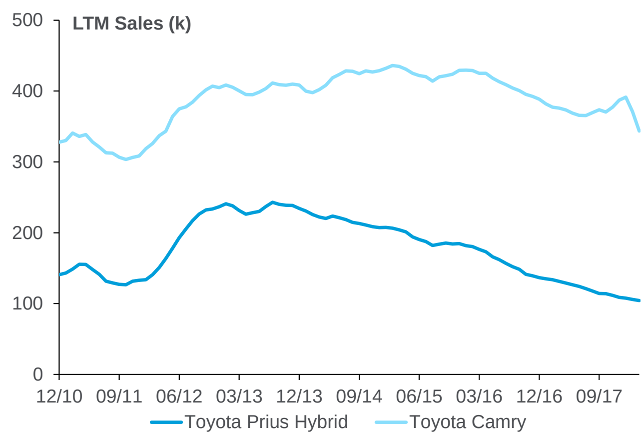
Source: Published forecasts, Ricardo

We believe further penetration is a function of *push* vs. *pull* demand. Our own forecasts for EV penetration (see section Citi's Powertrain Forecasts) are a function of both the production plans of the OEMs and what we believe the carmakers will realistically achieve in BEV and PHEV volumes as they strive to be complaint with fuel-efficiency targets. Arguably, our forecasts are based largely on *push* demand in the sense that we make no assumption around consumers actively pursuing EVs over and above ICE vehicles. We view this as the upside risk to our forecasts, but, as we explain below, the timing of this swing is at least five years away and far from being assured. For now, we think regulatory pressures will be the key driver of adoption.

What Will Drive Adoption?

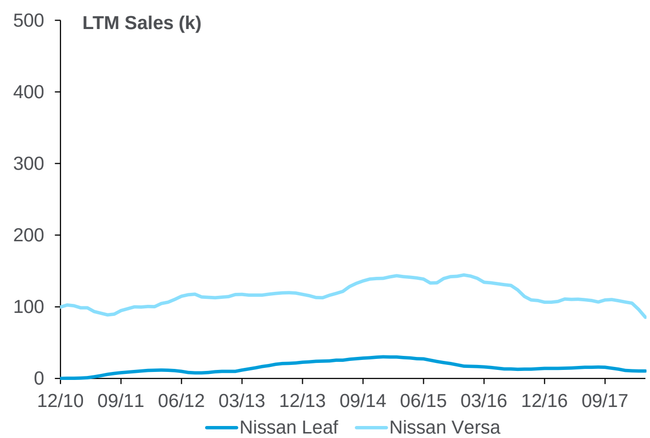
In the absence of government support EVs need to be as good as, or better than, an ICE. Car buying, like purchases of many consumer products, is an emotive topic. The suggestion that one vehicle or brand is better than another is almost guaranteed to generate significant debate. However, it is worth remembering that more than half of the vehicles sold today, depending on the market, are to business users. We argue their purchasing decisions are more rational, based on utility vs. cost i.e., what is the most cost-effective vehicle that will complete the required function. Furthermore, we argue utility vs. cost is still a key element in the decision-making process among private buyers, especially where the main intended use of the vehicle will be commuting. Mainstream adoption of EVs requires equivalent, or better, utility versus conventional technology, which is not currently the case due to limited range, higher total cost of ownership, and limited charging infrastructure. This is clearly illustrated when contrasting comparable EV and ICE model sales volumes in Figure 13 and Figure 14.

Figure 13. Toyota Prius Hybrid and Toyota Camry (ICE) Sales in the U.S.



Source: Citi Research, Autodata

Figure 14. Nissan Leaf BEV and Nissan Versa (ICE) Sales in the U.S.



Source: Citi Research, Autodata

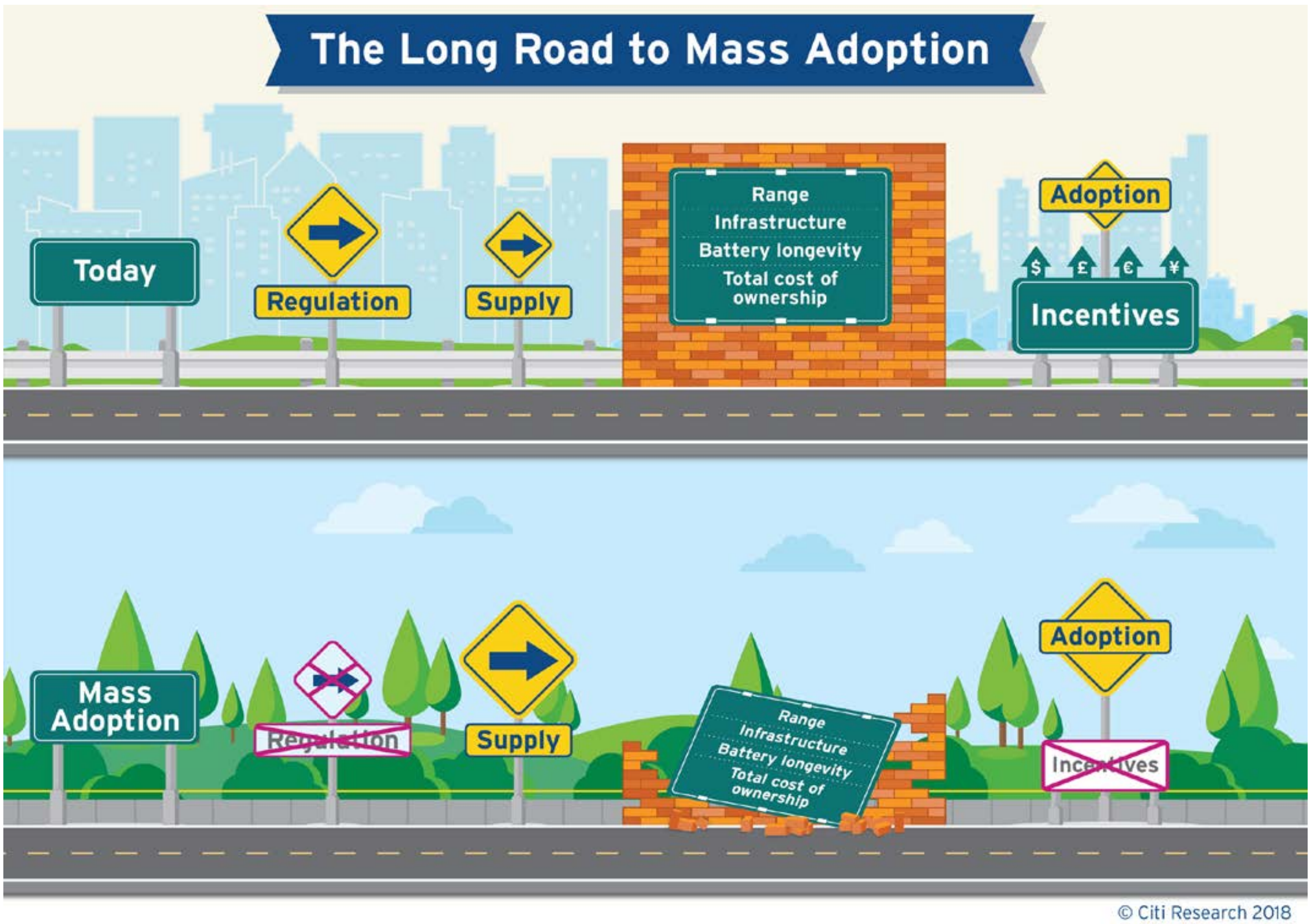
Electric vehicles, however, also suffer from a perception problem that makes this gap in utility difficult to narrow. When drivers switch from ICE to EV, they are overwhelmingly pleased with their decision. According to a survey of over 850 EV drivers in Europe and North America conducted by a group of car manufacturers and EV organizations, 85% of electric vehicle drivers are happy having made the switch to an electric car.[2] This suggests that although there are clear functional benefits of driving a conventional gasoline or diesel vehicle, there are also aspects of driving electric that consumers prefer. The problem is that the former (range, total cost of operating, infrastructure, battery longevity) are more prominent in the minds of consumers than the latter (environmental benefits, quieter drive experience, fuel costs). Both the actual and the perceived disadvantages of electric vehicles will need to be overcome in order for mass adoption to occur.

[2] 85% of electric vehicle drivers are happy having switched to electric driving, EVBox, Apr-17 link

Mass Adoption Requires the Stars to Align

We are in the early stages of electric vehicle adoption, with some car manufacturers still deciding on their respective strategies. Up until now, much of the supply has been driven by regulation, with some countries enforcing minimum sales requirements and/ or implementing stricter fuel efficiency targets that will only be attainable with higher EV penetration. In the absence of regulation we believe EVs would have remained a niche offering, as the costs to manufacture (and therefore the price to buy) would have remained prohibitively high. It is regulation that has forced the hands of OEMs, making them reallocate capital in order to provide an EV offering, to avoid being fined or, worse still, being considered irrelevant (as an EV-brand) by consumers. The bottom line is that in order to encourage adoption of EVs at this stage, financial incentives have been necessary.

Figure 15. There Is Still a Long Road to Navigate Before We See Mass Adoption of Electric Vehicles



Source: Citi Research

We believe that true mass adoption will be reached when neither regulation nor incentives are required to force OEMs to supply, or consumers to buy, EVs. In order to reach this stage there are numerous barriers that need to be overcome. We take each of these in turn in a later section of this report.

Regulatory Factors

In the near term, we expect EV demand to be largely propelled by a combination of regulation and government incentives. Thus far, the growth of EVs has been distinctly supply- rather than demand-driven as EV enthusiasm among consumers remains muted. Despite the fact that EVs are currently margin-dilutive (Daimler estimates that, at least initially, EVs will be half as profitable as their ICE equivalents), OEMs are working on changing the perception of EVs among consumers. We believe this is largely due to the regulatory environment in which OEMs operate requiring them to do so.

A combination of carrots and sticks from local, national, and supranational governments is the real engine behind EV market growth. Carmakers are being pushed towards increasing investment in and development of EVs as a result of the regulatory environment. In China, the government is targeting 2 million New Energy Vehicle (NEV) units by 2020 (vs. ~580k in 2017), and we estimate 1.3 million units will need to be sold in Europe in 2020 (vs. 270k in 2017) to comply with emissions targets. In order to help generate demand, subsidies and non-financial incentives are being implemented, and we see a strong correlation between generous subsidies and EV penetration.

We summarize the key areas of regulation that are driving demand in the world's three largest markets in Figure 16 and analyze the relationship between regulation and EV penetration for each region in further detail in the section *Regulation by Region.*

Figure 16. Summary of Regulatory Drivers for EV Adoption in Top 3 Markets

Region	Market Size (mn units)	EV Driver	Government Target/ *Implied EV Volume	Comment
China	25	Dual credit NEV system: 1) NEV credits must reach 10%/12% of 2019/20 annual volumes 2) Corporate average fuel consumption (CAFC) credits must be at a non-negative balance each year	2020: 2m units 2025: 7m units	New Energy Vehicles (NEV) is a collective term used in China for BEV and PHEV models.
U.S.	17	CAFE fuel-economy targets originally set under the Obama administration, which targeted average fuel efficiency of 41/50mpg by 2021/25, are currently under review and are expected to be relaxed.	N/A	California and 12 other states have historically been allowed by an EPA waiver to set and opt in to stricter standards, but this waiver is also likely to be challenged by the Trump administration.
Europe	16	CO_2 emissions targets of 95g/km in 2020/21 and 15%/30% reductions by 2025/30	2020: 1.56m BEVs* 2025: 3.7m BEVs*	Additional regulation is driving up ICE vehicle costs while local authorities are simultaneously pushing for low-emission zones in major cities.

Source: Citi Research, MIIT, NHTSA, European Commission

In **China**, the carmakers operate under a dual-credit system whereby credits are received based on both NEV production and average fleet fuel consumption, which the government hopes will help meet the target of 2 million NEV sales by 2020 and 7 million by 2025.

U.S. fuel-efficiency regulation is in a state of flux as the 2021/25 targets implemented by the Obama administration are under review and likely to be relaxed by the Environmental Protection Agency (EPA). California's EPA waiver, which historically has allowed it to set its own (stricter) standards and for other states to opt in, is also likely to be challenged by the EPA. Of the three markets, regulatory supply-driven factors are weakest in the U.S., and EV penetration is also set to grow the slowest.

In **Europe**, emissions targets are the most significant regulatory driver of EVs. Manufacturers are required to reduce average fleet CO_2 emissions to 95g/km by 2020/21, which in an environment of falling diesel sales and growing popularity of SUVs is putting pressure on OEMs to improve sales of low- and zero-emission vehicles. Local authorities are also aiming to reduce emissions in cities through the implementation of Low Emission Zones and other measures that are driving up ICE vehicle total cost of ownership.

The Supply Outlook for EVs

Let's take a step back and think about the shift towards EVs from the perspective of the auto manufacturing companies and their boards. Companies with a long-history of manufacturing traditional vehicles tend to make decisions based on the prospective investment return relative to their cost of capital. Structural threats, like the shift towards EVs, can derail the traditional process, although this is rare. The majority of decisions (particularly those of material size) require sign-off by the company's board, which can slow down the process. This is an important distinction between incumbent operators and new entrants, where decision making is more fluid.

This leads us on nicely to what we dub as 'The CFO's Conundrum.' What do we mean? Automotive OEM margins are thin, and while their balance sheets are more robust than they were a decade ago, they need to be disciplined with their capital investment decisions. The dilemma is how capital spend should be split between improving existing technologies/ infrastructure and investment in new technology — like EVs – where there is significant uncertainty about the demand outlook.

The CFO's Conundrum Matrix

We think 'The CFO's Conundrum' is best illustrated by the following matrix:

Figure 17. The CFO's Conundrum: Where Are We Most Comfortable?

Technological Evolution/ Progression (Low → High)

Follower • Makes the decision to invest once there is proven demand • At the point in time when the decision to invest is made the cost of development is much lower, and therefore it takes less capital to manufacture a technologically advanced product (no learning costs etc.)	**Leader** • New entrants and disruptors occupy this quadrant • For industry incumbents positioning the company in this segment may impair profitability in the short term, but enables association with the new developments (gaining market share early-on)
Laggard • All incumbents start off in this quadrant • If demand for technologically advanced products takes time, then these companies benefit	**Improver** • Investing to be the best in the old technology (generally seen as a prediction that there will be no structural change in customer preferences) • Like with 'laggards', if demand for technologically-advanced products takes time, then 'improvers' benefit

Capital & Research Expenditure (Low → High)

Source: Citi Research

Carmakers Will Dictate the Pace of Adoption

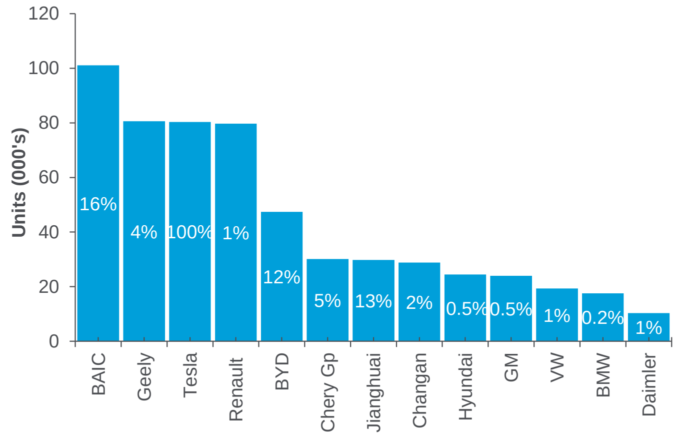
The automotive industry is vital for some of the world's largest economies. It employs 14% of industrial workers in Germany, 7% in France, and 5% in U.S. It also accounts for 14% of gross domestic product (GDP) in Germany and 3% in U.S. For that reason governments of the respective countries keep a watchful eye, setting regulation, injecting money to stimulate demand (incentives, scrappage etc.), and giving worker unions a degree of power that is rare in other industries. That does not mean the car makers are given a free-ride; this is best highlighted by the tightening of fuel efficiency regulation following the diesel crisis.[3] It is no surprise that battery electric vehicles have gone from being tenth on a list of key trends that automotive executives are focused on in 2014 to first in 2017. This does not mean that EVs make economic sense for car-makers right now, but we would argue that the future is inevitably going to be electric. In the meantime, carmakers need to decide where they want to sit in our 'CFO's Conundrum' matrix, while at the same time playing lip service to the rise of EVs if for nothing else but the sake of their brands.

Who is Leading Today, and What Have the OEMs Announced?

As shown Figure 18, BAIC sold the most EVs globally in 2017, but with EVs accounting for 16% of the group's volumes. In 2017 it only sold 7 models but plans to have 13 models available by 2020 and 2025. The picture in 2020/25 looks rather different, as shown in Figure 19, with VW and SAIC leading in terms of absolute volumes globally, although pure-play EV manufacturers aside (i.e., Tesla), BAIC and Jianghuai are expected to have the highest EV penetration in 2025.

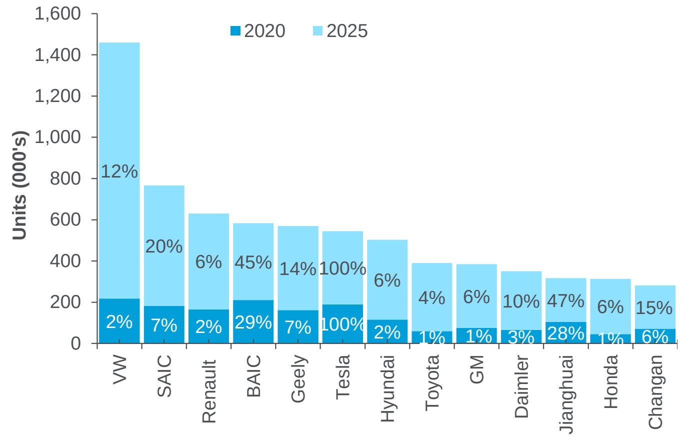
[3] European Autos - Diesel outlook remains hazy.

Figure 18. Automotive OEMs: BEV Volumes (Global; 2017) and % Penetration



Source: LMC, Citi Research

Figure 19. Automotive OEMs: BEV Volumes (Global; 2020 and 2025) and % Penetration

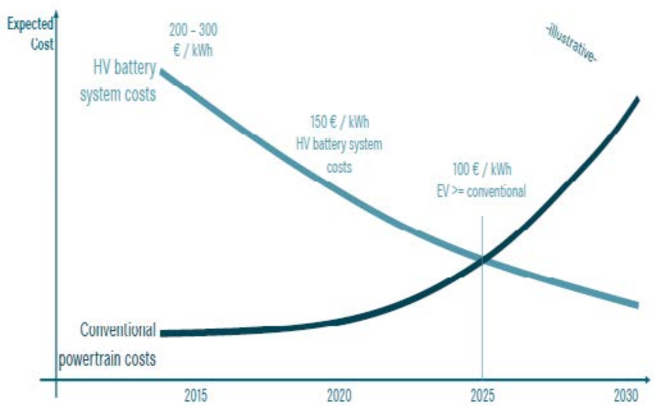


Source: LMC, Citi Research

Cost Parity Is a Critical Milestone for an Inflection of Supply

Ultimately, the auto OEMs are faced with a choice: Either invest today in EVs when the cost of the technology is highest and demand is uncertain, or wait for costs to fall and demand to rise. The critical milestone for supply to inflect will be when cost parity between EVs and traditional internal combustion engines is reached. With the cost of batteries expected to decline, and with the cost of emissions compliance for conventional engines (ICE) rising, we wouldn't be surprised if cost parity is reached before 2025 (see Figure 20). The challenge, until then, is that electric vehicles are considerably more expensive to manufacture (see Figure 21), and as (most) carmakers are unable to charge consumers to compensate for this gap, the sale of electric vehicles, as it stands today, is a loss-making endeavor.

Figure 20. EVs vs ICE – Estimated Industry Costs



Source: Daimler

Figure 21. Estimated Breakdown of Costs by Powertrain

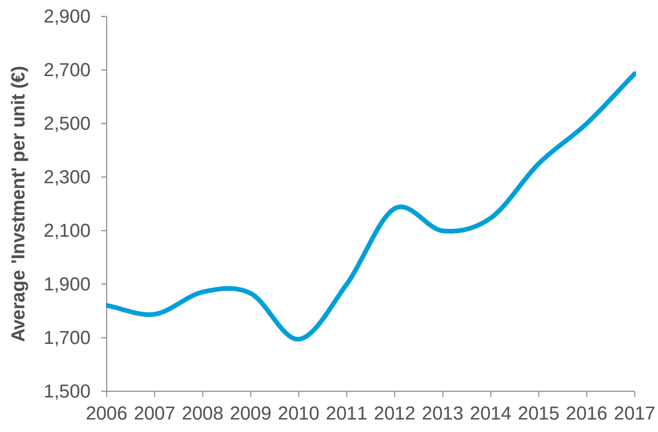
USD	Gasoline	Diesel	48V	PHEV	BEV
Engine	2,000	2,200	1,800	1,200	-
Transmission	1,600	1,600	1,600	1,840	800
Fuel System	400	800	400	400	-
Axles	800	800	800	800	800
GPF*	100		100	100	
SCR/ LNT	-	500	-	-	-
Electric Motor	-	-	380	842	1,684
Additional Battery	-	-	400	2,838	11,350
DC/DC convertor	-	-	50	50	
TOTAL	4,900	5,900	5,480	8,020	14,634
Cost vs ICE-gas		*+1,000*	*+580*	*+3,120*	*+9,734*
Battery size (kWh)	-	-	0.2	12.5	50

Source: BorgWarner, Delphi, American Axle, Magna, IHS, Robert Bosch, Aumann, McKinsey. Citi Research estimates. * Gasoline Particulate Filter

OEMs have been readying themselves for EV-adoption

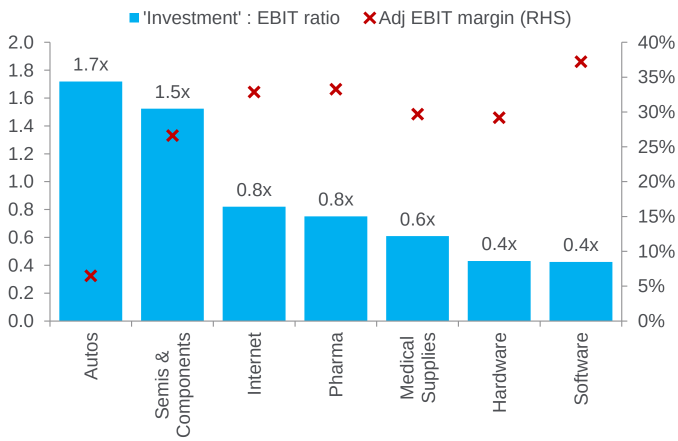
While some argue electric vehicles are just hype, the actions of the carmakers suggest that they believe EVs have a sustainable future. In Figure 22, we show how capital expenditure (capex) and R&D (i.e., 'investment' by our definition) per unit (i.e., vehicles sold) have evolved for global carmakers over the past decade. We attribute the greater than 40% increase in investment since 2006 to EV-related expenditure, and recent commentary from OEMs suggests the upward trajectory is set to continue.

Figure 22. Automotive OEMs: Evolution of 'Investment' Per Unit



Source: Citi Research, Company Data (BMW, Daimler, FCA, Ford, GM, Honda, Renault, PSA, Toyota, Volkswagen)

Figure 23. Cross-Sector 'Investment' to EBIT Ratio and EBIT Margins



'Investment' = Capex + R&D expenditure
Source: Citi Research, Company data. 2017 data

Despite their thin EBIT[4] margins we found it interesting to see that carmakers featured six times in the list of top 20 R&D spenders globally[5] — the most of any industry. The six auto manufacturers in the list are VW, Toyota, GM, Ford, Daimler, and Honda. This point is further accentuated in Figure 23, where we analyzed the relationship between 'investment' and EBIT across the 20 companies, split by industry group. This shows that on average the automotive OEMs spent 1.7 times EBIT on capex and R&D (in 2017) compared to an average of 0.8 times in other industries.

[4] EBIT = earnings before interest and taxes, which is a measure of a firm's profit.
[5] https://www.strategyand.pwc.com/innovation1000#VisualTabs1.

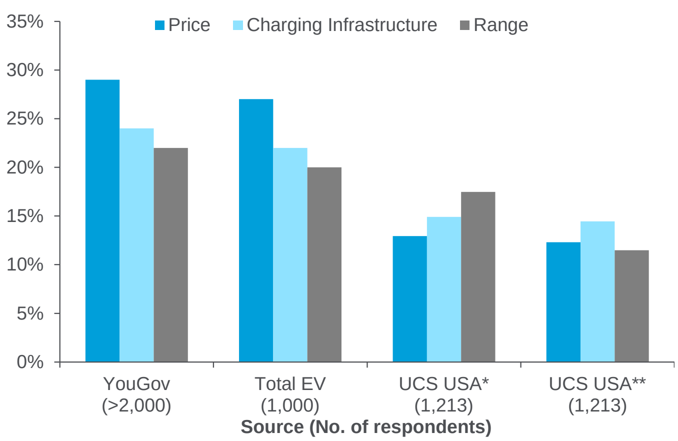
Current Barriers to Mass Adoption

As it stands today, we see four barriers to mainstream adoption of EVs. In the section below, we consider the current situation on each issue and more importantly, what we see happening around each concern over the coming years.

1. Range: "Will It Get Me There?"

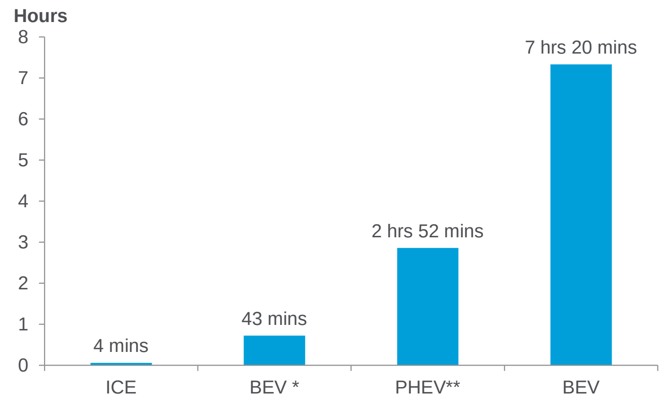
Range anxiety is one of the greatest hurdles for BEV adoption. In Figure 24 we show the results of various surveys which asked the question 'What is the single biggest barrier to you owning a BEV?' While price and charging infrastructure feature as barriers, range anxiety is consistently one of the top three reasons given. We suspect this is a function of consumers wanting the option to drive long distances, even though the average trip length is only 15 miles in the US[6] and 7 miles in Europe[7] – both well within the available range of current BEVs. A further complication is that it takes significantly longer to recharge (refuel) a BEV than it does a traditional vehicle equipped with a fuel tank (as shown in Figure 25). We believe this places even greater emphasis on range as refueling is less convenient in terms of time taken, but to the degree charging can take place when the vehicle is not in use, the range challenge can be reduced.

Figure 24. Survey Querying 'Main Barrier for Higher Adoption of EVs



* respondents from California
** respondents from 9 Northeast U.S. states
Source: Citi Research, YouGov, Total EV, USC USA

Figure 25. Average Refueling Time: ICE is the Clear Winner

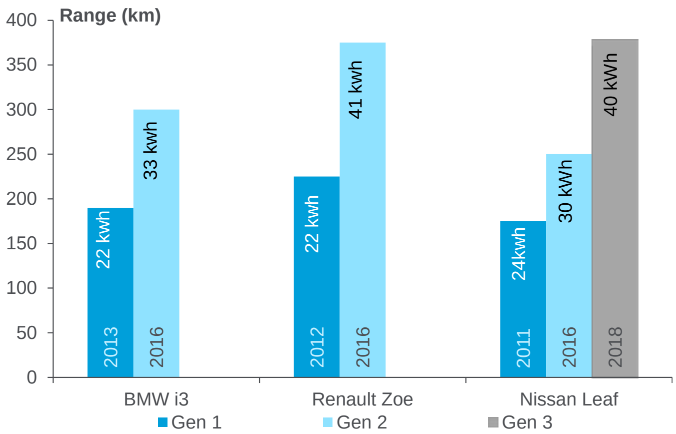


* Rapid charging to 80%
** Time taken to charge battery, refuelling combustion engine in ~4 mins also available
Source: Citi Research, Zap Map, Pod Point, Smart EV

Successive BEV generations have seen an improvement in range. While BEV penetration is rising, we would argue the niche adoption thus far has in large part been a function of limited range. It might be argued that infrastructure and residuals also pose a challenge, but as Figure 26 shows, the range hurdle appears to be at the forefront of existing carmakers development plans for BEVs — each model update has seen a meaningful jump in range. The car industry has made the news in recent years for the gap between real world and claimed emissions, and there is a similar story to tell for BEV driving range (Figure 27). This issue is exacerbated for BEVs given the range deterioration at different ambient air temperatures (extremes impact the battery performance and energy consumption), when interior functions are used (e.g. cabin climate control) and depending route topography (flat is good, hills are not).

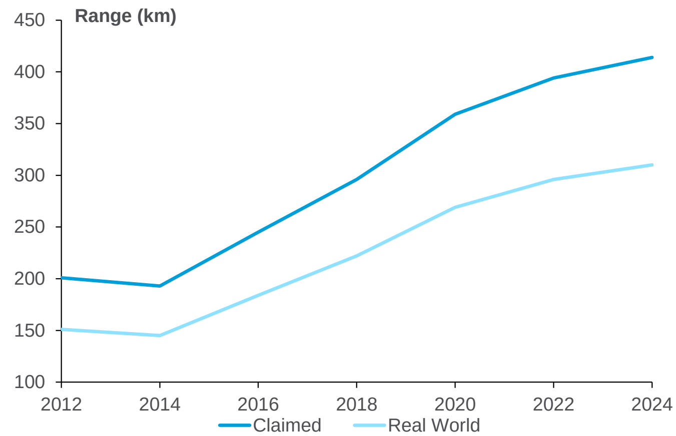
[6] National Household Travel Survey, *U.S. Department of Transport (2001-2002).*
[7] Analysis of National Travel Statistics in Europe, *European Commission (2013).*

Figure 26. Battery Range in Successive BEV Model Generations



Source: Citi Research, Clean technical, Autocar, Greencar reports, Inside EVs, Company data

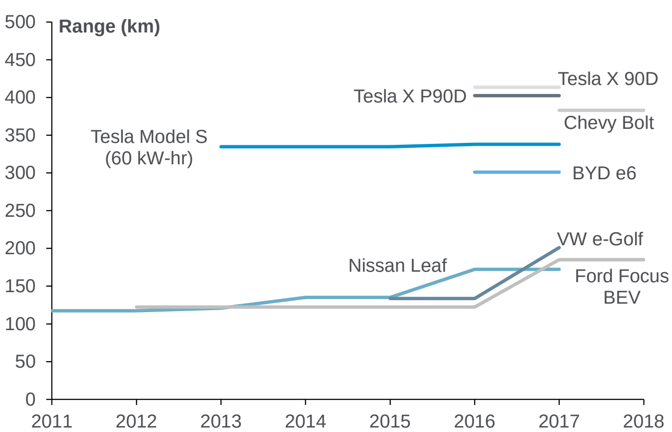
Figure 27. Average BEV Range Evolution: Claimed and Real-World



Source: Citi Research, LMC

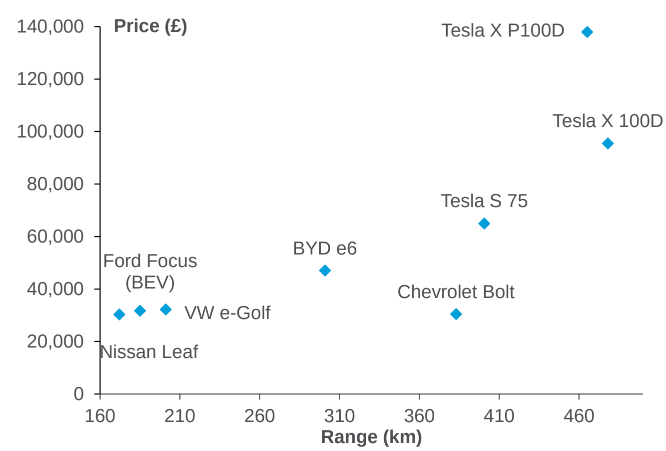
As battery costs come down. vehicle range is being extended. In Figure 28 we show how the driving range (on a single charge) has changed for various BEV models since 2011. All three models at the mass-market end of the spectrum (Nissan Leaf, Ford Focus BEV, and VW e-Golf) have seen an improvement in range, which is largely due to an increase in battery capacity. More interesting is the recent launch of the Chevrolet Bolt, which is equipped with a larger battery and offers a quoted combined range of 383km/238miles, but is priced around £30k. In Figure 29 we plot range against vehicle price, and the Chevrolet Bolt is the outlier on this scatterplot. It looks to us as though GM (the manufacturer of the Chevrolet Bolt) is acting as a price-aggressor, i.e., offering a superior product (if range is the key determinant) at a low price point.

Figure 28. Range (km) Evolution of BEVs, According to the U.S. EPA



Source: Citi Research, U.S. Department of Energy

Figure 29. Range (km) vs. Price – For a Selection of BEVs

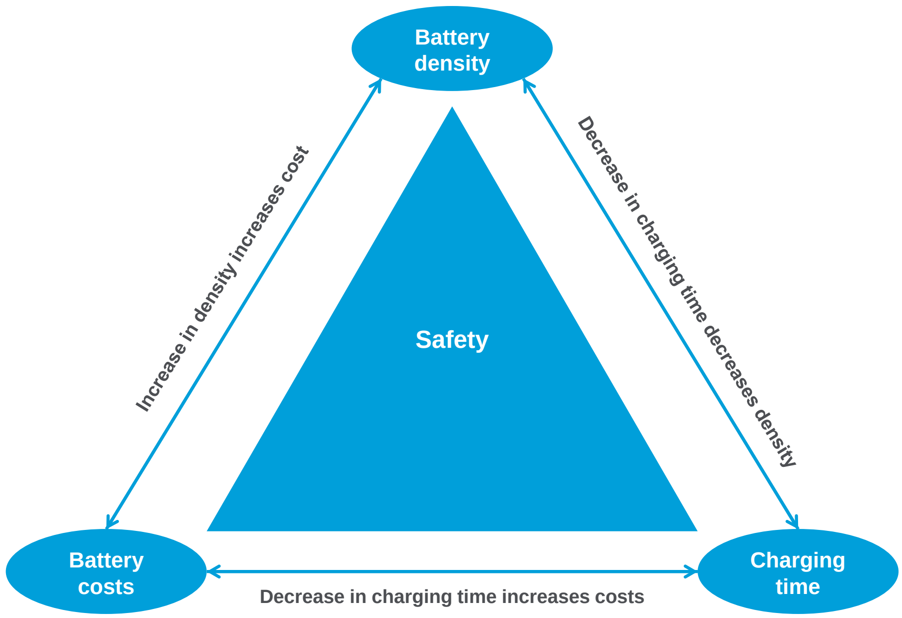


Source: Citi Research, WhatCar, AutoCar, U.S.Department of Energy

Why Not Just Add Bigger Batteries?

Battery size is a key determinant of driving range, but also vehicle price. The interplay between battery size and efficiency, charge time, and cost is problematic, and there is also the added complication of safety (see Figure 30). To keep weight down, ideally, manufacturers would like to increase energy density, but at the same time reduce charging times. Faster charging creates more heat, as does higher energy density, which in turn presents a bigger challenge in terms of fire propagation. It's a tricky conundrum.

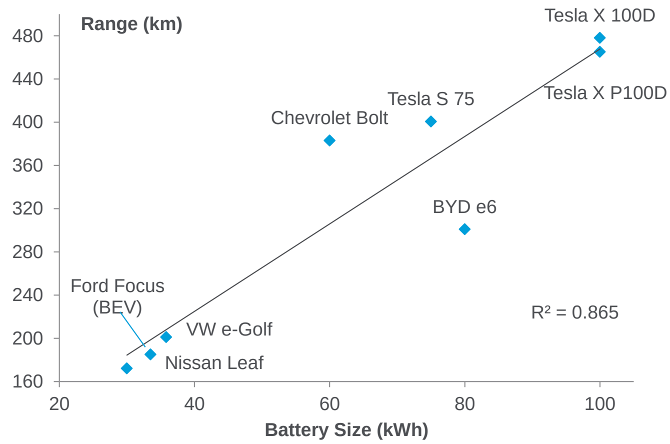
Figure 30. Citi's Battery Challenges Diagram



Source: Citi Research

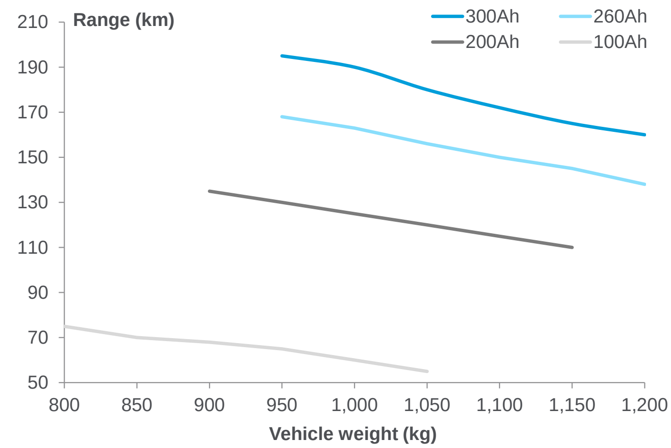
A larger battery leads to improved range, but is less efficient. As you would expect (Figure 31), battery size and range show a strong positive correlation, with an R^2 of 0.865. If range is an issue, it would therefore makes sense to make the battery bigger (i.e., higher kWh), but this would also make the vehicle heavier. As you might expect, vehicle weight is a key factor in determining an EV's potential driving range, and it follows that the charge time for a larger battery would also be longer. A study "Analysis of Parameters Influencing Electric Vehicle Range" by Martin Mruzek et al. at the University of Zilina (Slovakia) found the larger battery to be less efficient. We expect vehicle range to remain one of the foremost factors when buying a BEV, although we are cognizant that as range anxiety lessens, consumers may opt for the more efficient battery size.

Figure 31. Battery Size vs Range (km) — For a Selection of BEVs



Source: Citi Research, WhatCar, AutoCar

Figure 32. Vehicle Weight vs Range (km) — By Battery Capacity



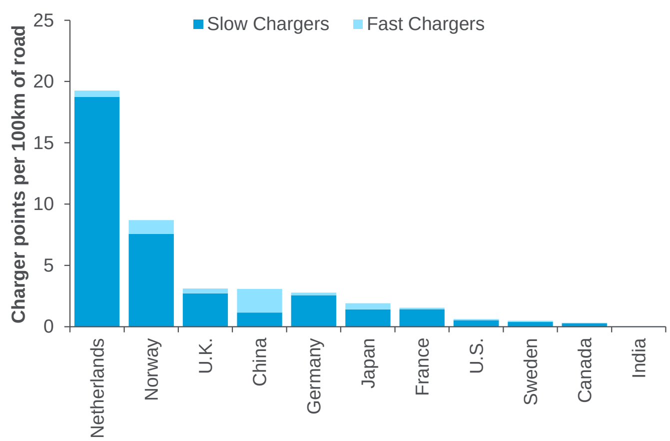
Source: Citi Research, University of Zilina

Falling battery costs should alleviate range issues. Given the correlation between battery size and range, and range and price (see section above), it follows that battery size and vehicle price are well correlated. GM's decision to offer a vehicle (Chevrolet Bolt) equipped with a 60kWh battery pack is somewhat aggressive compared with similarly priced vehicles (e.g., VW e-Golf, Nissan Leaf and Ford Focus BEV), which all have a battery size below 40kWh. As the costs of battery systems (cell + pack) fall, the potential driving range (on a single charge) will rise, and this will help address the range anxiety. We look at this in our Battery Cost section.

2. Infrastructure: "Where Do I Plug It In?"

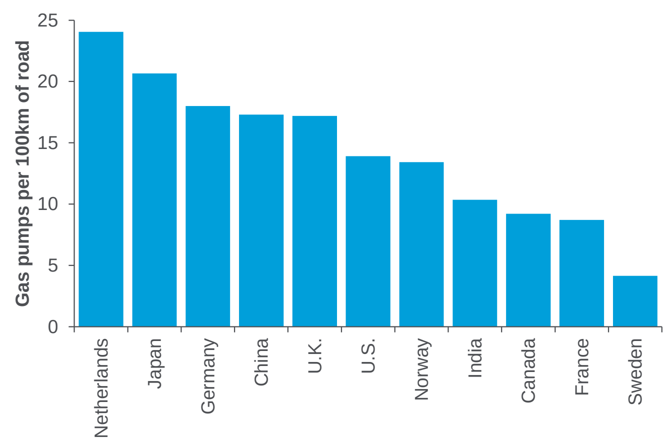
There is a chicken and egg quandary with EV charging networks. As we pointed out in Figure 24 charging infrastructure is consistently seen as a barrier to broader adoption of EVs. If we consider the density of charging networks compared to gas stations (see Figure 33 and Figure 34) it is clear the availability of public charge points for EVs still significantly lags the already well-established network of gas pumps for ICE vehicles. But a comparison of EV and ICE public infrastructure is somewhat academic given the different practices of refueling an electric vs. a conventional car. The option to refuel (charge) an EV at home or work and the longer charging times diminishes the need for public charging infrastructure, while on the other hand range anxiety and a lack of visible public infrastructure act as barriers to adoption. It's not as simple as "*if you build it, they will come.*"

Figure 33. Charge Points per 100km of Road



Source: Citi Research, IEA, CIA

Figure 34. Gas Pumps per 100km of Road

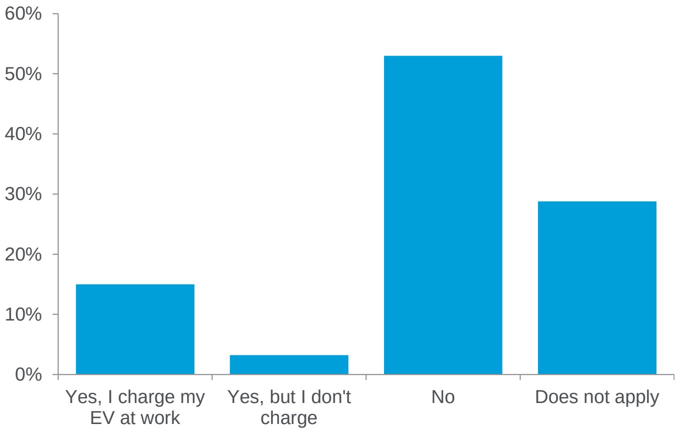


Source: Citi Research, IEA, Fuels Europe, Petrol Plaza, U.S. Census data, Global News, Statista

Home charging is popular, but this is partly explained by the lack of charging infrastructure elsewhere. A survey conducted by the EV website Zap Map in 2016 found that 81% of EV owners have access to chargers at home and only 15% charge their cars at work (Figure 35). Yet it also revealed that only 18% of respondents had the option to charge their car at their workplace, and of those who did, over 80% chose to do so. Therefore, although home-charging is more common than charging at work or at public stations, where workplace chargers are available they are popular with drivers.

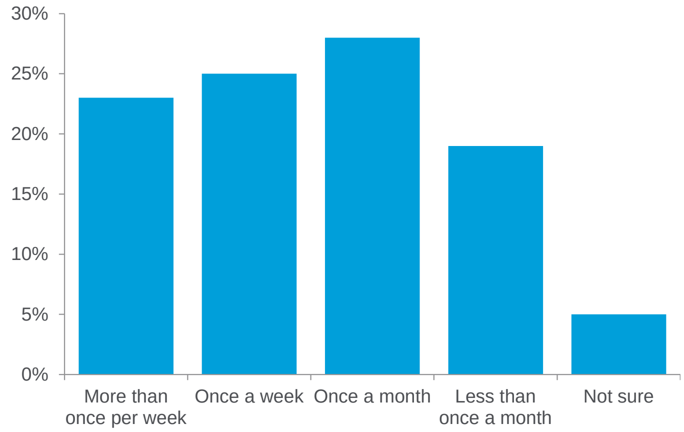
Secondly, the results suggest that public chargers are still required in combination with home and workplace charging as almost half of respondents said they use public facilities at least once a week (Figure 36). This figure may come down as vehicle ranges improve, but, for now, it shows that regular charging using public facilities remains a reality for many drivers, and it follows that improving the infrastructure available to drivers will therefore be key to addressing range anxiety.

Figure 35. Do You Have Access to Dedicated EV Charging Point at Your Workplace?



Source: Citi Research, Zap Map survey 2016 (1,463 respondents)

Figure 36. How Often Do You Use Public Charging Facilities?

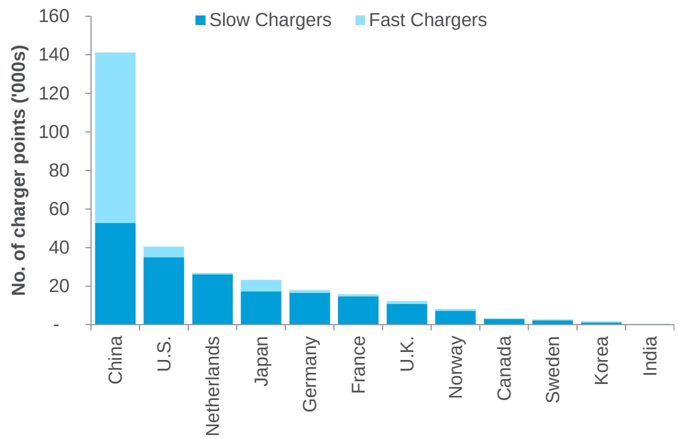


Source: Citi Research, Zap Map survey 2016 (1,283 respondents)

Outlook for Charging Points by Region

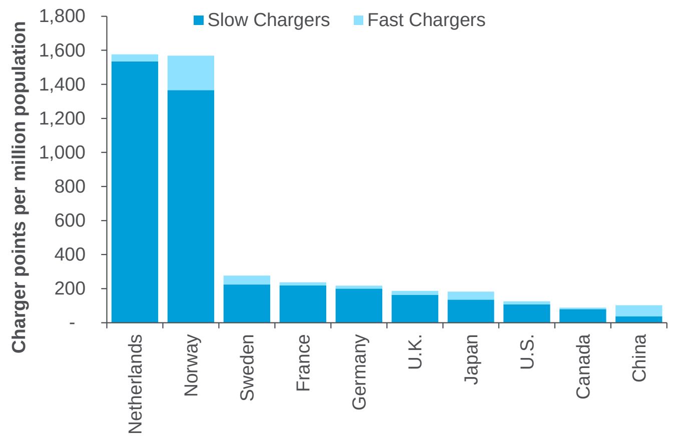
Although China boasts the largest charging infrastructure in absolute terms, the European nations have the best charging infrastructure per capita. In 2016 there were over 88,000 publicly available fast charging points in China, almost 15 times as many as in Japan, which had the second most. Interestingly, despite the boom in fast charging points in China, which increased from 9,000 in 2014 to over 88,000 in 2016, the development of slow charging units has not kept pace. In fact, China's EV/EVSE (relationship between number of vehicles and charging stations) ratio when considering only slow chargers has increased each year since 2014.

Figure 37. Publicly Available Charging Points per Country



Source: Citi Research, IEA

Figure 38. Publicly Available Charging Points per Million Population



Source: Citi Research, IEA, World Bank

When accounting for population size, Norway and the Netherlands provide the best charging infrastructure. We have analyzed the number of publicly accessible chargers per million people in order to assess how developed the infrastructure is across key EV markets relative to population size. Our findings (see Figure 38) suggest that the Netherlands and Norway, which have the highest EV market shares (Figure 39), are also leaders in charging point infrastructure relative to their population size. Norway's slow charger electric vehicle (EV)/electric vehicle supply equipment (EVSE) ratio (Electric, however, is the highest of the countries we analyzed, suggesting that although it is one of the most developed relative to population size, there is still room for improvement when it comes to servicing the 133,000 EVs currently on its roads.

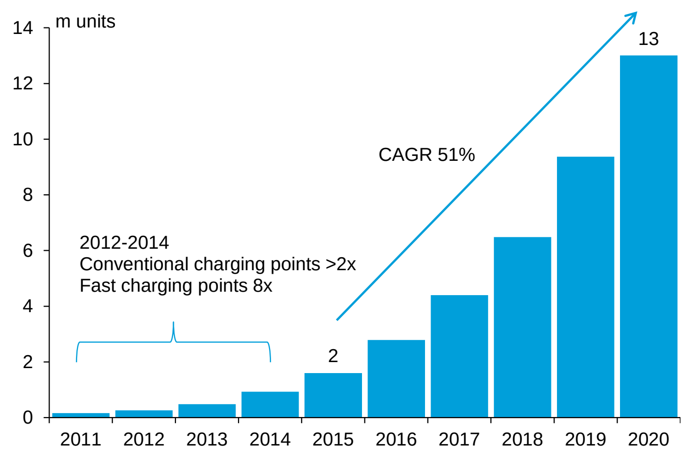
Figure 39. EV Charging Infrastructure by Country

	EV Market Share (BEV & PHEV)	EV/EVSE (Public slow chargers)
Norway	28.8%	19
Netherlands	6.4%	4
Sweden	3.4%	13
France	1.5%	6
U.K.	1.4%	8
China	1.4%	12
U.S.	0.9%	16
Germany	0.7%	4
Canada	0.6%	10
Japan	0.6%	9
Others	0.5%	4
Korea	0.3%	10
India	0.0%	15
Total*	1.1%	10

*Calculated based on total market size of all countries within IEA report

Source: Citi Research, IEA

Figure 40. Global Charging Points



Source: Citi Research, Aumann presentation

At the national level, there appears to be little correlation between charging infrastructure and market share. We have summarized the EV/EVSE ratio for publicly-available slow chargers in Figure 39. The data do not suggest a strong correlation exists between EV/EVSE and EV market share. Norway has the highest market share and EV/EVSE ratio, but the Netherlands has the 2nd-highest market share and among the lowest number of EVs per EVSE. India has the lowest market share, but the 3rd-highest EV/EVSE ratio.

Figure 41. European Infrastructure Policy Initiatives and Incentives

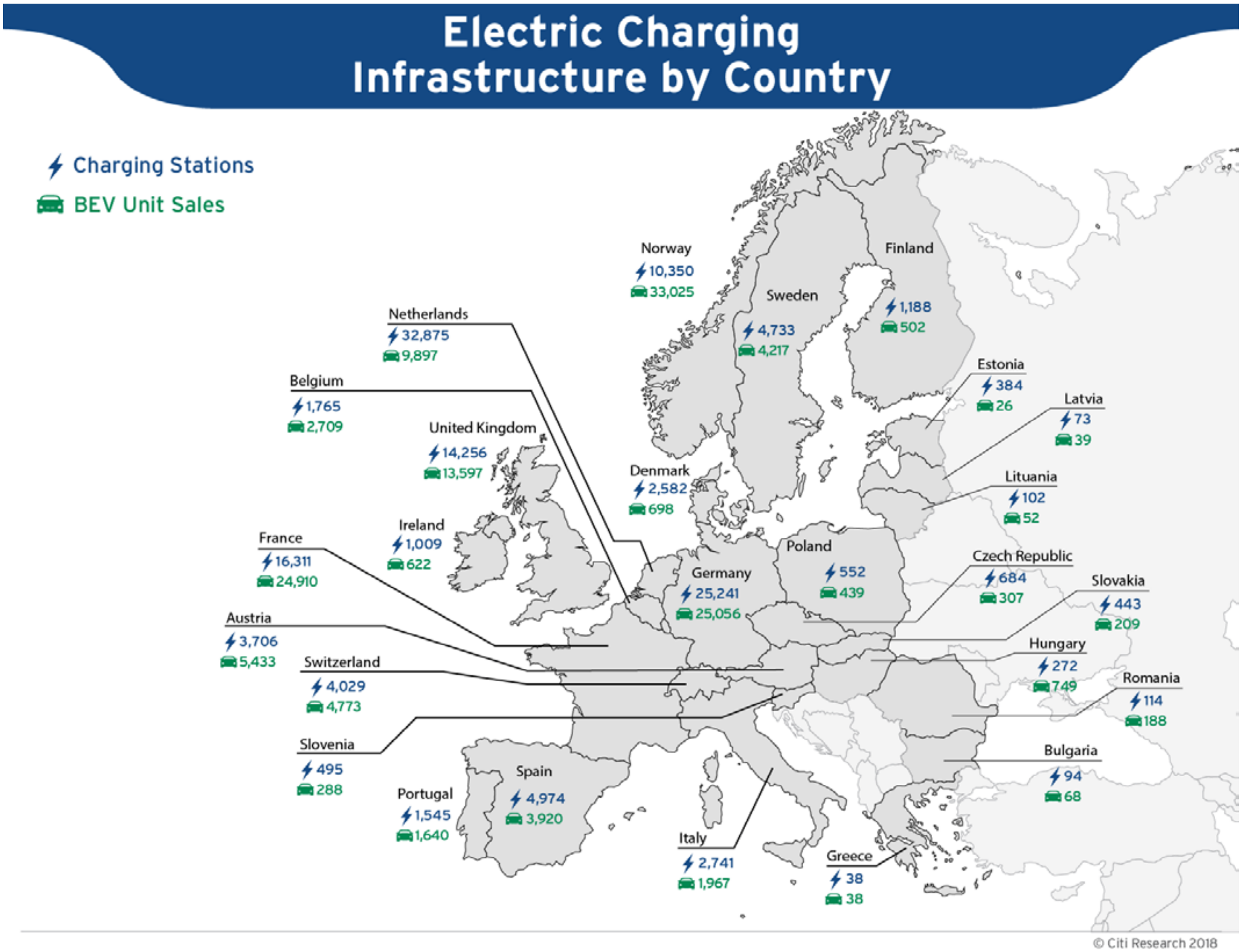
Country	Infrastructure Incentives
Denmark	- Individuals receive a tax rebate of up to 18,000 DKK on the home installation of EV chargers
Ireland	- Individuals installing the first 2,000 home chargers in Ireland would receive a grant for the total cost. This target was reached in 2017 - New €600 grant from the government towards installation of home charging points from 1 Jan 2018
Italy	- Large non-residential building will be required to install EV charging points in order to meet building regulations
Malta	- €2,000 grants are available for companies to purchase charging points (up to a maximum of 5 per company)
Norway	- Government is providing public funding in order to reach its target of having at least one fast charging station per 50km of main road
Spain	- Subsidies are available for both private and public charging points
UK	- Individuals receive a £500 subsidy when installing a home charger; business receive a subsidy worth £300 per socket - Local Authorities can receive a 75% refund (capped at £7,500) from the government for costs relating to installation of roadside charge points in residential areas

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

European Infrastructure

Below we illustrate the distribution of BEV sales and charging stations across Europe. There is a notable divide between the levels of infrastructure development in Western Europe and the rest of the continent. Clearly, charging stations are far more prevalent in markets such as Norway, the Netherlands, Germany, France, and the U.K. than in Southern and Eastern Europe.

Figure 42. European Charging Infrastructure and BEV Unit Sales

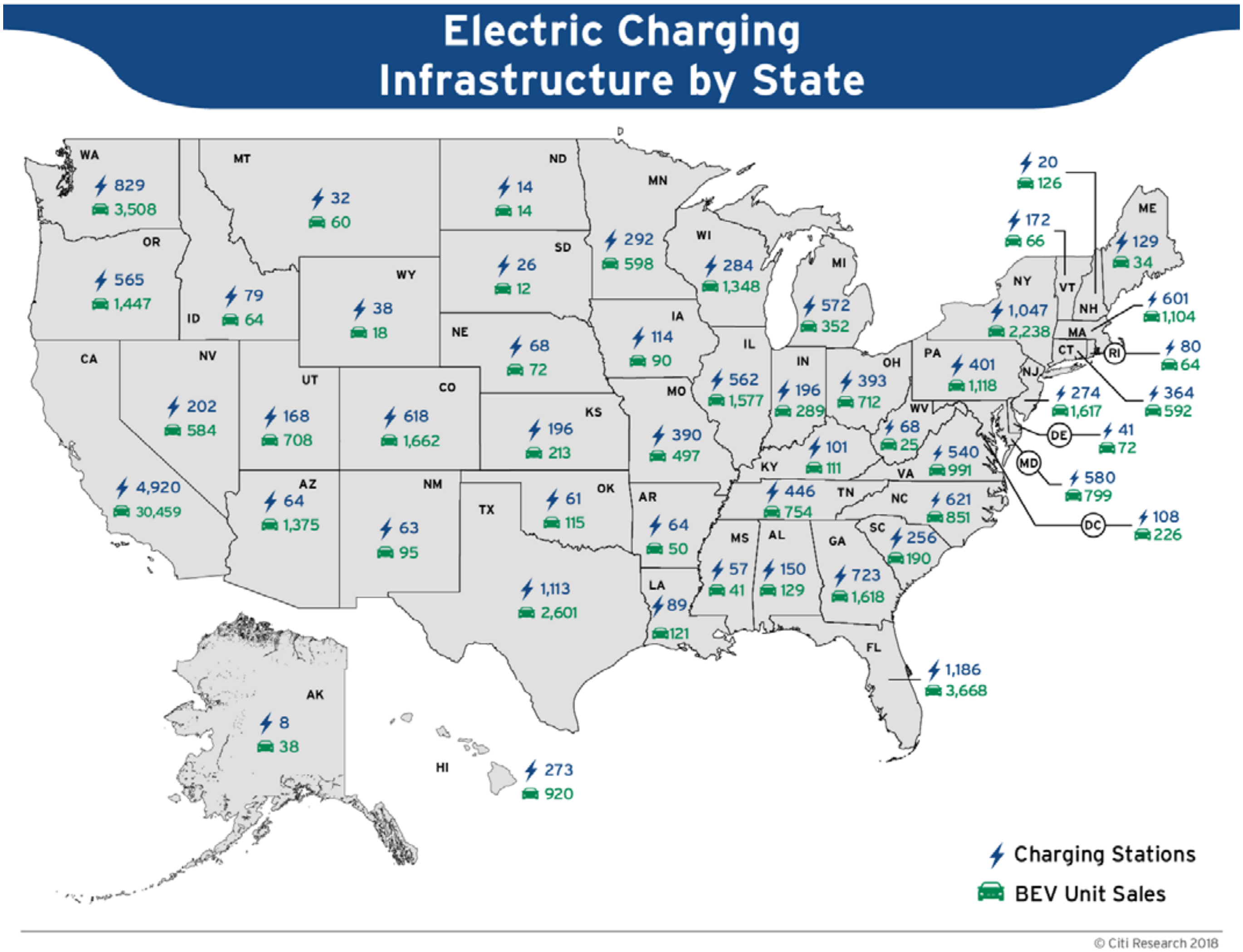


Source: Citi Research, ACEA, EAFO

U.S. Infrastructure

Below we show U.S. BEV unit sales and charging stations by state in order to illustrate the geographical spread of charging infrastructure in the U.S. The average BEV unit sales per state in 2016 was 1,300 units, and sales were clearly driven by the state of California, where over 30,000 units were sold. The average number of charging units per state is just 412, and again these are disproportionately found in California, where there are almost 5,000 charging stations available.

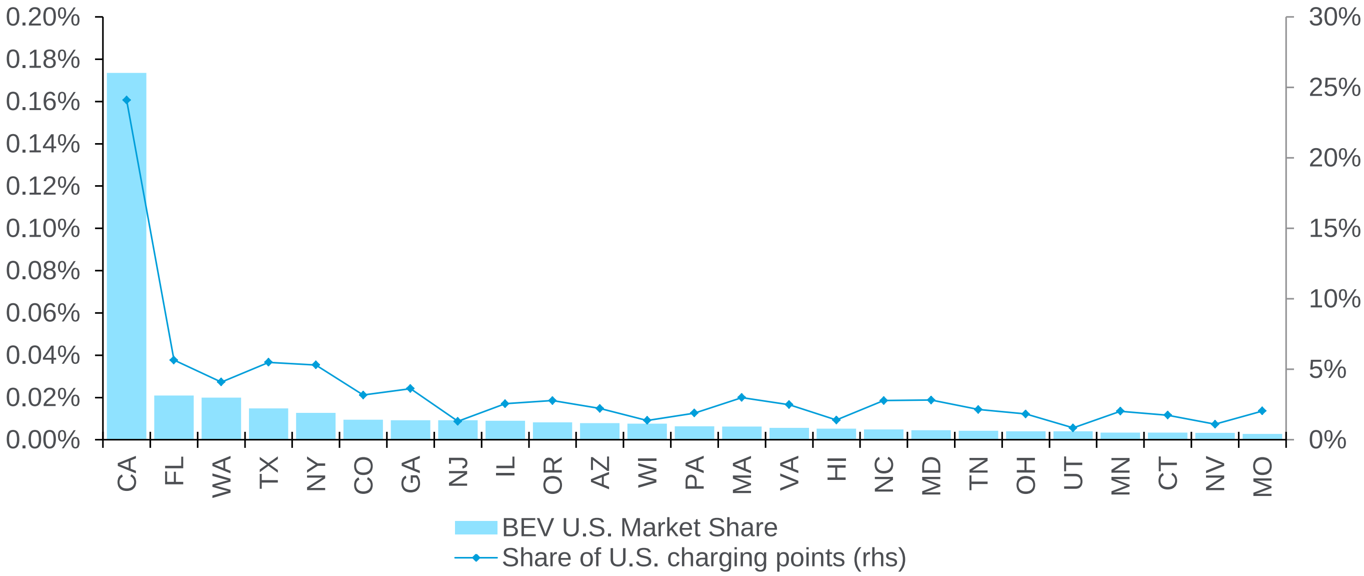
Figure 43. U.S. Charging Infrastructure and BEV Unit Sales



Source: Citi Research, Polk Automotive, Autodata, U.S. Department of Energy. Note BEV Unit Sales relate to 2016 volumes.

U.S. infrastructure and sales highly concentrated in California. The total number of BEVs sold in the U.S. in 2016 was 66,000 compared with total vehicle sales in excess of 17.5 million, implying penetration of 0.4%. California accounted for 46% of U.S. BEV sales, or ~0.2% of overall U.S. volumes. No other U.S. state saw penetration higher than 0.02%. Unsurprisingly, our analysis of the geographical split of EV charging points (Figure 44) tells a similar story: 24% of charging points in the U.S. can be found in California. Only 6% are in Florida, which has the second largest share, and 30 states have less than 1%.

Figure 44. Charging Infrastructure Across the Top 25 U.S. States by 2016 BEV Sales

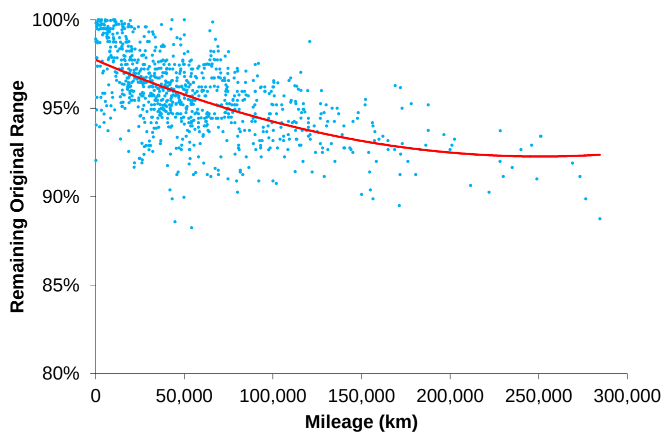


Source: Citi Research, Polk Automotive, Autodata, U.S. Department of Energy

3. Battery Longevity: "How Long Will the Battery Last?"

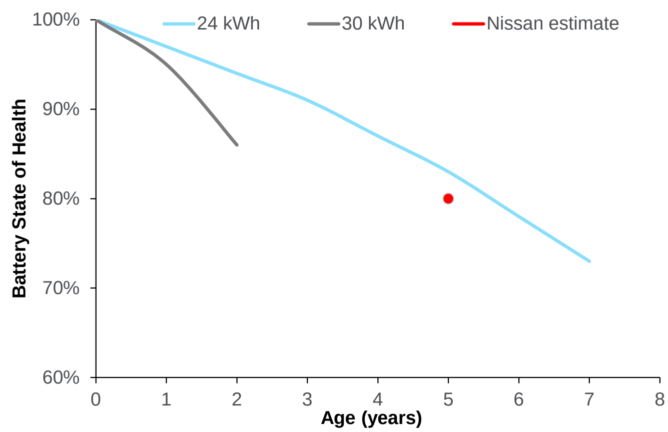
Battery degradation continues to weigh on consumer confidence, despite signs of durability from Tesla. The relatively recent, and limited, adoption of EVs means the data available on battery longevity is limited; however, a crowdsourced dataset containing inputs from almost 1,000 Tesla owners offers an insight into the longevity of the battery in a Tesla Model S (see Figure 45). Interestingly, at 200,000 miles (often cited as the life expectancy of a conventional car), the Tesla Model S is on average still operating at 93% of its original range, suggesting fears of battery degradation could be overstated.

Figure 45. Tesla Model S Battery Degradation



Source: Citi Research, Tesla Motors Club

Figure 46. Nissan Leaf Battery Degradation



Source: Accelerated Reported Battery Capacity Loss in 30 kWh Variants of the Leaf[8]

However, the battery life issues at Nissan Leaf seem to have already dented the credibility of electric car batteries. The state of health of the 24k-Wh and 30-kWh Leaf batteries has been shown to decline by 3% and 7% per year, respectively, after one year (Figure 46). Nissan has stated they are aware of battery degradation issues in some models and are investigating, though it is concerning that the larger battery has shown a much worse rate of decline. The latest 40-kWh battery and the 60-kWh battery, which will be launched in 2019, are likely to improve on this level of degradation, but the issues with earlier models have already contributed to consumer concerns over battery longevity.

Vehicle-to-grid (V2G) charging could offer a solution by curtailing capacity fade. V2G technology transfers energy from EV batteries to power the grid when energy is not required by the vehicle, such as when a car is left to charge overnight. This could present a significant benefit to the system through increased flexibility as well as increasing the use of renewable energy and helping to address the intermittency problem, especially if one considers that over 90% of vehicles are parked at any given time. Further, a recent study has shown the process can improve battery life by 9% over a year,[9] suggesting that the decline in the state of health of a battery is not irreversible and battery performance can be improved without the need to pay for a replacement.

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[8] Myall, D., Ivanov, D., Larason, W., Nixon, M., and Moller, H. Accelerated Reported Battery Capacity Loss in 30-kWh Variants of the Nissan Leaf. *Preprints* 2018.
[9] Uddin, K. et al. On the possibility of extending the lifetime of lithium-ion batteries through optimal V2G facilitated by a flexible integrated vehicle and smart-grid system. Energy, 2017.

Figure 47. EV Battery Warranties Available on Popular Models

Brand	Model	Warranty Duration (yrs)	Warranty Distance ('000 miles)	Capacity Threshold (%)
Kia	Soul EV	10	100	70
BMW	i3	8	100	70
Chevrolet	Bolt	8	100	60
Mercedes	B250e	8	100	70
Nissan	Leaf	8	100	70
VW	e-Golf	8	100	70

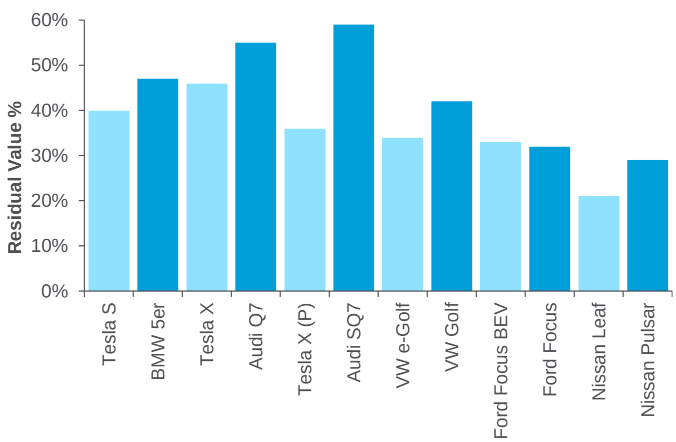
Source: Citi Research, fleetcarma

Carmakers hope to ease consumer concerns over battery longevity by offering warranties. In order to reinforce confidence in the longevity and quality of their products, some carmakers offer warranties on the batteries contained within their EVs. A battery is eligible for replacement if it fails once capacity has degraded below a certain threshold before either a set number of years or a distance driven. The examples listed in Figure 47 give an indication of the level of confidence manufacturers have in the lifetime of the batteries in their vehicles. On average, the warranties offered suggest batteries should retain 70% capacity after 100,000 miles or 8 years.

4. Residual values and TCO: "Why Should I Pay over 30% Higher List Price for an EV?"

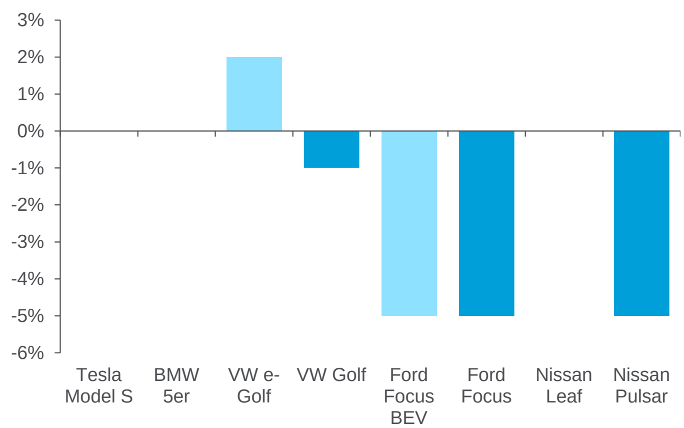
BEV residuals are weak, but improving. As well as having a higher entry price, BEVs also suffer from worse three-year residual value assumptions. If we exclude the premium end of the market, the residual values of BEVs are 6 percentage points lower than their ICE alternative (Figure 48). As BEV technology improves and is more widely understood by consumers, we expect residuals will improve. Interestingly, when we compared the change in residual value assumptions between June 2016 and November 2017 (Figure 49), we observed that BEV residuals deteriorated less than their ICE alternatives. This may be the first signs of improving BEV residuals, which is crucial for total cost of ownership (TCO).

Figure 48. 3-Year Residuals: Selection of Popular BEVs vs. ICE Alternatives



Source: Company data, Whatcar

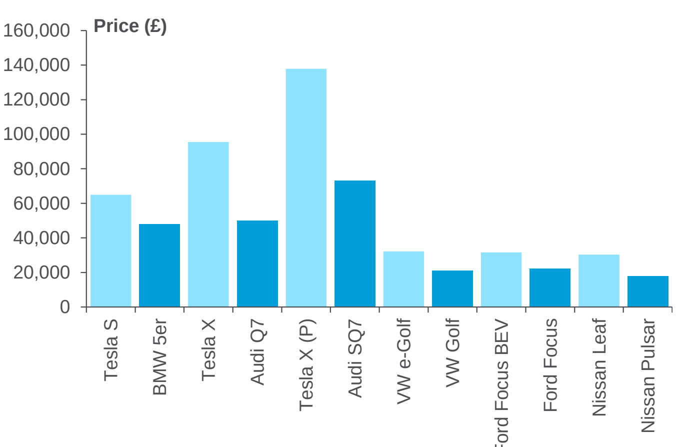
Figure 49. Change in 3-Year Residual Value (%, Nov-17 vs Jun-16)



Source: Company data, Whatcar

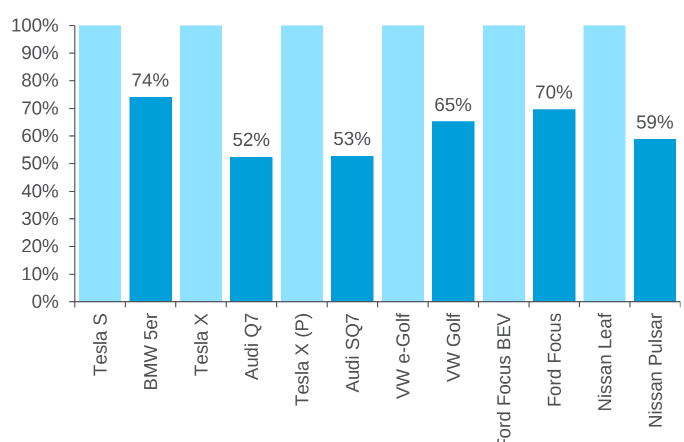
Price is the single-biggest barrier, and it is clear to see why that is. The results of the surveys we analyzed showed that price was the greatest hurdle for BEV adoption. We compared the prices of a selection of popular BEVs in the U.K. with their internal combustion engine alternative (see Figure 50). If we strip out the more premium end of the market (e.g., Tesla Model X / Audi Q7), the list price of an ICE alternative is 33% below that of its BEV equivalent (see Figure 51).

Figure 50. List Price of a Selection of Popular BEVs vs. ICE Alternatives



Source: Company data, Whatcar

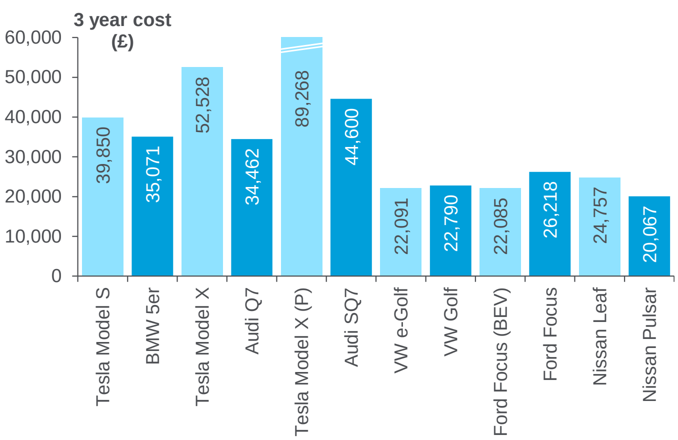
Figure 51. ICE Alternative Price Relative to BEV Model



Source: Company data, Whatcar

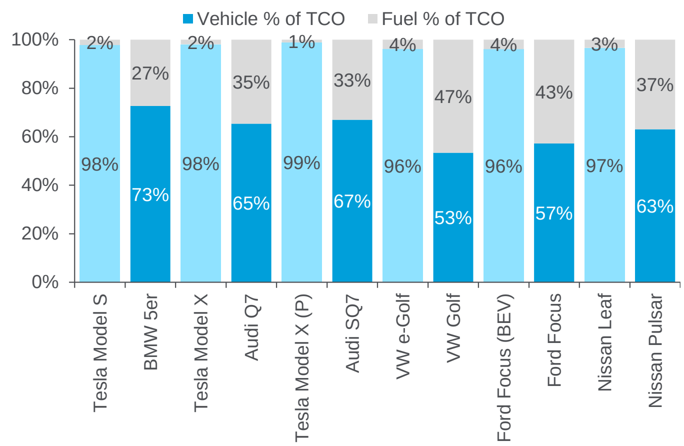
The total cost of owning a BEV is not as high as you might think. Given the large delta in price and lower residual-value assumptions, there is a perception that BEVs are not priced attractively (compared with their ICE alternatives). We analyzed the total cost of ownership over three years of several models (Figure 52), and found the delta to be lower than what is commonly perceived. In fact, the electric versions of the VW Golf and Ford Focus are 3% and 16% cheaper than their ICE versions, on a three-year view. Our calculation assumes the average numbers of miles driven per year to be 7,500 (which in 2016 was the average distance traveled per year for a private owned car in the U.K.). In Figure 53 we show how much of the total cost of ownership (over three years) relates to vehicle depreciation and fuel cost. For the BEVs, vehicle depreciation accounts for 97% of the three year TCO, while for the ICE alternative, depreciation accounts for 63% of the TCO.

Figure 52. 3-Year Total Cost of Ownership: Various Models



Source: Citi Research, Whatcar, eOn, DfT

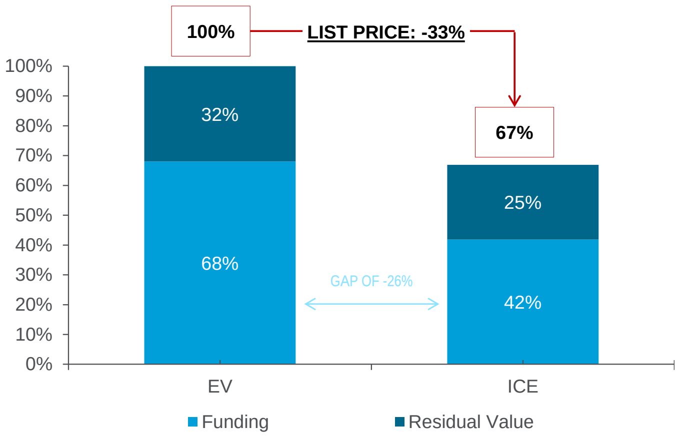
Figure 53. 3-Year TCO Split by Vehicle Depreciation & Fuel Cost



Source: Citi Research, Whatcar, eOn, DfT

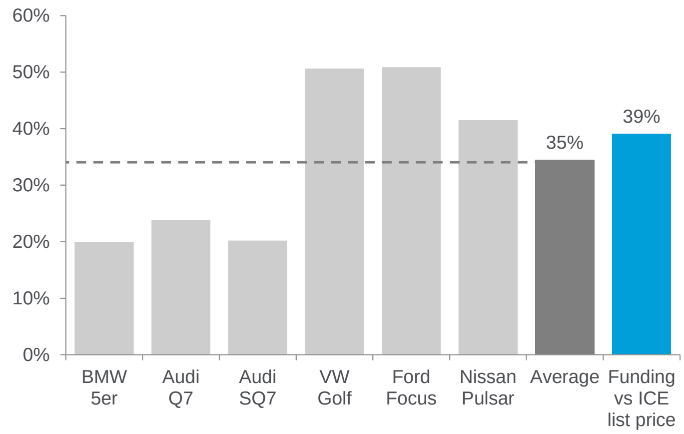
We are cognizant that an increasing proportion of new vehicle purchases are via a finance plan (i.e. loan). In Figure 54 we show the funding-gap between a BEV and ICE to be on average of 26% of the list price of a BEV; therefore, purchasing an ICE saves 39% of the vehicle's list price. The trade-off is the cost of fuel, and in Figure 55 we show how much three years of fuel costs vs. the ICE list price. Our analysis suggests that an ICE remains ~5% cheaper than a BEV on a three-year view (typical lease length), but we expect this to fall as battery costs fall.

Figure 54. BEV vs. ICE - Funding the Gap



Source: Citi Research, Whatcar, eOn, DfT

Figure 55. 3-Year Fuel Cost as % of ICE List vs. Saving From Buying an ICE



Source: Citi Research, Whatcar, eOn, DfT

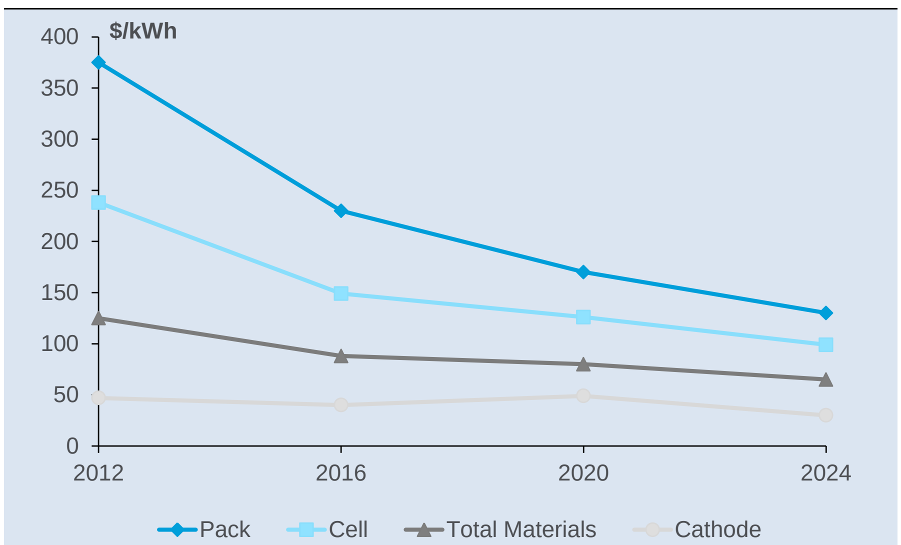
Figure 56. Dr Menahem Anderman, PhD

Dr Anderman is a globally renowned expert on automotive battery technology with 35 years of industry experience. He founded Total Battery Consulting Inc. in 1996 and Advanced Automotive Batteries Inc in 2000, and is President of both companies. He holds a PhD in Physical Chemistry from the University of California and has written extensively on the EV industry.

Deep Dive into Battery Cost

Figure 57 below presents EV-battery cost curves between 2012 (best estimate) and 2024 (projected). The associated key battery design aspects and production volume are tabulated in Figure 58. Battery cost can be divided into 4 relatively similar cost components: (1) the cell cathode; (2) the balance of cell materials; (3)) cell assembly; and (4) the battery module and pack components and assembly. Pack cost has come down from about $375/kWh in 2012 to around $200/kWh today. Cost reduction was achieved by: (1) cell designs with lower power-to-energy ratios; (2) economy of scale; (3) the use of more energetic materials; (4) the use of lower-cost solutions in the pack; (5) the maturity of the manufacturing process; and (6) the drop in metal pricing between 2013 and 2016.

Figure 57. EV battery cost-curves $/kWh



Source: Total Battery Consulting

Figure 58. Key Battery Design Aspects and Production Volume

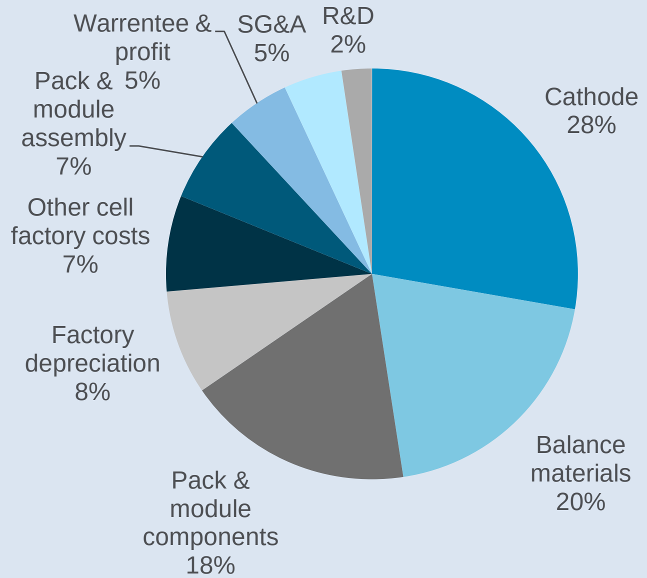
	Year	2012	2016	2020	2024
Pack size	kWh	24	42	60	65
Cathode chemistry		LMO-NMC 1,1,1: 70-30	NMC 5,3,2	NMC 6,2,2	NMC 8,1,1
Power to energy ratio	kW/kWh	5	3	2	2
EV volume*	000 units	62	247	650	1,600
Production volume	GWh	1.5	10.4	39	104

*Excluding China

Source: Total Battery Consulting

With production volumes ramping up at an annual rate of 30%–50%, we expect a steady reduction in cost — averaging 6%–10% per year — for all aspects of battery cost excluding the cathode. The latter has seen a significant rise in the price of key raw materials, which has resulted in a price increase for current quotations (for the 2020 production year) versus those from 2016 (for 2018–19). Figure 59 exhibits a cost breakdown for EV packs featuring the common NMC '6,2,2' cathode for 2020 production.

Figure 59. Cost Breakdown for $170/kWh EV Packs Featuring the Common NMC '6,2,2' Cathode for 2020 Production



Source: Total Battery Consulting

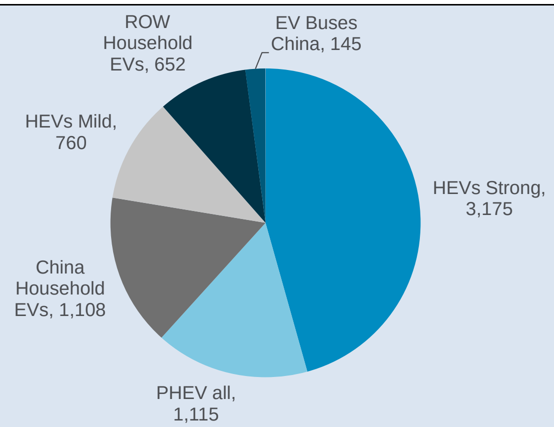
Future cost improvements are likely to mainly come from the same sources as historical cost reductions, with economy of scale and improvements in battery design allowing further gains. However, given that the cathode material already accounts for over 25% of battery costs, with that percentage set to rise as more scale efficiency is developed, we expect continued margin pressure on cathode-material producers in order to support overall cost improvement. Larger battery manufacturers are already reported to be operating on razor-thin margins in order to gain share.

EV penetration beyond regulated or highly-incentivized volumes is largely dependent on reaching parity or better in terms of total cost of ownership compared with ICEs, and it assumes that customers will accept a vehicle with a 200–250 miles range and a refueling time of 30 minutes or longer. Batteries are the single most-expensive component in an electric vehicle; for example, the 2017 Chevy Bolt battery is listed at $15,734 (although its cost to GM is not known), representing an estimated 40% of the vehicle price. Greater BEV and PHEV penetration is above all limited by higher relative cost vs. ICE; the issues of dependence on subsidy and high total cost of ownership are primarily caused by this cost disparity. Falling battery costs as well as increasing battery energy per unit volume and increasing charge rate are critical to achieving competitiveness on an unregulated basis.

For similar power levels, the cost of the all-electric powertrain, excluding the battery, is currently similar to that of conventional gasoline engines and is about $1,500–$2,000 lower than that of the advanced diesel powertrains used in premium European brands. Thus, cost parity with ICE powertrains at the vehicle point of purchase for an EV with a 60-kWh battery is not achievable. At our projected future battery pricing of $130/kWh, the equivalent total cost of ownership for the European market at current European fuel and electricity prices will require fuel amortization over 4–6 years, and for the U.S. market, over 10 years. This drives the battery price targets communicated by automakers to below $100/kWh.

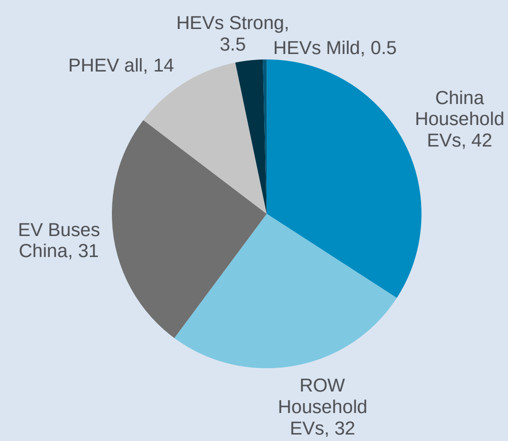
Figure 60 and Figure 61 below provide our best estimates for production volume in units and GWh for the key electrified vehicle architectures projected for 2020. Note the dominant position of China in the EV unit count and the dominant aspects of EVs on MWh consumed. In dollar value, the full electric vehicles present the largest opportunity for the battery business including battery and cell production as well as cell materials and pack components.

Figure 60. Projected Global xEV Production Volume, '000 Units



Source: Total Battery Consulting

Figure 61. Projected 2020 Global xEV Battery Demand, GWh



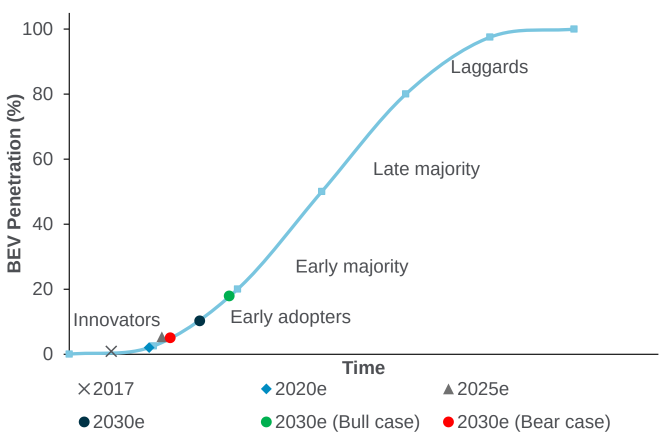
Source: Total Battery Consulting

Demand-Driven Factors

It's clear from volumes that we are still in the early stages of EV adoption. In 2017, BEV and PHEV vehicles combined accounted for just 1% of new car sales globally. While we expect this to increase to 18% by 2030, the path to full EV adoption is certainly a long one. We categorize consumers into five types in Figure 62 and would argue that today's EV owners are the "innovators" on the long journey to full EV adoption.

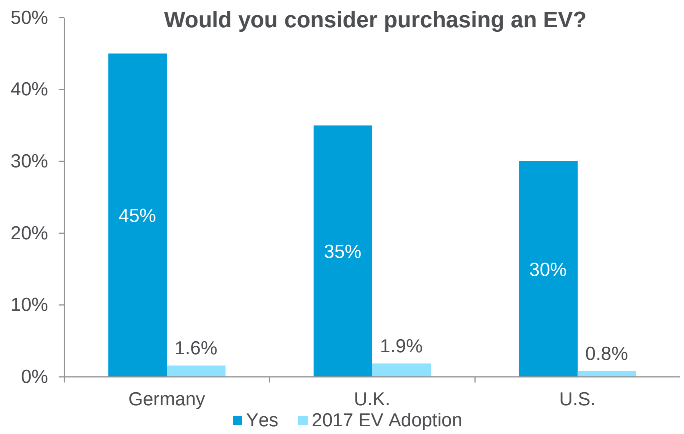
For us to move along the curve towards full adoption, demand will need to inflect among the "early majority" and "late majority" consumers. We're not there yet as demand for electric vehicles remains weak, and we would argue that, particularly in the early stages of development, the EV market is being driven predominantly by supply factors.

Figure 62. There's a Long Way To Go Before Reaching Full EV Adoption



Source: Citi Research estimates

Figure 63. Intentions Are Not Translating into Purchases Just Yet



Source: Citi Research, McKinsey, CarGurus, ACEA, LMC

The public is warming to the idea, but barriers to adoption are inhibiting demand. Although interest in electric vehicles has been growing and consumers are increasingly open to the idea of buying an EV (Figure 63), this is yet to translate into meaningful sales figures. The main barriers to adoption discussed earlier (range, infrastructure, battery longevity, residual values) clearly contribute to this disparity, and the relatively limited range of EV products currently available is also likely to be impeding demand.

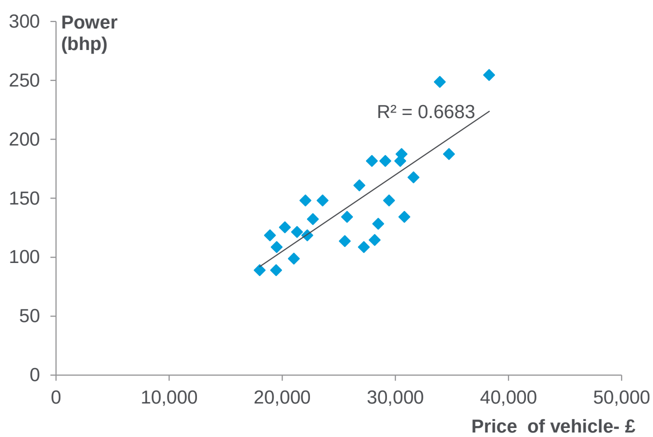
Fleet buyers are a potential catalyst for driving EV demand. While an individual's decision to buy a new car is determined by a range of factors including more subjective criteria such as brand loyalty and public perception, fleet buyers are more rational actors, driven by economics and costs. They therefore offer a potential catalyst for adoption rates whereby demand inflects among fleet buyers when it makes financial sense to switch to an electric fleet. This is not to say cost parity is not also a key driver among individuals, but rather that it is the main driver for fleet buyers and a point that is often overlooked despite the fleet market accounting for roughly 23% of annual new car sales in Europe.[10]

[10] Peugeot, Ford, Renault lead in high-margin sales to private customers. *Automotive News Europe, June 2017.* link

Will Consumers Pay?

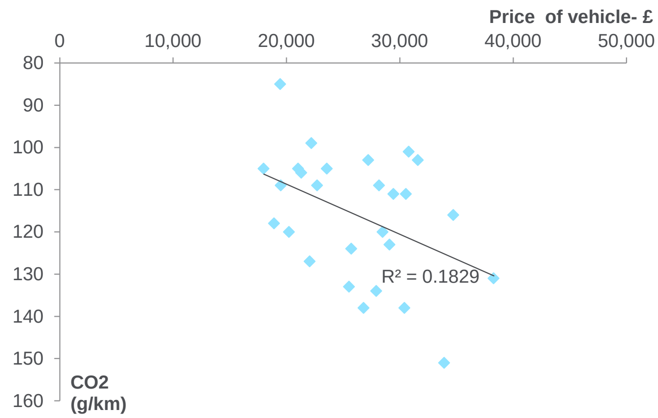
Ingrained buying habits present a challenge for EVs. We have long argued (see here) that consumers are generally open to paying for power, but less willing to pay for fuel efficiency. This is especially true when fuel prices are low, as they are today. As such, OEMs have historically been reluctant to add fuel-saving content to vehicles as there is limited financial return to them for doing so. We analyzed the relationship between price and power (bhp) and that between price and CO_2 emissions, and the results support our view (see Figure 64 and Figure 65). In our analysis we captured the data for a range of engine sizes/types for the following models: BMW 3-series, Ford Focus, Mercedes C-class, Nissan Qashqai, Renault Clio and VW Golf.

Figure 64. Relationship Between Vehicle Price and Power



Source: Citi Research, WhatCar (June 17 issue)

Figure 65. Relationship Between Vehicle Price and CO_2 Emissions



Source: Citi Research, WhatCar (June 17 issue)

Battery costs are an obstacle for price-reductions. The above analysis reinforces our view that the primary hurdle to mass EV-adoption is the cost of batteries. If the average consumer is not willing to pay for fuel efficiency (as above) it must be offered at little (or no) additional cost, and while battery costs are prohibitively high (as economies of scale are not being attained) it is nigh-on impossible for manufacturers to reduce the selling price of their electric vehicles (without significantly damaging their financial performance). We believe list prices need to fall to entice the average consumer, and until this happens electric vehicles will remain in the 'early-adopters' phase.

How Many EVs Are Required?

Model for European Powertrain Mix

Lower diesel penetration creates a major CO_2 challenge for the industry. The future may well be electric — maybe not wholly, but an increasing proportion of new car sales will either be full electric (we see 6% by 2025) or partial electric. That means the carmakers are still heavily reliant on diesel to deliver the CO_2 savings required to meet 2021 EU targets. However as we mapped out in this report, we think diesel penetration will continue to fall. That begs the question of how many EVs need to be sold to reach the emission targets, or conversely what is the efficiency hurdle for gasoline engines given their popularity looks set to rise. We have modeled this and present our findings below.

Model for European Powertrain Mix in 2020/2021, 2025, and 2030

We have built an industry model to gauge the magnitude by which either full-battery electric vehicle (BEV) penetration needs to rise, or the efficiency of gasoline engines needs to improve in order to meet the upcoming CO_2 targets. We also include the impact of super-credits {Note: in 2020 the carmakers will benefit from super-credits for producing vehicles with < 50g/km]. Each vehicle that emits less than 50g CO_2 will be counted as two cars in 2020, 1.67 in 2021, and 1.33 in 2022. The super-credits will be phased-out by 2023, when no multiplier will be awarded for the sale of low-emission vehicles.

Figure 66. Europe: What Would BEV Penetration Need to be to Meet the Upcoming CO_2 Targets?

Europe	NEDC			WLTP					
Powertrain Mix	2015	2020	2021	2021	2022	2023	2024	2025	2030
Diesel	52%	33%	31%	31%	28%	26%	24%	21%	19%
Gasoline	*46%*	*60%*	*62%*	62%	*62%*	*59%*	*59%*	*59%*	*52%*
PHEV	1%	1%	2%	2%	2%	3%	3%	4%	9%
BEV	1%	5%	5%	5%	8%	12%	14%	15%	20%
Super-credits		2.00	1.67	1.67	1.33	1.00	1.00	1.00	1.00
CO_2 (g/km)	2015	2020	2021	2021	2022	2023	2024	2025	2030
Diesel	108	92	90	104	101	99	97	96	86
Gasoline	135	115	113	129	127	124	122	119	108
PHEV	46	43	43	49	49	48	48	47	45
BEV	0	0	0	0	0	0	0	0	0.0
Fleet	119.5	95.0	95.0	109.2	104.9	100.7	96.7	92.9	76.5

Assumes a factor of 1.15 as we move from NEDC to WLTP
Assume that the fuel efficiency improvement for diesel and gasoline vehicles is 3.2% per year until 2020 (this is the same magnitude of improvement as seen between 2010 and 2015). Until 2020 we assume that PHEV efficiency also improves, but to a lesser extent (~1.2% per year)
In 2021 and beyond we assume fuel efficiency is harder to come by and assume diesel and gasoline fuel efficiency improves by 2.0% /year. For PHEVs we assume 0.8%/ year.
Source: LMC, IHS, Citi estimates. Yellow highlight indicates the balancing figure obtained by use of 'goal-seek', solving for fleet emissions

All else equal, we estimate that in order to meet the 2021 95g/km CO_2 target the penetration of BEVs will need to increase to 5% (from less than 1% today), which compares to LMC's expectation of ~4% BEVs in 2021. As we have outlined in this report, there are a number of factors that are critical for greater adoption of electric vehicles that still need to be overcome, and in that context a figure of 5% seems a stretch. While we are in no doubt that electric vehicle penetration will accelerate in the next decade, we are skeptical about the pace of ramp in the next few years. The end of 2021 is a little over three years away, and while we estimate BEV volumes will triple in that time, we expect it to still only account for a little over 2% of sales.

Interesting observations from the analysis in Figure 66:

- Despite the reduction of super credits in 2021, BEV penetration need not rise as the overall target remains 95g.
- The phasing out of super credits in 2022 and in 2023 has a material impact on the number of BEVs required to achieve the fleet target (jumps 3–4 percentage points per year).

Figure 67. Europe: How Much Would the Efficiency of Gasoline Engines Need to Increase to Meet the Upcoming CO_2 Targets?

Europe	NEDC			WLTP					
Powertrain Mix	2015	2020	2021	2021	2022	2023	2024	2025	2030
Diesel	52%	33%	31%	31%	28%	26%	24%	21%	19%
Gasoline	46%	64%	65%	65%	67%	68%	68%	68%	58%
PHEV	1%	1%	2%	2%	2%	3%	3%	4%	9%
BEV	1%	2%	2%	2%	3%	4%	5%	6%	14%
Super-credits		2.00	1.67	1.67	1.33	1.00	1.00	1.00	1.00
CO_2 (g/km)	2015	2020	2021	2021	2022	2023	2024	2025	2030
Diesel	108	92	90	104	101	99	97	96	86
Gasoline	135	104	105	120	114	109	105	103	96
PHEV	46	43	43	49	49	48	48	47	45
BEV	0	0	0	0	0	0	0	0	0
Fleet	119.5	95.0	95.0	109.2	104.9	100.7	96.7	92.9	76.5
Gasoline fuel efficiency improvement (% per year)		4%*	-1%		5%	5%	3%	2%	1%**

Assumes a factor of 1.15 as we move from NEDC to WLTP
* per year improvement in the period from 2015 to 2020 / **per year improvement in the period from 2020 to 2025
Source: LMC, IHS, Citi estimates. Yellow highlight indicates the balancing figure obtained by use of 'goal-seek', solving for fleet emissions

Required improvements in gasoline-efficiency are too tough to achieve target. Assuming 2021 BEV penetration is as we predict (i.e., 2%), the efficiency of gasoline engines needs to improve by 23% (or >4% per year) in the period to 2020 in order to meet the CO_2 target. In 2022 and 2023 fuel efficiency will need to improve by 5% (assuming BEV + PHEV penetration rises by only 100 basis points) as super credits are phased out. For reference the European-wide fleet reduced CO_2 by 1.2% (from 119.5g to 118.0g) in 2016, but rose 0.4% in 2017 (to 118.5g[11]) as lower diesel limited the progress. On the basis of the historic evolution of fuel efficiency, we do believe it will be possible to achieve the CO_2 targets by exclusively relying on an improvement here. To reach the targets we expect a mixture of both EV penetration and improvement in combustion engine efficiency will be required. Given the ever reducing popularity of diesel-cars (~20% more efficient than gasoline equivalents), we believe that technologies such as 48-volt (which offers a 10%–20% fuel efficiency improvement) will have to become far more prevalent if carmakers are to achieve efficiencies of the magnitude that our analysis suggests is required.

Interesting observations from the analysis in Figure 67:

- Due to the increase in BEV and PHEV penetration in 2021 the efficiency of gasoline in 2021 can deteriorate by 1% (vs 2020) and still meet the 95g target.
- Beyond 2023, the magnitude of improvement for the fuel efficiency of gasoline vehicles is not particularly difficult (2.8% per year in 2024 and 2.1% in 2025), provided PHEV and BEV penetration rise by ~100 basis points in each year.

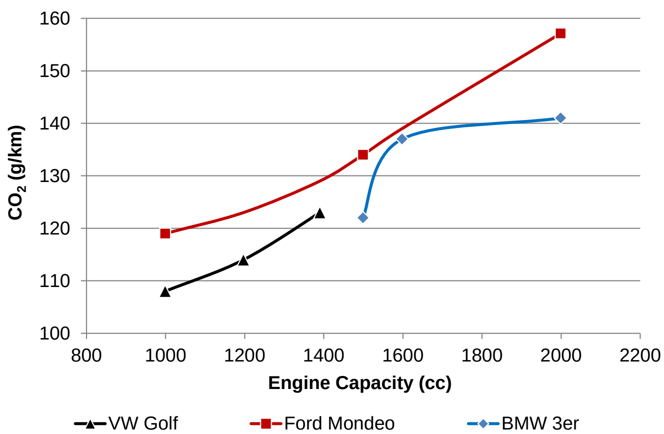
[11] https://www.eea.europa.eu/highlights/no-improvements-on-average-co2.

- It is worth bearing in mind that the shift from NEDC to WLTP will make efficiency improvements more difficult to achieve.

We have detailed the changes to the new-vehicle testing procedures in Appendix 6: *Navigating the Shift from NEDC to WLTP.*

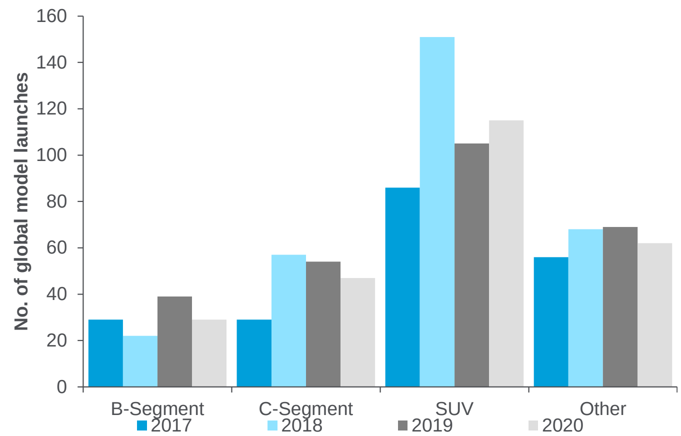
It's all in the mix. It is worth noting our model assumes mix remains constant, and so it is positively biased in that regard. We are, however, cognizant that OEMs are making a conscious effort to downsize engines, thereby improving the fuel efficiency of their fleet. This may be offset by the continued rise in demand for larger, and therefore heavier, vehicles. SUV popularity (see Figure 69) and model offerings mean the hurdle may even be higher than what we have derived.

Figure 68. The Engine Downsizing Trend Will Help Reduce CO_2 Emissions



Source: Citi Research, www.parkers.co.uk

Figure 69. Model Launches by Segment Shows a Raft of Upcoming SUVs



Source: Citi Research, IHS

Model for China Powertrain Mix

The Chinese have made it clear that they want to be global leaders in electric vehicles, and they have set ambitious targets for the number of New Energy Vehicles (NEVs) they want to sell in 2020 and 2025: 2 million and 7 million. To encourage supply of NEVs the Ministry of Industry and Information Technology (MIIT), the country's regulatory body, has set for manufacturers an 'NEV target score'. The methodology for calculating the NEV target score is as follows:

- A) In 2018, 2019, and 2020 the percentage requirement is 8%, 10%, and 12% respectively. The percentage beyond 2020 is to be formulated separately.
- 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.]

Figure 70. Dual Credit Management System

Regulatory authority	Ministry of Industry and Information Technology (MIIT)	
Two parallel system	CAFC credit	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 2016-17/2018-19/2020 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 0.012 + 0.8 (cap at 5) NEV point per PHEV = 2
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 80% conversion ratio in 2018 and 90% in 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 - NEV credit is not allowed to be carried forward - The 2019/20 NEV balance will be examined together
Assessment companies	All PV OEMs selling in China (including import)	All PV OEMs with annual production volume or import volume greater than 30k 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%
Assessment period	2016+2017, 2018, 2019, 2020	2019+2020
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

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 OEM has a specific target, and like in Europe, the more fuel-efficient vehicles benefit from super-credits.

Model for Chinese Powertrain Mix in 2020 and 2025

We calculated the sensitivity of BEV volumes in China by modeling two different scenarios: (1) how many BEVs are required in China to comply with the 2020 and 2025 CAFC targets; and (2) assuming the fleet reaches the *required* NEV score (in 2020 and 2025), how much does fuel efficiency need to improve. We present the results of our sensitivity in Figure 71 and Figure 72.

Figure 71. Scenario 1: Solving for 2020 and 2025 CAFC Targets (number of NEVs)

	2015	2016	2020	2025
Fuel consumption (L/100km)	7.02	6.65		
vs 2012 (annual improvement)	*2.3%*	*3.8%*		
After credits	6.67	*6.44*		
Calculated fuel consumption	6.78	6.42	5.13	4.10
NEV multipliers	5	5	2	1
TARGET	6.90	*6.70*	5.0	4.0
vs 2015 (annual improvement)			*-6.2%*	
vs 2012 (annual improvement)	*-2.9%*		*-5.0%*	
NEV vehicles (million)			2.0	7.0
Total Pas-Cars ('000)	21,248	24,788	31,181	35,313
o/w conventional fuel	21,064	24,448	29,181	28,313
NEVs	185	340	2,000	7,000
BEV	124	245	*1456*	*5290*
PHEV	61	94	544	1,710
Gasoline	99.1%	98.6%	93.6%	80.2%
BEV	0.6%	1.0%	4.7%	15.0%
PHEV	0.3%	0.4%	1.7%	4.8%
Fuel efficiency				
Gasoline	7.08	6.86	5.80	5.02
BEV	0	0	0	0
PHEV	*1.96*	1.93	1.79	1.67
NEV "credit" targets			12%	22%
NEV credit requirement			3502	6229
NEV score			5449	26350
BEV			2.99	4.33
Range (km)			183	295
PHEV			2.0	2.0

Source: Citi Estimates, CAFC

Yellow highlight indicates the cells we used to 'seek our goal'

In deriving our forecast for BEV sales in 2020, we assume gasoline fuel efficiency will improve by 4% per year in China (from 2016 until 2020). It's worth noting the efficiency of gasoline vehicles in China improved at a rate of 1.8% per year in the period from 2006 until 2015. And for reference we assume the improvement in Europe will be ~3% per year over the same period. Our model tells us that in order to meet the fleet-wide fuel consumption target of 5L/100km (in 2020), ~1.46 million BEVs must be sold. To reach the 2025 target of 4L/100km, 5.3 million BEVs will need to be sold. It is possible that with higher penetration of fuel-efficiency technologies (e.g., turbochargers enabling engine downsizing, 48-volt systems, direct injection), the efficiency improvement may be greater than our base-case assumption, which will reduce the number of NEVs that need to be sold.

Interesting Observations from the Analysis in Figure 71:

- The target of 2 million and 7 million NEV vehicles to be sold in 2020 and 2025 seems quite optimistic in the context of the government's NEV credit requirements.

Figure 72. Scenario 2: Solving for NEV Score and Required Fuel Efficiency Improvements

	2015	2016	2020	2025
Calculated fuel consumption	6.78	6.42	5.00	4.00
NEV multipliers	5.00	5.00	2.00	1.00
TARGET	6.90	6.70	5.00	4.00
Total Pas-Cars ('000)	21,248	24,788	31,181	35,313
o/w conventional fuel	21,064	24,448	29,806	32,731
NEVs	185	340	1,375	2,582
BEV	124	245	831	872
PHEV	61	94	544	1,710
Gasoline	99%	99%	96%	93%
BEV	1%	1%	3%	2%
PHEV	0%	0%	2%	5%
Fuel efficiency				
Gasoline	7.08	6.86	5.43	4.23
BEV	0.00	0.00	0.00	0.00
PHEV	1.96	1.93	1.79	1.67
Improvement in consumption			23%	22%
vs 2015 (p.a improvement)			*5.2%*	*5.0%*
vs 2020 (p.a improvement)				*4.9%*
NEV "credit" targets			12%	22%
NEV credit requirement			3577	7201
NEV score			3577	7201
BEV			2.99	4.33
Range (km)			183	295
PHEV			2.00	2.00

Source: Citi Estimates, CAFC

Yellow highlight indicates the cells we used to 'seek our goal'

Calculating the required improvement in fuel efficiency in order to meet the fleet-wide fuel consumption targets (5L/100km in 2020 and 4L/100k in 2025) cannot ignore the stated NEV credit requirements, and so this is the first-step in this model. [Note: We assume the average BEV range improves to 183km by 2020 and to ~295km by 2025. Given diesel cars are not relevant for the Chinese market we can ignore these, and simply calculate by how much the efficiency of gasoline vehicles need to improve to reach the CAFC targets. We calculated that by 2020 fuel consumption needs to improve by 5.2% per year (recall it improved by an average of 1.8% per year in the 9 years to 2015), and by ~5% per year in the five years to 2025.

Interesting Observations from the Analysis in Figure 72:

- Despite the precondition of this model being the NEV credit requirement, the number of NEVs in 2020 is 31% below the target (~1.4 million vs target of 2 million), and more than 63% below in 2025 (~2.6 million vs target of 7 million).

The Future of Electric Vehicles

In the research for this report, we spoke with many experts, one of whom was Carl Sanderson, Former GM of BMW i-brand. Mr. Sanderson confirmed that an electric vehicle is less complex, insofar that it only has 200 moving parts vs. 2,000 in a conventional vehicle. At this stage of development, lower complexity does not mean lower cost. The biggest hurdle for the mass-production of EVs is the cost of batteries, but if we are to assume this is inevitable then the question that follows is how much additional room for improvement exists? We considered a handful of the components in an EV with the aim of understanding the potential for improvement, and the impact this could have on performance.

Figure 73. The Evolution of Electric Motors

TODAY | **TOMORROW**

Today:

- Our research suggests most motors are indirectly wound and in-house by OEMs
- We think this is largely as a function of scale (i.e., low EV volumes)

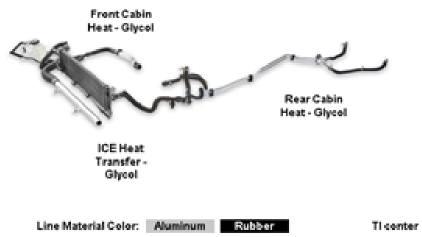
Tomorrow:

- Directly wound motors offer a 20% space saving and use ~50% less copper wire
- In one test case, one of these motors resulted in a 17% better performance
- It is cost effective at >100k units per year

Source: Aumann, Citi Research

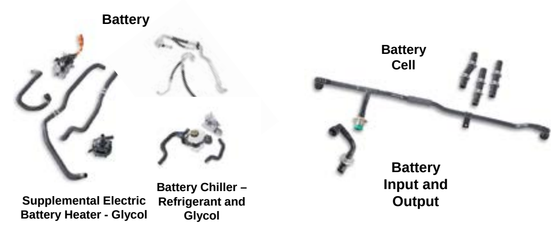
Figure 74. The Evolution of Battery Thermal Management Systems

TODAY



- Traditional engines required heating and cooling, and therefore needed more sophisticated tubing
- The current EV generation utilize these tubes (to maximize economies of scale)

TOMORROW



- Nylon tubes offer a 30-60% weight saving vs conventional tubes
- The coolant is not heated and therefore does not require heat resistant tubes

Source: TI Fluids, Citi Research

Figure 75. The Evolution of Power Electronics

TODAY

- The components used today are primarily made using Silicon instead of the more complex compound semiconductor materials such as Silicon Carbide (SiC) for example.
- The reason for the widespread use of Silicon is because of relatively low cost and high availability of substrates.

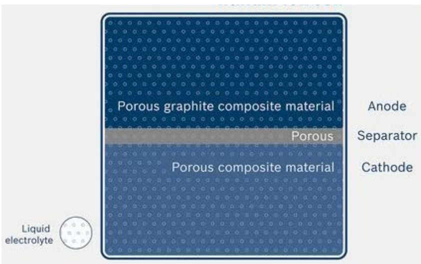
TOMORROW

- Silicon Carbide enables a smaller form factor and less weight, higher efficiency, and density vs. Silicon-based products.
- Product wise, Silicon Carbide allows 50% volume reduction for onboard chargers and ~5% efficiency gains in real-life driving cycle in Main Inverter.

Source: Infineon, Citi Research

Figure 76. The Evolution of Battery Technology

TODAY



- Battery technology is ever-evolving; the convention today is for a liquid electrolyte
- Battery manufacturers currently favor NMC due to its higher energy density
- Today anodes are mostly made of graphite (which has a limited capacity)

TOMORROW

- Solid state cells can store double the energy
- The cells are non-combustible
- They are ~75% smaller and also much lighter
- Cathode of the future will likely have higher nickel content
- Anode of the future will be made of silicon

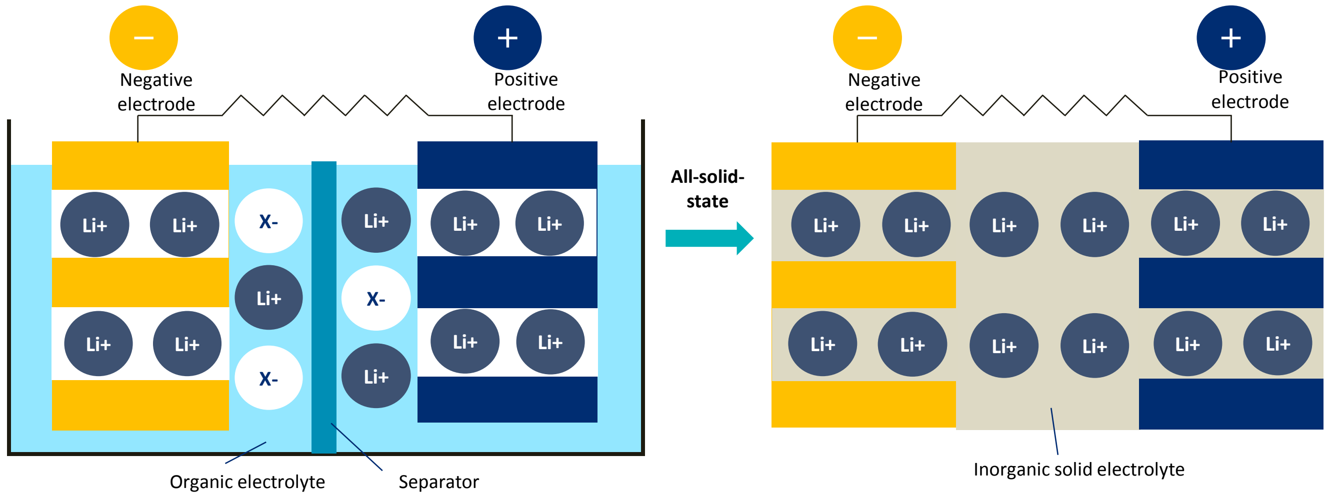
Source: Bosch, Citi Research

Solid-State Batteries Will Help Overcome Range Issues

Of these four components, we believe solid-state batteries to be the biggest "game-changer," insofar that they will directly address some of the main barriers to adoption: range, charging time, and battery degradation. We dig a bit further into this below.

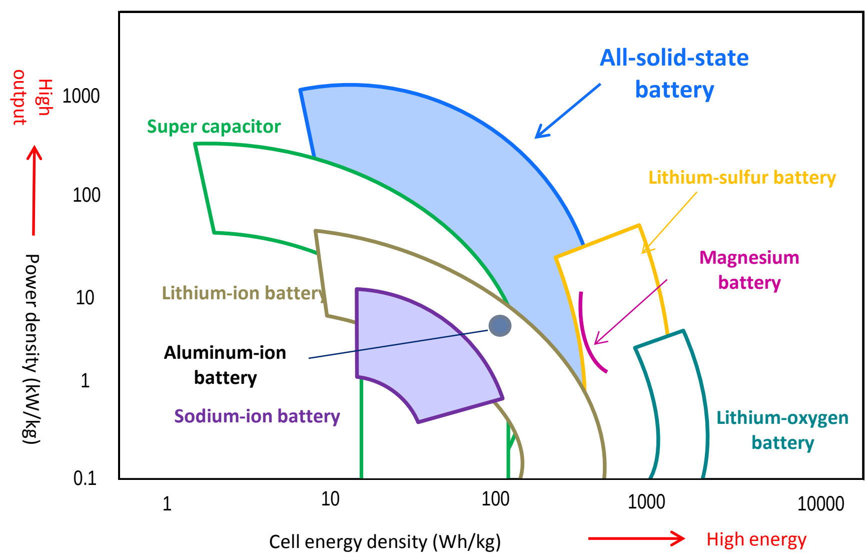
All-solid-state batteries are a leading candidate for mainstream next-generation battery technology. Current lithium-ion batteries are made up of the cathode, the electrolytic solution, the separator and the anode, whereas the electrolyte is solid in a solid-state battery. In fact, all components and materials are solid, hence the "solid-state" terminology. The properties of all-solid-state batteries will depend on which materials are used, but research to date reveals clear potential in terms of safety, resistance to leakage, resistance to combustion (simplified cooling structure), miniaturization, flexibility of design in terms of direct layer formation for cells, relative long discharge cycle lifespan, lack of degradation thanks to good high/low temperature properties, short charge times, high energy density, and high power density. In the past, low power density has been seen as a weakness, but the Tokyo Institute of Technology and the Toyota Group's research team have together developed an all-solid-state battery with three times the power density and twice the energy density of existing lithium ion batteries. We think that all-solid-state batteries have the potential to overcome the disadvantages of EVs.

Figure 77. Lithium-ion Battery Versus All-Solid-State Battery



Source: Nature Energy, Citi Research.

Figure 78. Battery Power and Energy Density



Source: Joint press release by the Tokyo Institute of Technology and Toyota (March 17, 2016), Citi Research.

Figure 79. All-Solid-State Battery Potential and Hurdles to Commercialization

All-Solid-State Battery Potential

- All-solid-state batteries are highly fire-resistant and very safe as they have no leakage
- Lithium-ion is the only molecule that moves within the electrolyte and side-effects on the positive electrode surface are therefore unlikely. This lengthens battery life.
- Performance deterioration is limited across a broad temperature range (works well in low and high temperatures)
- Resistance to high temperatures allows the cooling structure to be simplified
- Cell design allows a high degree of flexibility
- Cells can be stacked directly on top of one another without packaging
- Discovery of superionic conductors enables high diffusivity and high output
- Energy density can be increased because batteries can be used at high voltage
- High-speed charge/discharge that is not possible with electrolytes; shortens discharge time

Hurdles to Commercialization

- Reducing interface resistance between electrodes and solid electrolytes
- Cell development process
- Sulfide solid-state electrolytes offer high conductivity but measures to deal with the hydrogen sulfide that results are an issue ⇒ additives being mixed in and research being undertaken into blends with oxidized materials
- Demonstrating the reliability required for use in vehicles
- Establishing a battery pack structure
- Developing low-cost mass production technology

Source: Various materials, Citi Research.

How Do We See the All-Solid-State Battery Market Developing?

Based on the timing of development, we see little likelihood that an all-solid-state battery using leading-edge materials capable of realizing the full potential outlined above will emerge by 2022. When first introduced, the appeal of the batteries is likely to be in the reduction in battery pack size (increase in cabin space and greater battery capacity) and safety.

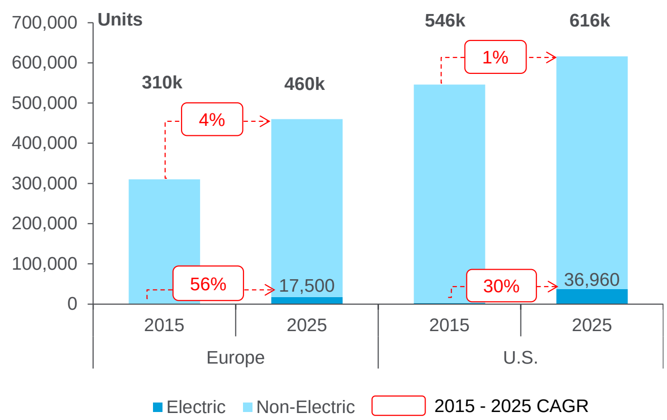
Aside from the aforementioned developments on the part of Toyota, other related names are making similar in-roads in the solid-state battery space. U.K. household appliance manufacturer Dyson announced recently that it would put an EV with all-solid-state batteries on sale by 2020. Some media reports indicate that it plans to use technologies from Sakit3, acquired in 2015, or from its in-house development team; it appears the batteries' technical characteristics are a closely guarded secret. Reports also suggest that VW, Hyundai, BMW, and others are developing EVs that use all-solid-state batteries. Audi exhibited a concept car called the Aicon, which was equipped with all-solid-state batteries at the Frankfurt Motor Show 2017. Audi says it can travel 800km or more on a single charge and that the batteries can be replenished to 80% of capacity in 30 minutes or less. It is of course possible that there will be performance innovations in existing lithium-ion batteries on the shift to mass production and lower prices, such as at the joint Tesla-Panasonic Gigafactory. It is conceivable that the all-solid-state battery narrative will be interrupted if there are innovations with lithium-ion batteries in key areas such as charging times, range, battery depletion, and costs. As things stand, the possibilities of any future propulsion technology cannot be completely discounted.

What About Buses and Commercial Vehicles?

This report has largely focused on the future for electric passenger cars, but electric bus and commercial vehicles (c-EV) also warrant a mention given their relevance to the EV debate is likely to increase as the number of such vehicles on the road grows. Penetration in Europe and U.S. is negligible today, but the markets are expected to grow in the coming years.

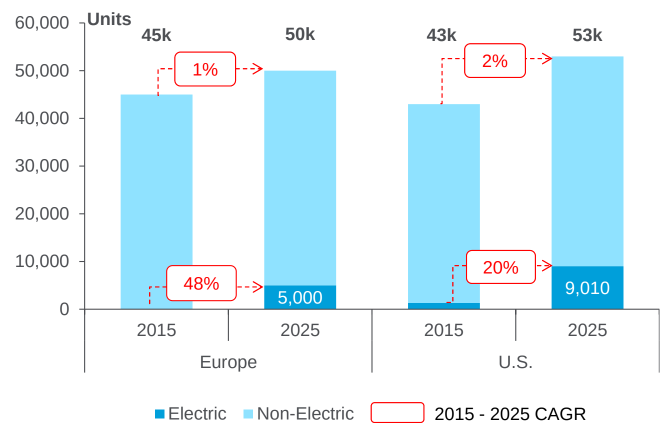
While the European commercial vehicle market is expected to grow at a rate of 4% per year (to 2025), the e-CV market is expected to grow by 56% per year. A similar trend is expected in the U.S., where sales of medium and heavy commercial vehicles are expected to grow at a rate of 1% per year, while the e-CV market is estimated to grow at a compound annual growth rate (CAGR) of 30%.

Figure 80. Forecast Commercial Vehicle Sales Growth in Europe and the U.S.



Source: Company presentation, Roland Berger data

Figure 81. Forecast Bus Sales Growth in Europe and the U.S.

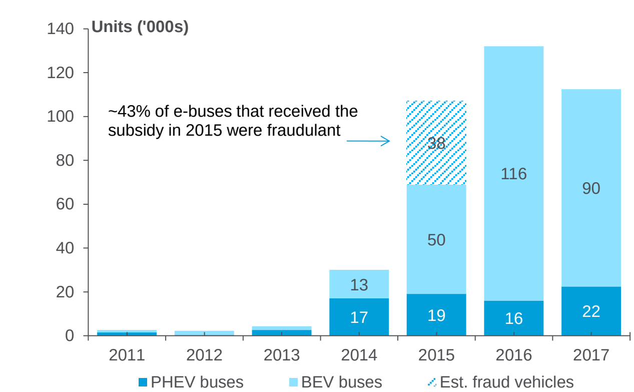


Source: Company presentation, Roland Berger data

With regards to the buses, in Europe overall bus and coach volumes are expected to grow 1% per year (to 2025), while e-buses are estimated to grow at a rate of 48% per year. The same figures for the U.S. forecast market growth of 2% per year and e-buses estimates to grow at a CAGR of 20%.

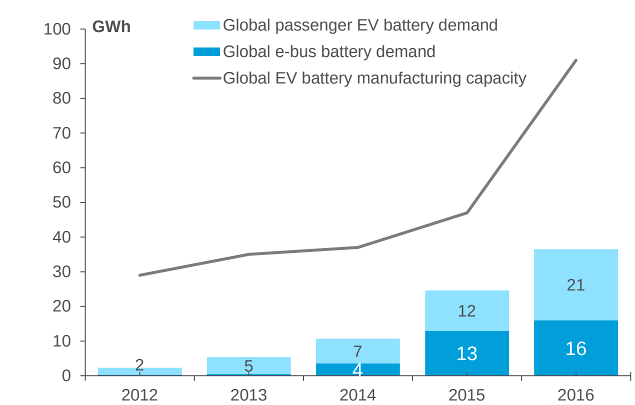
Although the e-bus market is in in the very early stages of development in Europe and the U.S. with 1% and 3% penetration of new bus registrations, respectively, in 2015, in China the e-Bus market is already well established.

Figure 82. China Electric Bus Sales



Source: Citi Research, Bloomberg New Energy Finance, Bloomberg Industries, OFweek, EV Sales Blogspot

Figure 83. Global E-Bus and Passenger Car Lithium-Ion Battery Demand

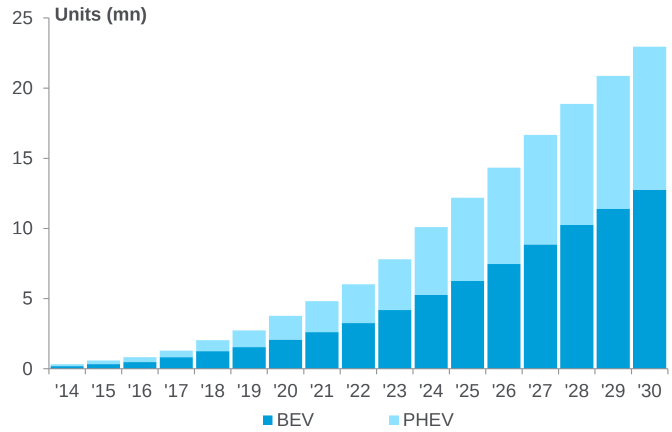


Source: Citi Research, Bloomberg New Energy Finance, China Automotive Technology & Research Centre

The Chinese market, supported by very generous subsidies, has already grown significantly (Figure 82). This in turn is helping drive lithium-ion battery demand as shown in Figure 83. As a proportion of global EV lithium-ion battery manufacturing capacity e-bus demand has increased from just 1% in 2012 to 18% in 2016.

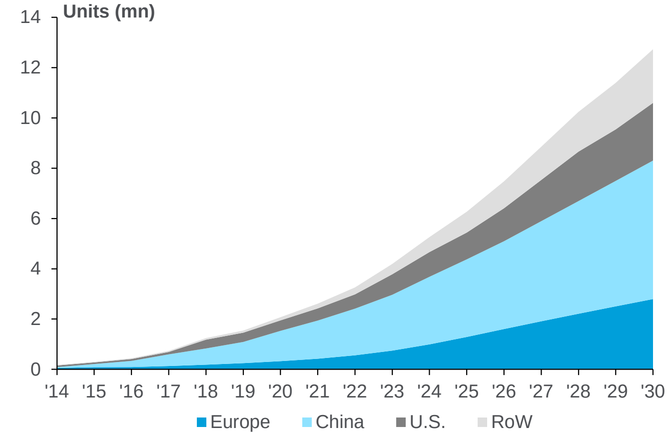
Citi's Powertrain Forecasts

Figure 84. Global EV Forecasts by Type (Citi's Base Case)



Source: Citi Estimates

Figure 85. Global BEV Forecasts by Region

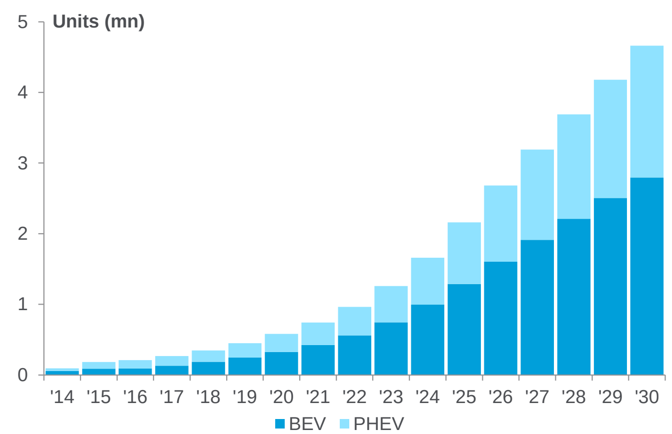


Source: Citi Estimates

We forecast global BEV penetration to reach 2% by 2020, 5% by 2025 and 10% by 2030. If we include PHEVs our estimate rises to 18% in 2030 and when also including full-hybrids, we expect penetration to reach 22%. We estimate BEV penetration (of new car sales) will reach 14% in Europe, China, and the U.S. by 2030.

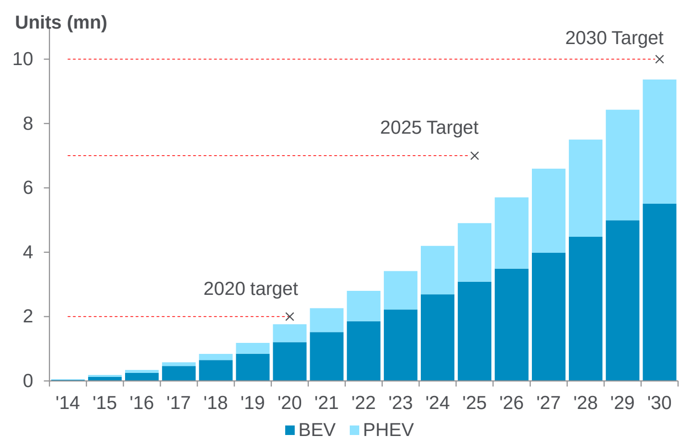
As illustrated in Figure 85, we expect China to continue to be the key region driving the BEV market in the near to medium term due in part to the size of the market but also higher penetration rates. European BEV penetration currently lags China by 1 percentage point, and we do not expect it will catch up until 2030.

Figure 86. European EV Forecasts by Type



Source: Citi Estimates

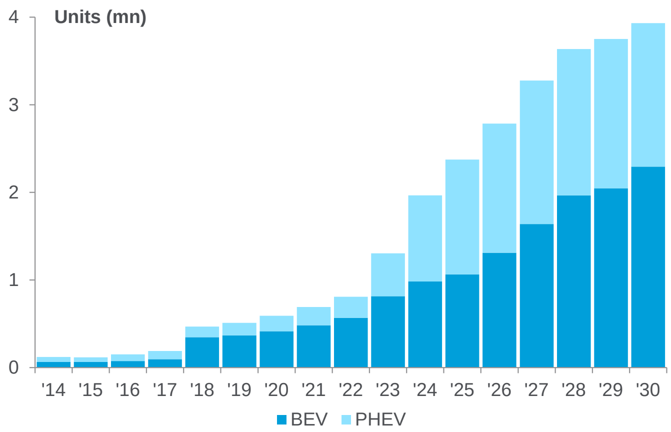
Figure 87. China EV Forecasts by Type



Source: Citi Estimates

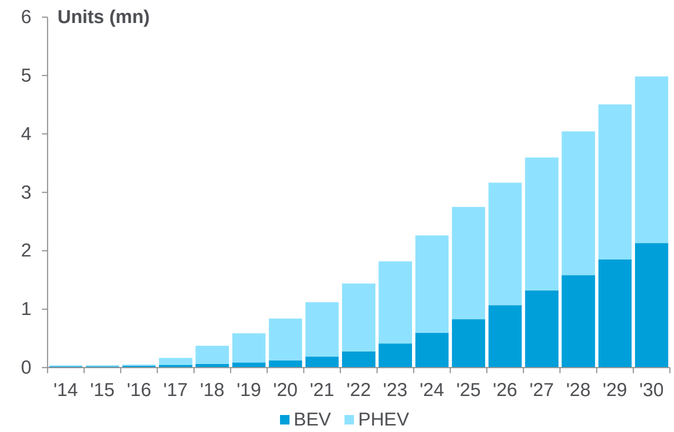
We expect Europe and China to remain the largest EV markets with BEV sales growing at a CAGR of 27% and 21%, respectively, between 2017 and 2030. We have been conservative in our base case assumptions for European EV penetration, insofar that our forecasts suggest the European emissions targets will not be met without significant improvement in ICE fuel efficiency. Similarly in China, we assume the NEV targets will not be met [Note: full hybrids do not count towards meeting these thresholds] — see Figure 87.

Figure 88. U.S. EV Forecasts by Type



Source: Citi Estimates

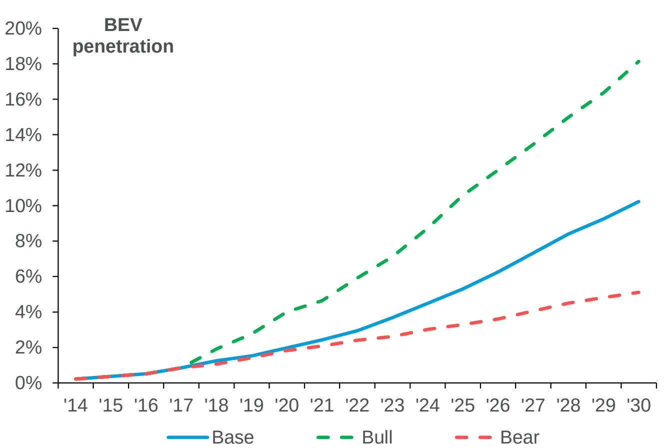
Figure 89. Rest of World EV Forecasts by Type



Source: Citi Estimates

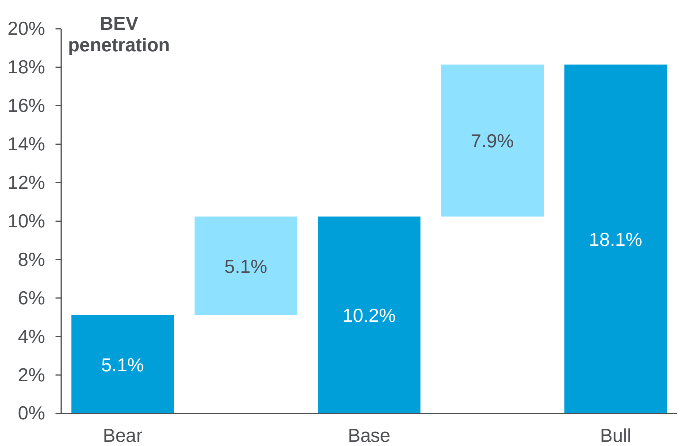
Our 2030 BEV estimate rises to 18% in our bull case and falls to 5% in our bear. In our bull scenario, we assume that both European emissions targets will be met (as a result of higher EV penetration) and China NEV targets will be reached, resulting in 26% BEV penetration in Europe and 24% in China. We also upgrade our growth rates for the U.S. and Rest of World (RoW) resulting in 30% and 6% penetration, respectively. Our bear case sees a more significant miss on European CO_2 targets and on China NEV targets, and slower growth in both the U.S. and RoW.

Figure 90. Bull-Bear Case for Global BEV Penetration



Source: Citi Estimates

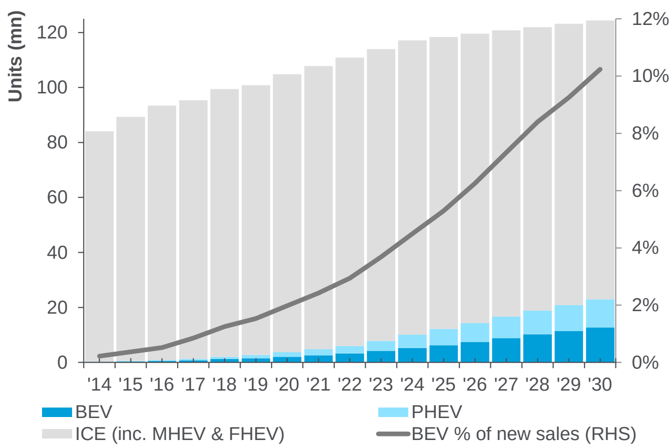
Figure 91. 2030 BEV Penetration Bull-Bear



Source: Citi Estimates

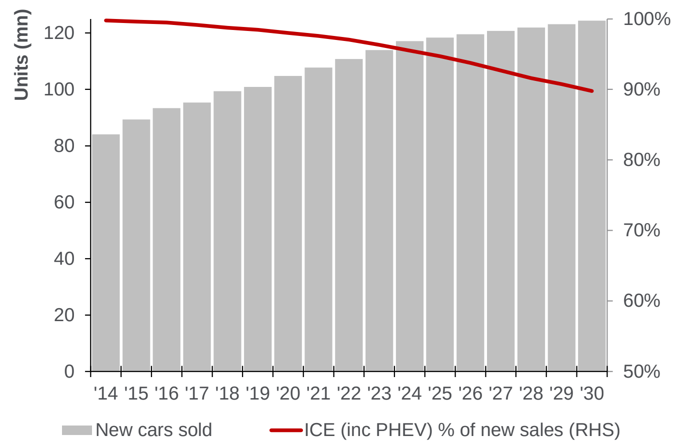
ICE new car sales should continue to dominate, but their market share will suffer. In Figure 92 we show growing BEV sales at the expense of ICE vehicle market share. However, in 2030, we still expect more than 90% of new cars sold to contain an internal combustion engine (including mild, plug-in, and full hybrids). The penetration of electric vehicles is of course growing, but it is exaggerated to predict the death of the combustion engine in the near term. Instead, as shown in Figure 93, new cars sold are likely to contain both a combustion engine and also a level of electrification (i.e., be a full hybrid electric vehicle (FHEV) or plug-in hybrid vehicle (PHEV)). In 2030, we expect at least 20% of vehicles sold will have a battery pack (in excess of 60-volts), while only 80% of vehicles will contain conventional ICE powertrains (of which 20% will have some form of electrical assistance, over and above the standard 12-volt battery).

Figure 92. BEVs Are Gradually Eating into ICE Market Share



Note: MHEV = Mild Hybrid Electric Vehicle
Source: Citi Estimates

Figure 93. Traditional Vehicles as We Know It Are on the Decline



Source: Citi Estimates

Figure 94. Global Base Case EV Forecasts

Global	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Volumes ('000s units)																	
	84,041	89,328	93,393	95,371	99,376	100,858	104,744	107,718	110,746	113,858	117,045	118,278	119,488	120,674	121,835	123,020	124,230
% change		*6%*	*5%*	*2%*	*4%*	*1%*	*4%*	*3%*	*3%*	*3%*	*3%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
ICE	81,723	86,762	90,303	91,450	93,556	93,068	93,572	93,634	92,792	90,514	88,341	85,522	82,623	80,080	77,610	75,604	73,504
Mild-hybrid	386	227	247	397	509	523	530	543	554	566	580	588	597	606	616	627	639
48-volt	0	0	0	0	255	967	2,672	4,418	6,967	10,438	13,380	15,367	17,367	18,803	20,248	21,466	22,703
Hybrid	1,608	1,758	2,018	2,235	3,004	3,547	4,172	4,282	4,393	4,507	4,624	4,568	4,515	4,468	4,424	4,387	4,355
PHEV	137	253	340	482	819	1,221	1,729	2,231	2,783	3,635	4,852	5,956	6,897	7,848	8,677	9,518	10,274
BEV	187	329	485	808	1,233	1,532	2,069	2,610	3,259	4,196	5,269	6,277	7,490	8,869	10,260	11,418	12,755
Penetration %																	
ICE	97%	97%	97%	96%	94%	92%	89%	87%	84%	79%	75%	72%	69%	66%	64%	61%	59%
Mild-hybrid	0%	0%	0%	0%	1%	1%	1%	1%	1%	0%	0%	0%	0%	1%	1%	1%	1%
48-volt	0%	0%	0%	0%	0%	1%	3%	4%	6%	9%	11%	13%	15%	16%	17%	17%	18%
Hybrid	2%	2%	2%	2%	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
PHEV	0%	0%	0%	1%	1%	1%	2%	2%	3%	3%	4%	5%	6%	7%	7%	8%	8%
BEV	0%	0%	1%	1%	1%	2%	2%	2%	3%	4%	5%	5%	6%	7%	8%	9%	10%

Source: Citi Estimates

Figure 95. Europe Base Case EV Forecasts

Europe	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Volumes ('000s units)																	
	16,503	16,804	17,489	18,145	18,890	19,248	20,033	20,390	20,797	21,149	21,486	21,503	21,477	21,405	21,287	21,172	21,059
% change		*2%*	*4%*	*4%*	*4%*	*2%*	*4%*	*2%*	*2%*	*2%*	*2%*	*0%*	*0%*	*0%*	*-1%*	*-1%*	*-1%*
ICE	16,211	16,402	16,984	17,422	17,861	17,526	17,617	17,167	16,465	15,823	15,039	14,258	13,421	12,558	11,674	10,801	9,937
Mild-hybrid	14	12	6	20	20	21	19	18	15	13	11	9	7	6	5	4	3
48-volt	0	0	0	0	94	577	1,002	1,631	2,496	3,172	3,867	4,193	4,510	4,816	5,109	5,399	5,686
Hybrid	184	206	290	435	545	651	775	788	802	815	827	785	744	704	665	627	592
PHEV	37	97	118	136	195	237	297	364	454	568	727	943	1,156	1,367	1,572	1,775	1,976
BEV	58	88	91	132	174	236	323	423	565	757	1,014	1,314	1,638	1,955	2,263	2,566	2,864
Penetration %																	
ICE	98%	98%	97%	96%	95%	91%	88%	84%	79%	75%	70%	66%	62%	59%	55%	51%	47%
Mild-hybrid	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
48-volt	0%	0%	0%	0%	1%	3%	5%	8%	12%	15%	18%	20%	21%	23%	24%	26%	27%
Hybrid	1%	1%	2%	2%	3%	3%	4%	4%	4%	4%	4%	4%	3%	3%	3%	3%	3%
PHEV	0%	1%	1%	1%	1%	1%	1%	2%	2%	3%	3%	4%	5%	6%	7%	8%	9%
BEV	0%	1%	1%	1%	1%	1%	2%	2%	3%	4%	5%	6%	8%	9%	11%	12%	14%

Source: Citi Estimates

Figure 96. China Base Case EV Forecasts

China	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Volumes ('000s units)																	
	19,652	21,248	24,788	25,387	26,936	28,417	30,833	32,220	33,670	35,185	36,769	37,136	37,508	37,883	38,261	38,644	39,031
% change		*8%*	*17%*	*2%*	*6%*	*5%*	*9%*	*4%*	*4%*	*4%*	*4%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
ICE	19,573	21,026	24,333	24,622	25,709	26,602	27,459	27,632	27,428	26,763	26,240	25,319	24,299	23,179	22,032	20,858	19,656
Mild-hybrid	2	0	0	5	5	5	5	5	4	4	3	3	2	2	1	1	1
48-volt	0	0	0	0	54	142	925	1,611	2,694	4,222	5,515	6,127	6,751	7,387	8,035	8,695	9,367
Hybrid	27	37	115	182	328	488	683	714	746	780	815	782	750	720	691	663	636
PHEV	17	61	94	114	194	337	555	741	942	1,196	1,507	1,819	2,212	2,613	3,022	3,439	3,863
BEV	33	124	245	465	646	843	1,205	1,517	1,855	2,220	2,688	3,086	3,492	3,981	4,480	4,989	5,507
Penetration %																	
ICE	100%	99%	98%	97%	95%	94%	89%	86%	81%	76%	71%	68%	65%	61%	58%	54%	50%
Mild-hybrid	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
48-volt	0%	0%	0%	0%	0%	1%	3%	5%	8%	12%	15%	17%	18%	20%	21%	23%	24%
Hybrid	0%	0%	0%	1%	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
PHEV	0%	0%	0%	0%	1%	1%	2%	2%	3%	3%	4%	5%	6%	7%	8%	9%	10%
BEV	0%	1%	1%	2%	2%	3%	4%	5%	6%	6%	7%	8%	9%	11%	12%	13%	14%

Source: Citi Estimates

Figure 97. U.S. Base Case EV Forecasts

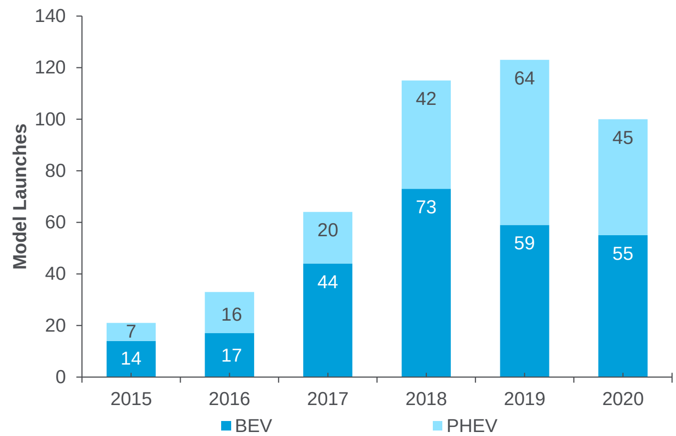
U.S.	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Volumes ('000s units)																	
	16,489	17,445	17,539	17,184	17,400	16,000	16,000	16,105	16,206	16,308	16,380	16,380	16,380	16,380	16,380	16,380	16,380
%change		*6%*	*1%*	*-2%*	*1%*	*-8%*	*0%*	*1%*	*1%*	*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
ICE	15,915	16,944	17,039	16,627	16,437	14,906	14,346	14,022	13,510	11,965	10,544	9,345	8,145	7,435	6,854	6,764	6,607
Mild-hybrid	35	24	8	3	3	3	3	2	2	2	1	1	1	1	1	0	0
48-volt	0	0	0	0	35	80	480	805	1,296	2,446	3,276	4,095	4,914	5,160	5,406	5,406	5,406
Hybrid	417	360	340	365	457	500	580	584	587	591	594	564	536	509	484	459	436
PHEV	59	51	77	94	121	143	175	209	242	489	983	1,310	1,474	1,638	1,671	1,704	1,638
BEV	63	65	74	95	348	368	416	483	567	815	983	1,065	1,310	1,638	1,966	2,048	2,293
Penetration %																	
ICE	97%	97%	97%	97%	94%	93%	90%	87%	83%	73%	64%	57%	50%	45%	42%	41%	40%
Mild-hybrid	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
48-volt	0%	0%	0%	0%	0%	1%	3%	5%	8%	15%	20%	25%	30%	32%	33%	33%	33%
Hybrid	3%	2%	2%	2%	3%	3%	4%	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%
PHEV	0%	0%	0%	1%	1%	1%	1%	1%	1%	3%	6%	8%	9%	10%	10%	10%	10%
BEV	0%	0%	0%	1%	2%	2%	3%	3%	4%	5%	6%	7%	8%	10%	12%	13%	14%

Source: Citi Research

The Outlook for Supply (from OEMs)

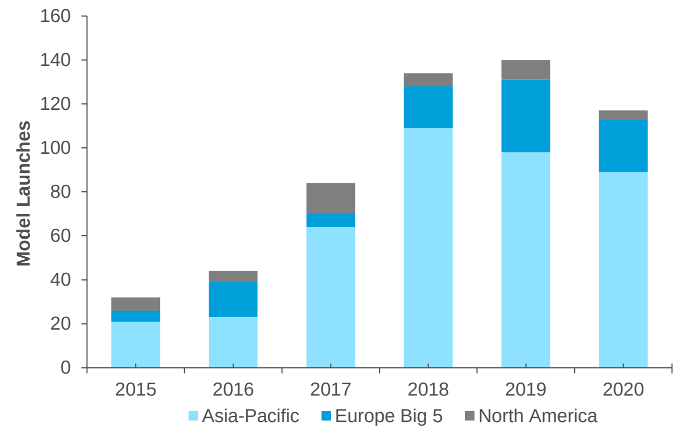
EV product range is set to expand significantly in the next 3 years. When it comes to deciding on what EV to buy today, customers are hardly spoilt for choice. Manufacturers offer a limited number relative to the number of conventional models available. However, the number of new BEV and PHEV models being launched globally doubled last year and is expected to almost double again in 2018 (see Figure 98). We only show those vehicles that LMC deem to be "highly likely" (i.e., where there is strong evidence of commercialization) to reach series production.

Figure 98. Number of BEV and PHEV Models to be Launched Globally*



* "highly likely" to reach series production per LMC
Source: Citi Research, LMC

Figure 99. BEV and PHEV Model Launches Split by Region*



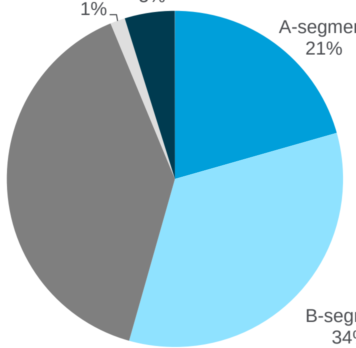
* "highly likely to reach series production per LMC
Source: Citi Research, LMC

The growth in the number of models is predominantly being seen in China. In 2017, the number of BEV and PHEV models launched grew by almost 3x and is expected to increase by another 70% in 2018. While the number of new BEV and PHEV models being launched in Europe's top five markets is also expected to grow significantly in 2018 and 2019, in North America the number of new models is expected to be lower in each of the next three years than the 14 models that were launched in 2017 (Figure 99).

Expect more electric SUVs as carmakers expand their EV product range. Manufacturers will be able to provide the consumer with greater choice as their electric product ranges grow and develop to meet consumer preferences with regard to vehicle size. Currently, the BEV market is dominated by smaller A-segment and B-segment vehicles (combined 55% of global BEV market share) and only 5% of BEV units sold in 2017 were SUVs (Figure 100). By comparison, the segment mix of ICE vehicles is dominated by larger vehicles; A-segment and B-segment vehicles represented only 17% of sales and SUV market share was over three times the size of BEV SUV market share at 16%.

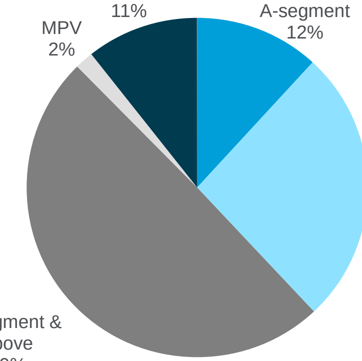
Car segmentation is based on LMC classification, which does not formally define characteristics of each segment. A-segment includes "basic" cars such as the VW Up!, B includes "sub-compact" cars such as the Fiat 500X, and C includes "compact" cars such as the Nissan Leaf. Larger segments include the BMW 3 Series (D-midsize), Tesla Model S (E-Large), BMW 7 Series (F-Large-Plus) and Porsche Mission E (G-Sport), as well as SUVs such as BMW X5 and Audi Q e-tron.

Figure 100. 2017 BEV Sales by Segment



Note: Data excludes the 'Unclassified' segment
Source: Citi Research, LMC

Figure 101. 2021 BEV Sales by Segment



Note: Data excludes the 'Unclassified' segment
Source: Citi Research, LMC

EV line-ups will soon better reflect conventional car model mix. The swathe of BEV models to be launched in the coming years should bring the BEV segment mix closer in line with ICE mix. While segment market share of ICE vehicles is not expected to change materially from 2017 to 2021, the opposite is true in the BEV market (Figure 101).

A-segment and B-segment combined share for BEVs is expected to fall from 55% to 38% in 2021 as manufacturers introduce larger models to the market that were previously unavailable with a fully electric powertrain. As a result, LMC forecasts market share of larger vehicles classified as C-segment & above to grow from 39% to 49% and SUV share to more than double from 5% to 11%, bringing it closer to the 17% 2021 market share for ICE vehicles.

The implication here is that consumers will soon have the choice between conventional and fully-electric powertrain without being restricted by choice of model.

Figure 102. What Size BEVs Are Available Today from Top 10 Global BEV Manufacturers?

BEV 2017 Sales (Units 000's)	A	B	C & Above	SUV	Unclassified	Total
BAIC	0	88	13	0	0	101
Geely	42	15	23	0	0	81
Tesla	0	0	46	34	0	80
Renault-Nissan	31	0	49	0	0	80
BYD	0	0	47	0	0	47
Chery Group	10	19	2	0	0	30
Jianghuai	0	0	30	0	0	30
Changan	8	17	3	0	0	29
Hyundai	0	8	16	0	0	25
GM	0	24	0	0	0	24
Average	9	17	23	3	0	53

Source: Citi Research, LMC

Figure 103. What Size BEVs Will We Be Buying in 2021?

BEV 2021 Sales (Units 000's)	A	B	C & Above	SUV	Unclassified	Total
VW	10	1	180	86	160	438
BAIC	14	171	45	0	16	246
Tesla	0	0	211	33	0	244
Renault-Nissan	39	7	129	2	64	241
SAIC	43	4	25	0	141	212
Geely	39	34	80	30	19	201
Hyundai	0	32	56	0	65	154
BYD	0	13	109	0	13	135
Toyota	0	1	85	0	42	128
Jianghuai	25	12	65	1	12	116
Average	17	28	99	15	53	212

Source: Citi Research, LMC

In Figure 102 and Figure 103 we demonstrate how this trend develops across the top 10 global BEV manufacturers. Interestingly, Tesla appears to be ahead of the trend, having sold 34,000 BEV SUVs (Model X) in 2017, whereas the other nine top OEMs did not offer a fully-electric SUV model last year. By 2021 however, VW is expected to sell 86k SUV BEV units, almost 3 times as many as Tesla will sell of its Model X.

Elsewhere the C-segment & above category on average should grow by 330% while average combined A-segment and B-segment grows by only 35%. The increase in unclassified units being sold is a result of where the segment details of future models is unclear.

Outlook by Carmaker

Europe

BMW: 25 electrified models by 2025, including 12 fully electric. BMW is explicit in its ambition to be a world leader in e-mobility and will launch a fully electric Mini and X3 in 2019, 3 Series BEV in 2020 (it already offers PHEV powertrain), and the iNext and i5 in 2021. It will offer a range of 12 BEV models by 2025, which is two more than Mercedes.

Daimler: Mercedes to offer electrified version of all models and Smart range to be fully electric by 2022. Mercedes will launch its EQ range, which is expected to include 3 SUV models, 3 sedans, and a hatchback by 2021, and Daimler plan to introduce more than ten new all-electric vehicles by 2022.

VW Group: All 300 VW Group models will have electrified versions by 2030. **Audi** plans to launch its fully electric E-Tron SUV in 2018 and is expected to follow this with the E-Tron coupe the following year. It will also offer BEV models from its A and Q ranges and a compact EV in 2020. The brand plans to offer more than 20 different electrified models by 2025.

The **VW brand** will launch its fully electric ID range on its new MEB platform with the VW I.D. hatchback (2019) and the ID Crozz SUV (2020). In China, FAW-VW is also expected to launch a fully electric New Bora in 2018.

Skoda's first BEV will be a fully electric Citigo expected in 2019, and this will be followed in 2020 by an SUV based on the Vision E concept that was on display at the 2017 Frankfurt Motor Show.

Lastly, production of **Porsche's** first fully electric car, the Mission-E, is expected to begin in 2019 after first being displayed as a concept in 2015.

Groupe Renault: 8 new electric and 12 new electrified vehicles by 2022. The Group already produces the Renault Zoe and Nissan Leaf, which have a combined BEV market share of 11%, as well as the Mitsubishi Outlander, which is the third-best-selling PHEV globally. In 2020, Mitsubishi and Nissan are both expected to start production of an SUV BEV, and Renault is expected to launch a fully-electric Kwid.

Groupe PSA: All car and light-trucks to offer electrified versions by 2025. PSA already offer fully-electric passenger cars in the Citröen C-Zero and Opel Ampera-e, and the Group's other brands both plan to launch their first BEVs in 2019, with a fully-electric Peugeot 208 and the DS 3 Crossback.

FCA: 10 BEV and 25 PHEV nameplates by 2022. To date, the company lags its peers on in the number of electrified vehicles it offers (only 3,000 Pacifica Hybrid van and 5,000 Fiat 500 BEVs were sold last year), and CEO Marchionne has been critical of electric vehicles in the past. Nonetheless, the company has committed to spend €9 billion on EVs over the next five years and is targeting fleet electrification of 20% in EMEA and NAFTA and 15% in APAC by 2022.

Volvo Cars: All new models to be electrified from 2019. Volvo will launch five fully electric BEV models between 2019 and 2021, of which three will be Volvo models and two will come from its high-performance brand Polestar. Other electrified options will include both plug-in hybrids and 48-volt mild hybrids, but pure ICE vehicles will be gradually phased out. The company plans to have sold 1 million electrified cars by 2025.

China

Beijing Automotive Group (BAIC): To go fully electric by 2025. The state-backed company plans to completely stop all production and sales of traditional ICE vehicles from its own brand range in China by 2025. It is the second Chinese manufacturer to make this pledge (Changan Automobile has set the same target). The BAIC EC-Series was the best-selling BEV globally in 2017, with 78k units sold compared with 45k Tesla Model S and 45k Nissan Leaf units.

Geely Group: 30 new energy vehicles (NEV) to be launched by 2020. The company has pledged to release several NEVs capable of driving over 500km on a single charge by 2020, which would rival the range that can be achieved on current Tesla models. In 2018 the company also launched its flagship B-segment hybrid sedan with MHEV and PHEV systems. The company claims the systems used in this model are the world's most efficient hybrid and plugin hybrid systems[12]

Japan

Honda: By 2025, two-thirds of European sales will be electrified powertrains. The Honda DF HR-V will be the company's first fully-electric BEV in 2018, and in 2019 it is expected the Urban BEV will go into production.

Toyota: 10 news BEVs by 2020 and electrified options across entire lineup by 2025. Toyota does not currently offer a fully electric vehicle, but announced in December 2017 that it will offer 10 BEVs by 2020. LMC forecasts sales for a Compact BEV from 2018 and an SUV from 2019.

[12] Geely Announces New Energy Strategy with Launch of Smart Hybrid Flagship, *Geely Global Media Center*, May-18, link

South Korea

Hyundai: Expect electric vehicles to represent 10% of sales by 2025. Hyundai will launch a fully electric Kona SUV in 2018 and is also expected to offer a BEV Elantra/Avante in 2020. The Kia Niro and Kia Stonic will add additional BEV SUVs to the range in 2018 and 2019.

U.S.

Tesla: Plans for the Model Y and Roadster to follow Model 3. Production of the highly anticipated Model 3 sedan is expected to ramp up in 2018 after further delays in 2017 and will be followed by what Tesla is currently referring to as the 'Model Y' crossover in 2019. The Model Y is yet to be officially unveiled by Tesla, but is understood to be in final development stages. In 2020 Tesla hopes to also launch the second generation Roadster.

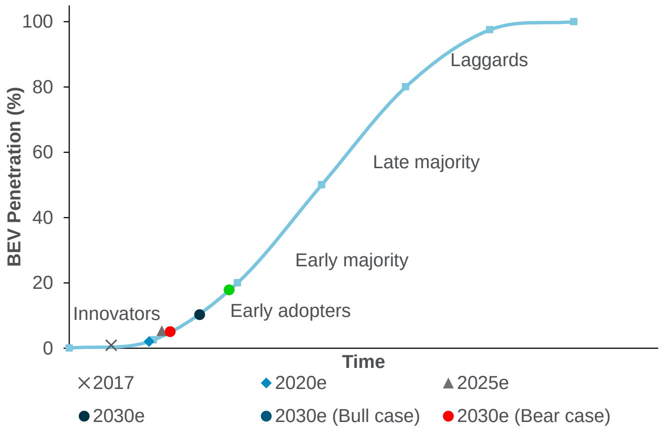
Ford: 40 electrified vehicles will arrive by 2022. In 2017 Ford announced seven of the thirteen electrified vehicles it initially planned to launch in the next five years, which includes two passenger cars, a fully electric small SUV, and a hybrid Mustang both expected in 2020. The range also includes a hybrid "high-volume autonomous vehicle designed for commercial ride hailing," a hybrid F-150 pickup, a hybrid Transit Custom plug-in, and two "pursuit-rated Hybridge police vehicles"[13]. At the Detroit auto show in January of this year, however, it significant increased its electrification ambitions and announced plans to invest up to $11 billion by 2022 (the previous figure was $4.5 billion). The ambition is to offer 40 electrified models, of which 16 will be BEV.

GM: 20 all-electric vehicles launched by 2023, including two by mid-2019. In 2017, GM announced its ambitions for the EV market with plans to offer 20 fully electric vehicles by 2023. LMC expect Buick to produce a midsize SUV, compact MPV, and Encore with fully electric powertrain in 2019 as well as a Cadillac XT4 and a new Chevrolet BEV in 2020.

[13] Ford Adding Electrified F-150, Mustang, Transit By 2020 In Major EV Push, *Ford Media Center*, Jan-17, link

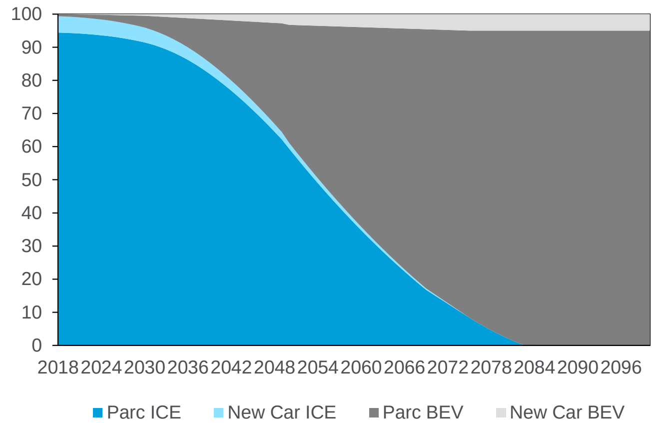
Conclusion

Figure 104. There's a Long Way to go Before Reaching Full EV Adoption



Source: Citi Research estimates

Figure 105. Penetration of Electric Vehicles Within the Global Car Fleet



Source: Citi Research estimates

We have no doubt that the *Car of the Future* will not be powered in the same way that it has been for the past century. For us it is a question of timeframe; 'how do you define *the future*'? Are we talking about five years, 10 years or 50 years? In our forecasts, our base case assumption is that in 2030 BEVs will account for 10% of global new vehicle sales. Our bull case scenario foresees global BEV penetration of 18% in 2030. Both of these outcomes would still only put us within what we define as the 'early-adopters' phase (see Figure 104).

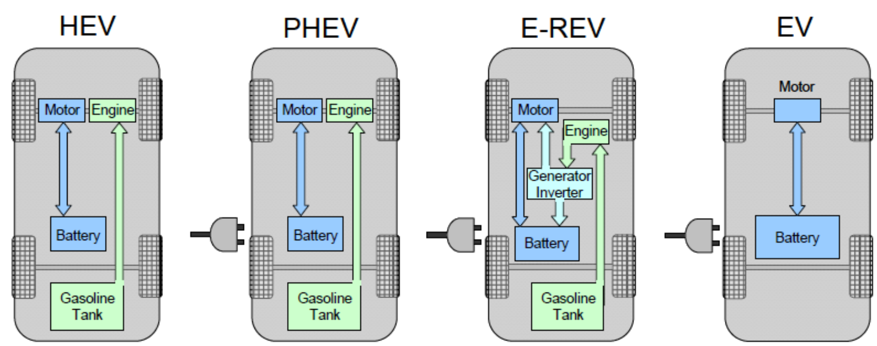
The barriers will (most probably) be broken down, they always are — it is a question of time. As we see it, the challenge that EVs face is they do not change the utility of a vehicle, and therefore the adoption curve will take longer to navigate (compared with truly disruptive tech). Given the lack of improved utility for consumers, having to pay a price premium is more-difficult to accept. Given consumer reticence to pay for fuel efficiency, the hockey stick effect (for demand) will occur when the total cost of ownership is obviously below that of a traditional combustion engine vehicle. As we have said in this report we think this is feasible, but we are not there yet.

Appendix 1

Vehicle Types

Electric vehicles can broadly be split into four categories, as shown in Figure 106 below. Hybrid Electric Vehicles (HEVs), Plug In Hybrid Electric Vehicles (PHEV), and Electric Range Extended Vehicles (E-REV) all include internal combustion engines that are supplemented (usually at low speeds, in urban areas) by electric batteries. Battery Electric Vehicles (BEVs), however, are entirely powered by electricity from the grid. The distinction between HEVs and PHEVs is that the batteries for the HEVs are charged from energy recuperation, while PHEVs, like EVs, are charged from the mains.

Figure 106. Structure of HEVs PHEVs, E-REVs and EVs



Source: Citi Research

- **Conventional hybrids:** A conventional hybrid combines an electric motor while still having a gasoline engine. Their battery cannot be charged using a plug, but only recuperates electricity from brake energy, converting kinetic to electric energy, which normally goes to waste with traditional gasoline engines. This efficiency gain allows cars to run electrically and thereby reduces gasoline use.
- **Plug-in hybrid electric vehicles (PHEVs):** The basic building blocks of this car are the same as in a conventional hybrid, as PHEVs also have an electric and a combustion engine. The difference (as one can guess from the name) is that the battery of these vehicles can be charged using a plug which increases the range of the car in electric-only usage using "grid-electricity" instead of gasoline. Even their short reach allows users to commute in electric-only mode, as many people commute less than 50km every day. Apart from a positive environmental impact, electric usage also has a variable cost benefit as running the car is cheaper.
- **Battery electric vehicles (BEVs):** These vehicles represent the other spectrum of cars and forego the internal combustion engine. Due to missing the combustion engine, these vehicles have larger batteries, which allow them to drive longer ranges compared with PHEVs in electricity-only mode. Even though these cars don't create emissions while driving, one may not forget that there are significant emissions when the electricity for charging these cars is produced.

Appendix 2

Top Selling EVs by Region and OEM

Figure 107. Specification Comparison of the Best-Selling BEV and PHEV in Europe & N. America During 2017

Model	Type	Global Segment	Battery	Battery capacity (kWh)	EV Range (km)	Rapid charging to 70/80% (min)	Standard charging (hour)	Average Price (€)	Average Price ($)	2017 Sales Volume (units)	% of total BEV & PHEV volume
Tesla Model S 75	BEV	E	Li-ion	75.0	489	40	11.0	105,659	124,678	39,683	8.9%
Renault ZOE ZE 40	BEV	A	Li-ion	40.0	402	60	6.0	24,585	29,101	30,381	6.8%
Nissan Leaf	BEV	C	Li-ion	30.0	249	30	4.5	32,125	37,908	29,728	6.7%
Tesla Model X 75D	BEV	SUV	Li-ion	75.0	565	40	11.0	115,465	136,249	26,092	5.9%
Chevrolet Bolt	BEV	B	Li-ion	60.0	238	60	5.9	50,148	59,175	23,343	5.3%
BMW i3	BEV	C	Li-ion	33.0	314	35	4.5	65,816	77,663	16,308	3.7%
VW e-Golf	BEV	C	Li-ion	35.8	299	35	5.0	42,404	50,037	16,137	3.6%
Weighted Average BEV				52.6	381	43	7.3	65,149	76,867		
Toyota Prius	PHEV	C	Li-ion	8.8	63	N/A	2.8	29,778	35,138	21,621	4.9%
Chevrolet Volt	PHEV	C	Li-ion	16.0	53	N/A	4.4	46,134	54,438	20,125	4.5%
VW Golf	PHEV	C	Li-ion	8.7	50	N/A	2.0	31,717	37,426	16,137	3.6%
Mitsubishi Outlander	PHEV	SUV	Li-ion	12.0	53	25	3.5	39,131	46,175	14,390	3.2%
BMW 330e	PHEV	D	Li-ion	7.7	40	N/A	2.0	40,445	47,725	14,022	3.2%
Volkswagen Passat	PHEV	D	Li-ion	9.9	35	N/A	3.0	39,240	46,303	13,168	3.0%
Audi A3 e-tron	PHEV	C	Li-ion	9.0	50	N/A	3.0	37,277	43,987	10,891	2.5%
BMW 2-series AT 225xe	PHEV	C	Li-ion	7.6	40	N/A	2.0	37,456	44,198	10,835	2.4%
Mercedes GLC 350e	PHEV	E	Li-ion	6.2	31	N/A	1.8	43,052	50,801	10,356	2.3%
BMW 530e	PHEV	E	Li-ion	9.2	47	N/A	3.0	50,111	59,131	10,033	2.3%
BMW X5 xDrive40e	PHEV	SUV	Li-ion	9.0	31	N/A	3.0	62,963	74,296	9,791	2.2%
Volvo XC90	PHEV	SUV	Li-ion	9.2	40	N/A	3.0	72,587	85,653	9,295	2.1%
Ford C-Max	PHEV	C	Li-ion	7.6	20	N/A	3.0	36,276	42,806	8,612	1.9%
Weighted Average PHEV				9.7	45.1	N/A	2.9	41,914	49,459		

Source: Citi Research, LMC, Company Data, Zap Map, Smart EV, Pod Point, EV Box, Elektrek, Edmunds, AutoHaus, Broadspeed, VoitureNeuve

Figure 108. Specification Comparison of the Best-Selling BEV and PHEV in China During 2017

Model	Type	Type 2	Battery	Battery capacity (kWh)	EV Range (km) (MIIT)	Fast charging to 70/80% (min)	Standard charging (hour)	Min price (USD)	Max price (USD)	2017 sales volume (units)	% of total NEV PV volume
BJEV EC180	BEV	Sedan	NCM	20.3	156	N/A	7	22,458	23,346	78,079	14.0%
BJEV EC200	BEV	Sedan	NCM	20.5	162	36	8	23,494	24,382		
Zhidou D2	BEV	Sedan	NCM	18	155	N/A	6-8	22,458	27,932	42,342	7.6%
Chery eQ 2017	BEV	Sedan	NCM	23.6	200	30	8-10	25,136	25,432	25,784	4.6%
JAC IEV6S	BEV	SUV	NCM	33	251	90	12	32,519	32,519	24,210	4.4%
BYD e5 EV300	BEV	Sedan	LFP	43	305	80	7	28,983	31,942	23,601	4.2%
Geely Emgrand EV300	BEV	Sedan	NCM	41	300	45	7	28,968	31,927	23,324	4.2%
Zotye E200	BEV	Sedan	NCM	24.52	160	30	10-12	26,897	26,897	16,751	3.0%
Chang'an Benben EV180	BEV	Sedan	NCM	23.2	180	30	8	22,902	24,677	14,549	2.6%
Chang'an Benben EV210	BEV	Sedan	NCM	27.5	210	45	9	23,790	25,417		
BAIC BJEV EU260	BEV	Sedan	NCM	41.4	260	30	6-7	30,462	31,942	13,158	2.4%
BAIC BJEV EU400	BEV	Sedan	NCM	54.4	360	30	6-7	33,273	33,273		
Zotye Cloud 100	BEV	Sedan	NCM	18	155	90	8	23,509	25,136	11,069	2.0%
JMC E100 EV	BEV	Sedan	LFP	15	152	N/A	7-9	23,080	23,080	10,663	1.9%
Weighted Average BEV				26	202	50	8	25,591	27,355		
BYD Song DM	PHEV	SUV	NCM	16.9	80	45	10	31,942	36,380	30,911	5.6%
BYD Qin 2017	PHEV	Sedan	NCM	13	100	N/A	6	26,024	29,574	20,738	3.7%
SAIC eRX5	PHEV	SUV	NCM	12	60	N/A	3	39,339	42,298	19,510	3.5%
BYD Tang 100	PHEV	SUV	NCM	22.8	100	N/A	7	39,339	44,369	14,592	2.6%
Weighted Average PHEV				16	84	N/A	7	34,161	38,155		

Source: Citi Research, CPCA, AutoHome

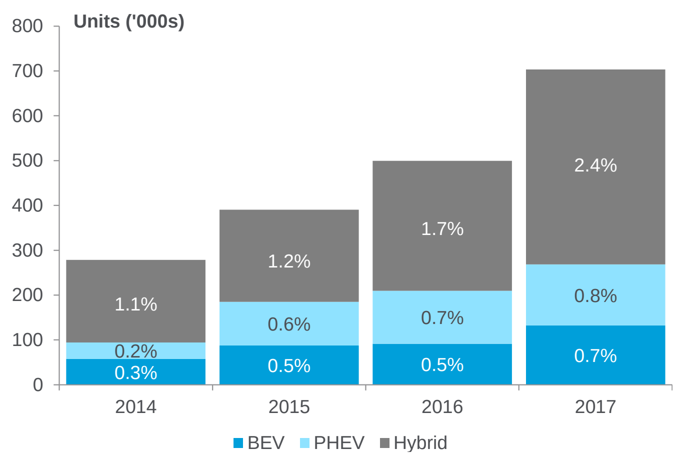
Appendix 3

Current Penetration by Region and OEM

Europe

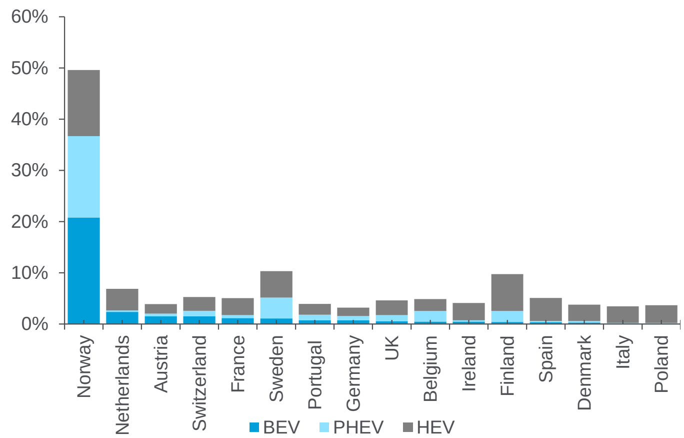
EV sales growing rapidly, but market penetration remains modest. Electric vehicle penetration is increasing; the number of plug-in EVs (BEV & PHEV) sold in Europe in 2017 grew by 38% to 279k, and including HEVs this number rises to 735k. This represents a twelve-fold increase in electrified vehicles compared with 2013. Despite the heady growth rates, as a share of the total European car market, EV volumes remain comparatively small; in 2017 HEV market share was 2% and BEV and PHEV sales each represented just 1% of the market.

Figure 109. European Penetration is Growing but Remains Modest



Source: ACEA, Citi Research

Figure 110. Penetration in Norway is Miles Ahead of the Rest



Source: ACEA, Citi Research

Norway is the clear EV leader in Europe with 21% BEV penetration. The Norwegian market has benefited from generous government subsidies (see Appendix 4 for further details) that have supported high EV penetration. Including hybrids, half of new cars sold in Norway last year were electrified, and a rate of 21% pure-electric penetration is around 10 times that in the Netherlands, which saw the second-highest level of BEV penetration (2%). Austria (2%), Switzerland (2%) and France (1%) had the next highest BEV penetration.

In terms of type of EV, the development of the three main variants has been:

- **BEV: Norway's generous incentives support its position as market leader.** In 2017, 135,000 new BEV vehicles were sold in Europe at a growth rate of 51% year over year, but BEVs still represent only 1% of total new car sales. In Norway, however, BEV market share was 21% largely due to some of the most generous incentives on the continent, which have helped BEV stock grow almost 20-fold from 5,000 in 2011 to 99,000 in 2016 according to the IEA. Although the German and French BEV markets are the next-two-largest in absolute terms (both saw sales of 25,000 units last year), BEV market share remains at just 1% in both countries.

- **PHEV: U.K. & Norway lead the PHEV charge.** In 2017, 144,000 new PHEV vehicles were sold in Europe at a growth rate of 29% year over year. PHEV, like BEV, also currently has just a 1% market share of total new car sales. Norway again has the highest PHEV penetration, but penetration is also high in Sweden (4%) and Finland (2%). In absolute terms, however, the U.K.'s PHEV market is the largest; 31,000 units were sold in 2017, and the country has seen a boom in PHEV stock from 1,000 in 2012 to 55,000 in 2016.

- **U.K. grants catalyze PHEV expansion.** EV supportive incentives have helped reduce total cost of ownership of EVs and facilitated the growth in PHEVs. U.K. plug-in grant, for example, which was launched in 2011, experienced just 109 claims in Q4 2011, but, by Q4 2015, this had risen to 8,453 claims[14] demonstrating the growth in popularity of such schemes. Other tax incentives and non-financial incentives such as access to bus lanes and free parking have also encouraged consumers to buy electric.

- **Improving charging infrastructure key for sales growth.** Improvements in charging infrastructure have also reduced one of the key barriers to entry for consumers. According to the European Alternative Fuel Observatory (EAFO), in 2011 there were 6,987 publicly accessible normal power and 31 high power charging positions in Europe. This has grown to 104,656 normal and 13,475 high power positions in 2017.

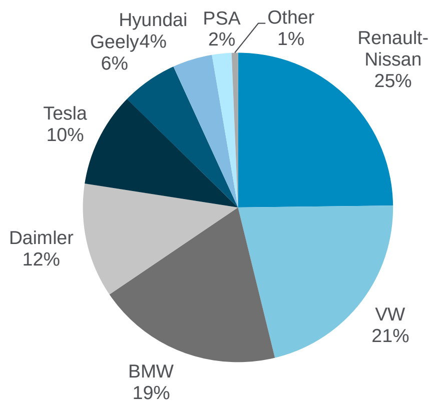
- **The range of EVs available to consumers is broadening.** Lastly, the range of PHEV vehicles available has increased in recent years as manufacturers have begun to focus on electrified powertrain and increased supply. In 2014, for example, 99% of PHEV sales in Norway were from just 5 models, whereas in the last 12 months the top 5 models represented only 62% of the new PHEV market.

- **HEV: The electrified vehicle of choice for now.** In 2017 456k new HEV vehicles were sold in Europe; over 175k more than BEVs and PHEVs combined, demonstrating the current consumer preference for plug-free hybrid technology over EVs that require charging infrastructure. HEV sales grew 59% YoY, and HEV market share is currently higher than both BEV and PHEV at 3%.

- **Limited charging infrastructure in Italy leaves consumers with little choice.** Interestingly, Italy, which is only the 9th- and 11th- largest European country in terms of PHEV and BEV sales respectively, had the third-highest number of HEV sales in 2017. According to the EAFO, between 2012 and 2016 Italy increased the number of normal power charging positions by just 33% whereas this same figure increased by 91% in Norway and 242% in the U.K. over the same period. Consumer preference in Italy for HEVs reflects this lack of investment in charging infrastructure required for BEV and PHEV models.

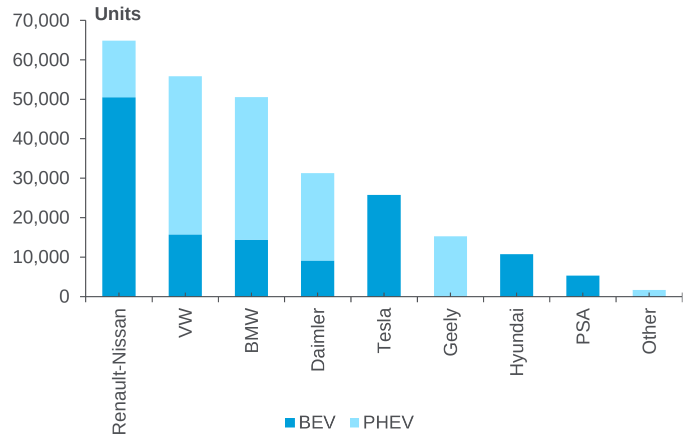
[14] Complete guide to the plug-in electric car grant, *Carbuyer*, 2nd March 16, link.

Figure 111. European 2017 Plug-in EV Vehicle Market Share



Source: Citi Research, LMC

Figure 112. European BEV and PHEV 2017 Sales



Source: Citi Research, LMC

Renault is the European electrified vehicle market leader for now. Renault's 25% share of the European plug-in EV (BEV & PHEV) vehicle market (see Figure 111) suggests it has benefited from acting early in the EV race; the top and third-best selling BEVs in Europe are the Renault Zoe and Nissan Leaf, respectively. The first generation Leaf was introduced to European markets in 2011, and first deliveries of the Zoe were in late 2012, which appears to have given Renault a first-mover advantage over competitors. VW's 21% market share is supported by the popularity of the e-Golf and Golf PHEV, which combined makes the Golf the second-most popular model in Europe.

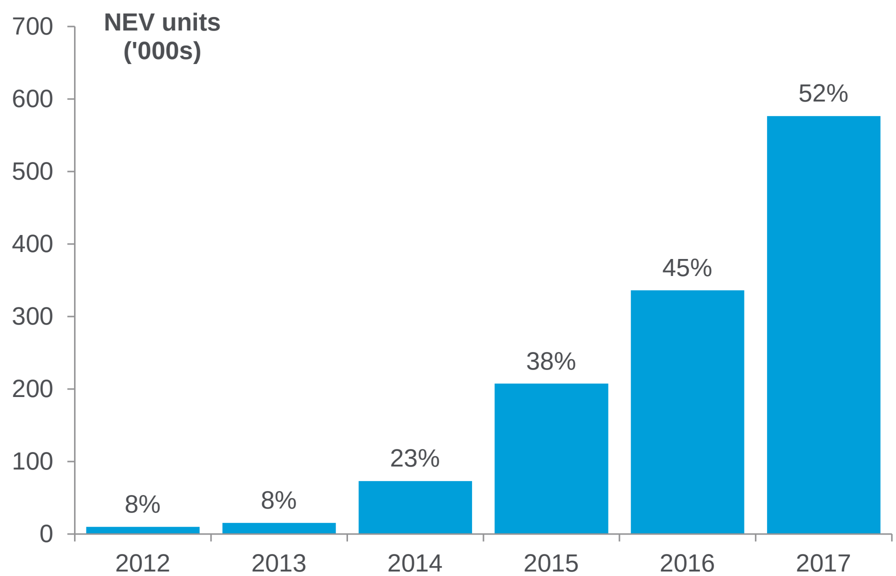
Renault also leads the race for BEV sales in Europe. Figure 112 illustrates the lead Renault has over competitors in Europe, specifically in relation to fully electric vehicles. The popularity of the Renault Zoe and Nissan Leaf in Europe has given Renault a 38% share of the BEV market, greater than the Tesla (20%) and VW (12%) BEV market shares combined. The Germans' market share is largely supported by sales of their PHEV models. At VW, 72% of sales were from PHEV models and similarly, at BMW and Daimler, the rate was 71%.

If we agree that OEMs are in the process of transitioning to fleets of zero tailpipe emission vehicles, then Renault is clearly leading this race. However, we expect market share to remain relatively fluid as demand for electric vehicles increases and new models hit the market in the coming years.

China

China alone in 2017 sold 577k NEVs (defined as BEV and PHEV units for the purpose of this analysis), representing a 52% global market share, significantly up from 8% in 2012. Despite this, the share of NEV to the total vehicle market remains low, at 1.3% globally and only 0.7% in China.

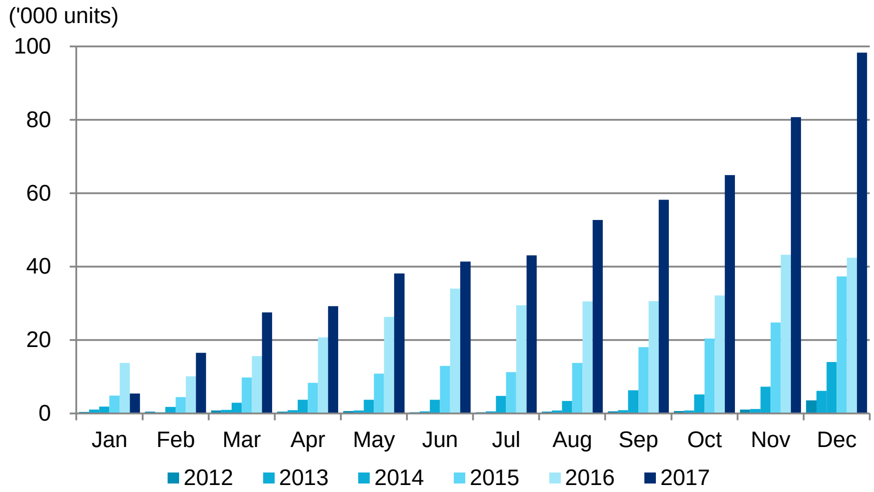
Figure 113. China's Share of Global NEV Passenger Vehicle Market Has Been Increasing Over the Past Five Years



Source: Citi Research, IEA

China accounts for over half of the global NEV market. The recent boom has been driven largely by generous government NEV subsidies for both manufacturers and customers. NEVs in China are produced overwhelmingly by local OEMs based on Chinese technologies. The Chinese government promotes NEV in an attempt to fight air pollution, improve energy safety (due to China's high dependence for oil import at 65%, according to Sinopec Economics & Development Research Institute), and develop the country into a world leader for NEV and its supply chain (such as battery) in terms of both shipment volumes and technology.

Figure 114. Monthly NEV Passenger Vehicle Sales Volume in China



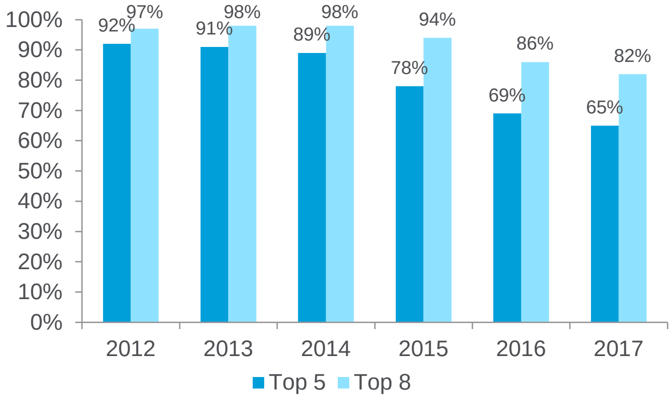
Source: CPCA, Citi Research

BEV should dominate the NEV industry in the coming years, but we expect the growth rates for PHEV to pick up dramatically from 2018 and surpass BEV's not only due to the low base effect, but also given PHEV's lower entry barrier. OEMs without proper BEV experience or joint venture brands that also struggle to meet CAFC targets under the vehicle upsizing trend can leverage on PHEV to fulfill both CAFC and NEV requirements (see China regulation section of report).

PHEV has been more appealing to users given its better flexibility, especially considering the low penetration for charging stations. The latest and a popular PHEV model, SAIC's eRX5, has a total range (electricity + gasoline) of around 500km, which is comparable to that of a gasoline vehicle, and has average fuel consumption (without electricity) at a reasonable 7-8L/100km, much lower than some older models, such as BYD Tang 100's nearly 13L/100km. Apart from this, the gradual phasing out of subsidies will more significantly decrease the attractiveness of BEV for customers and OEMs given BEV's higher reliance on subsidy vs. PHEVs.

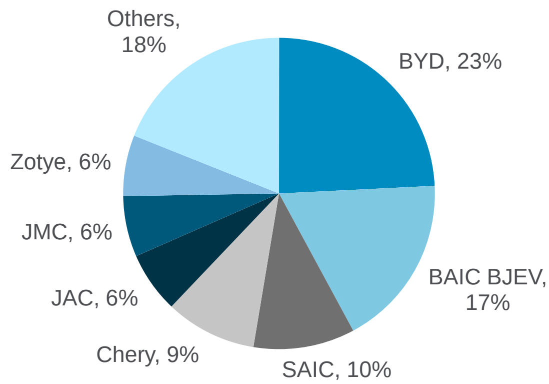
Big NEV makers getting bigger. The NEV passenger vehicle market is concentrated despite the entry of new players. In the first nine months of 2017, the top-5 makers took up a 65% market share and the top-8 took 82%. Among them, BYD remains the leader with a 23% market share (although this has over time), with four of its NEV models ranked as the top-15 best-selling ones in the first nine months of 2017.

Figure 115. Market Shares of Top-5 and Top-8 NEV OEMs



Source: CAPA

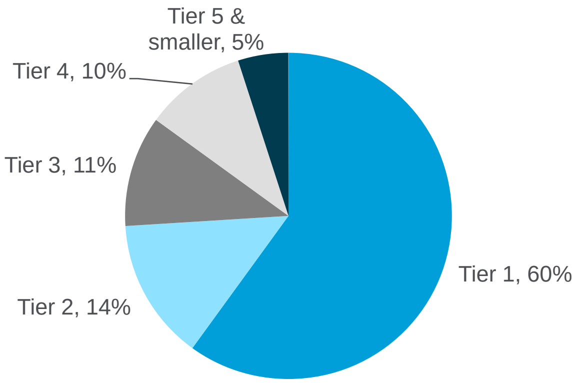
Figure 116. Share of the NEV Market in Through September 2017



Source: CAPA

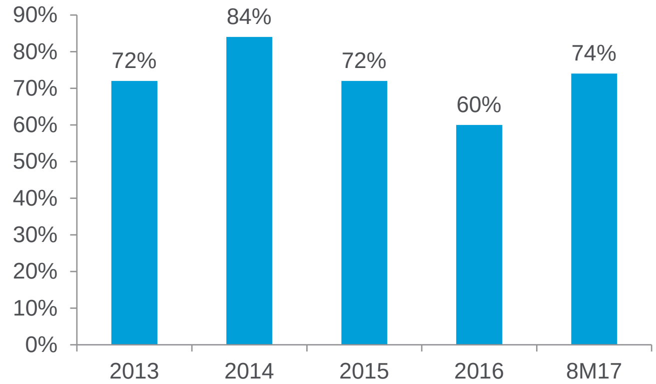
Geographically, Tier-1 cities accounted for 60% of NEV sales, owing to better local infrastructure (the charging stations, more specifically), and also because licensed car plates for conventional vehicles can only be acquired through public lottery or purchased at a high price in many Tier-1 cities such as Beijing and Shanghai.

Figure 117. 9M17 NEV Sales Volume Breakdown by City Tier



Source: CAPA

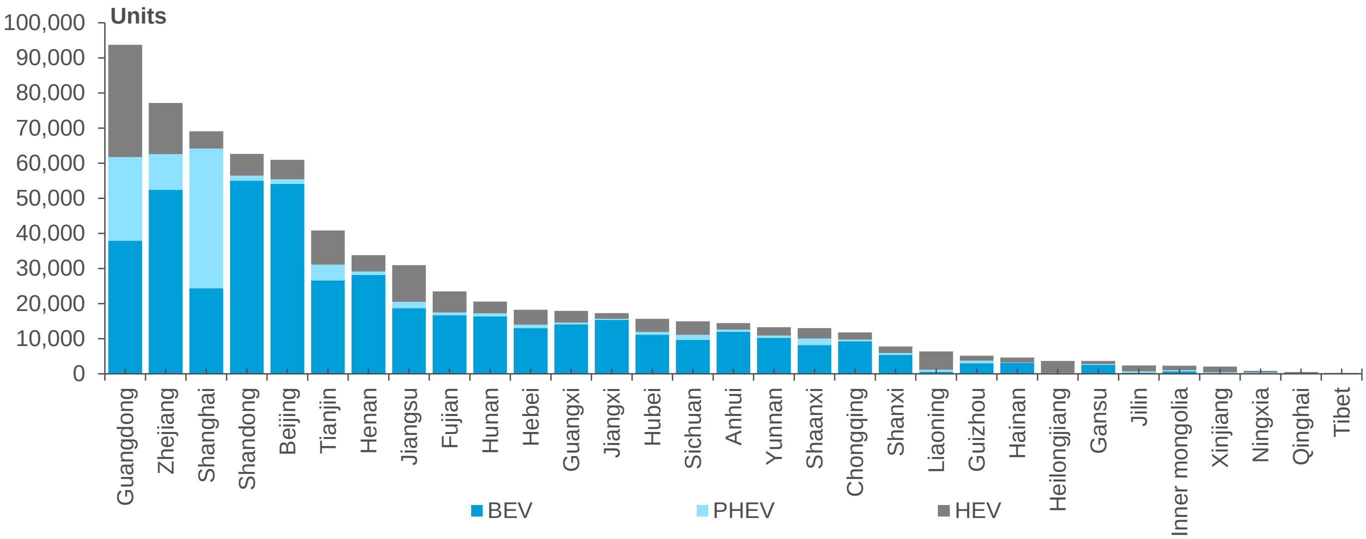
Figure 118. NEV Sales Concentrated in Tier 1 and Tier 2 Cities



Source: CAPA

We see a similar trend in Figure 119, which shows NEV penetration is concentrated in China's more urbanized provinces. Unsurprisingly, NEV sales were the highest in provinces home to China's largest cities (e.g., Shanghai, Beijing and Guangzhou).

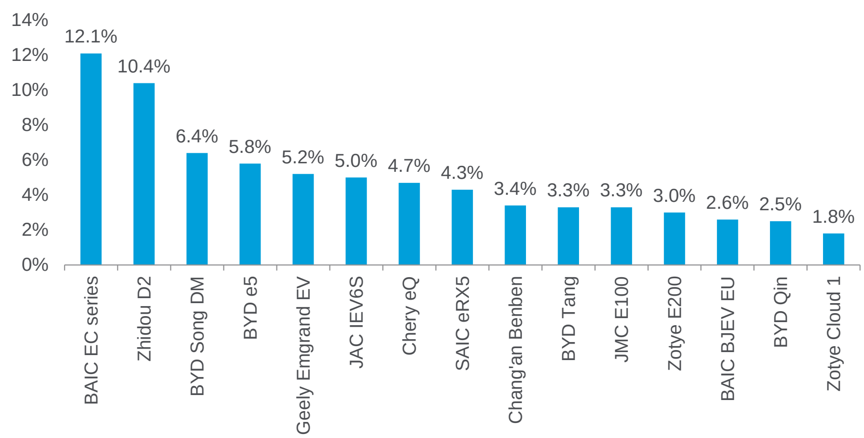
Figure 119. 2017 NEV Sales by Province Split by Powertrain Type



Source: Citi Research, Thinkercar

Of the top-15 best sellers in the first nine months of 2017, 73%, or 11, of them were BEV, all 11 of them were sedans, although BYD's PHEV SUV Song DM managed to come in at No. 3. Unlike gasoline vehicles that are gradually upsizing, small NEVs are still favored, with 53%, or 8, out of the 15 top sellers being of class A00 and A0, given subsidy remains a key reason behind the production and purchase of NEV. While we are still in an early lithium-ion battery (LFP)-to-lithium nickel manganese cobalt oxide battery (NCM) cycle, as pointed out by Citi's Basic Materials team, we find that NCM is becoming a standard configuration for the most popular NEVs, with only two of them equipped with LFP ones.

Figure 120. Top-15 Best-selling NEV Models in September 2017 and Their Respective Market Shares



Source: CPCA

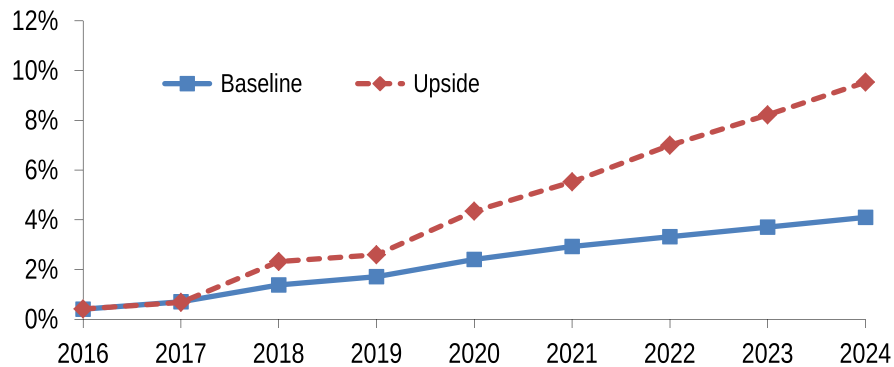
U.S.

The EV theme in the U.S. isn't new. Skeptics would probably point to the "EV rush" of 2008–09 — when EV enthusiasm (amid rising gas prices) ultimately ended with numerous companies failing amid overly optimistic projections. Indeed, the lessons learned from that era probably contributed to the industry's more cautious approach to re-embracing EVs up until the last few years or so. Two things changed in the past few years. First, Tesla's success was a game-changer with respect to the perception of EVs among consumers and industry observers. Second, continued battery cost reductions got to a point where a path towards ICE parity was visible.

Auto companies are speaking a different language today. Rather than treating EVs as a cost/endeavor of doing business or meeting regulations, today many companies understand that EV disruption is a matter of *when* not *if*. Nobody wants to be left behind, and no Automotive CEO wants to continue hearing about their future demise from the likes of Tesla and other EV newcomers.

So a race has clearly begun for the future of automotive propulsion.

Figure 121. U.S. EV Penetration

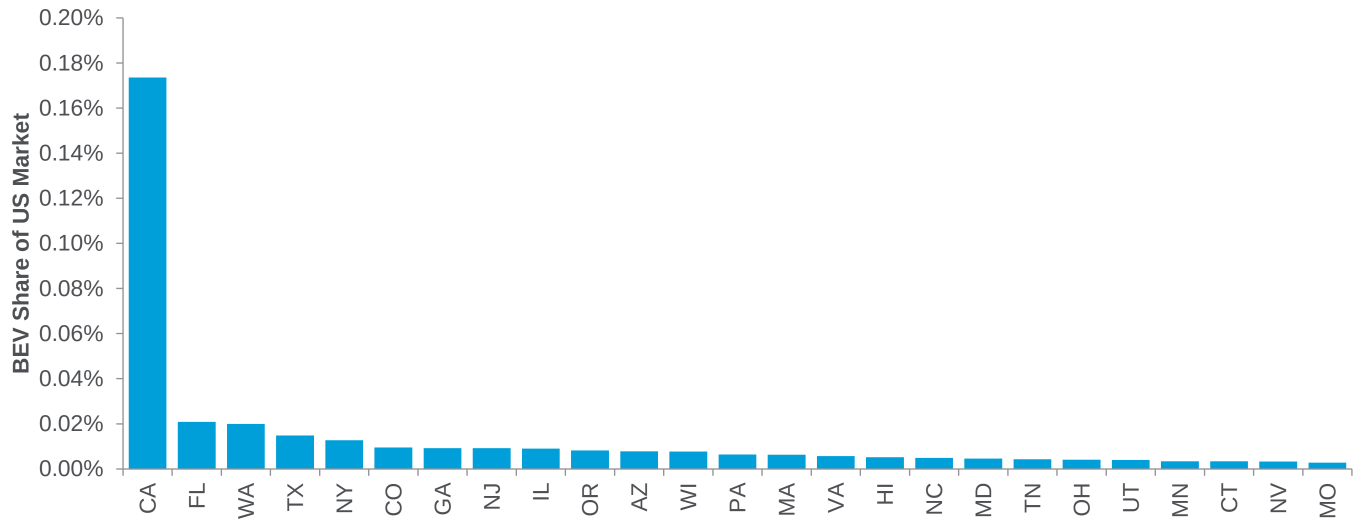


Source: Citi Research, Company Websites

Current U.S. Penetration

EV penetration today however remains low at just 1% of total new car sales. Furthermore, Figure 122 shows just how heavily concentrated BEV sales are in California relative to other U.S. states (over 8x as many BEVs were sold in California compared with Florida, the second-largest state by BEV sales). Apart from California (CA), Florida (FL) and Washington (WA), no U.S. state had BEV penetration over 0.02% in 2016.

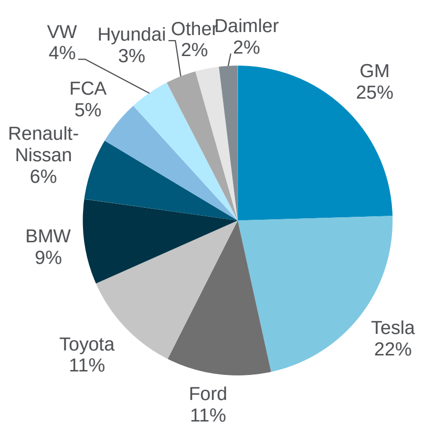
Figure 122. 2016 U.S. BEV Market Share Appears Negligible and a California Phenomenon



Source: Citi Research, Polk, IHS, Company Reports

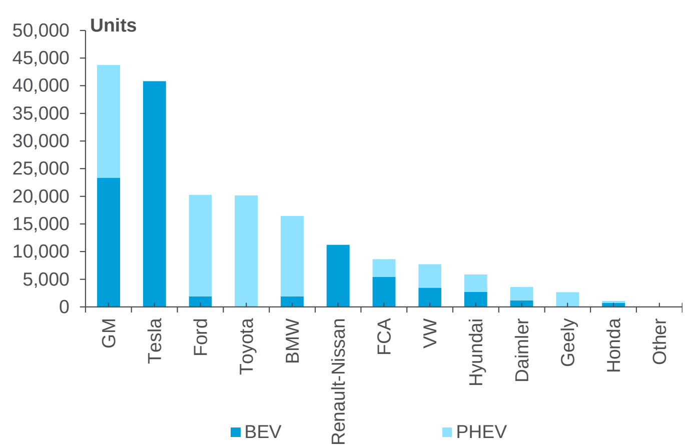
GM and Tesla are U.S. market leaders for now. A handful of popular models provide GM and Tesla with a combined 47% share of the U.S. EV market (Figure 123), and it was the popularity of Chevrolet's fully-electric Bolt (23,000 units) and plug-in hybrid Volt (20,000 units) that put GM ahead of Tesla in 2017 U.S. sales. Although Tesla's Model S was the highest-selling electrified vehicle last year in the U.S. (25,000k units), lighter Model X sales (15,000 units) and the well-documented Model 3 production problems left Tesla with 23% market share, compared with GM's 25%.

Figure 123. U.S. EV Market Share by Manufacturer



Source: Citi Research, LMC

Figure 124. U.S. BEV & PHEV Sales by Manufacturer



Source: Citi Research, LMC

Tesla dominates the fully-electric market in the U.S. When considering unit sales by BEV and PHEV split (Figure 124) it is clear that Tesla's all-electric range means it dominates the BEV market, whereas GM's sales are split almost evenly between fully electric (Bolt) and PHEV (Volt). Elsewhere Ford, Toyota, and BMW sales are almost entirely PHEV, whereas Renault-Nissan's sales are mostly BEV (95% of sales are generated by the fully electric Nissan Leaf).

What Lies ahead for EVs in the U.S.?

Unlike consumer electronics, the automotive supply chain is lengthy in nature and can't really accommodate an "overnight" conversion to any new propulsion system. Even under the most aggressive timeline and assuming no supply-chain bottlenecks, this is a matter of many years.

So rather than dwell on potential 2030+ EV penetration rates, we prefer to focus on the most telling data points in 2018–19 that will shape the speed of EV adoption and therefore EV investment. The next 12 months will prove very revealing for what we call Gen-3 EVs—the Tesla Model 3, Chevy Bolt, Nissan Leaf, and others expected to launch in 2018–19. These vehicles will test the market demand for EVs that offer good yet less than a full-range (200–310 miles vs. ICE at 250–300) at lower yet not quite mass-market sticker cost ($30–$50,000 as opposed to $20–$35k for small/mid sedans).

Much of the recent excitement around EVs hasn't necessarily stemmed from the specifications of these Gen-3 vehicles, but rather the market's apparent response to the Tesla Model 3. The existence of >400k global Model 3 pre-orders sent waves throughout the auto industry with the interpretation that the EV disruption was coming far sooner than many expected. Though the pre-orders themselves weren't firm orders per se ($1k fully refundable reservations, no credit checks), they at least gave the market a sense of the awareness and general intent to own an EV.

As Tesla scales up the Model 3, the rate of Model 3 order conversions — after initial enthusiasts and some Model S/X owners take delivery — could be the most important data point for the entire global EV story.

The Model 3 pre-orders do beg another question though. Why has the response to other Gen-3 EVs, namely the Bolt, been far less impressive? To be sure, by all accounts the Bolt has been well-received, reviewed favorably, and won awards, and it is gradually gaining sales momentum. But it hasn't generated nearly as much buzz as the Model 3.

Now, the first reaction when we pose this question is that the Model 3 is better styled than the Bolt. Even though styling is a matter of opinion, we'd still argue that the Bolt should be doing better *if* Gen-3 EV specs are as compelling as Tesla Model 3 pre-orders suggest they are. After all, one could easily counter that, at the $35–$40k price point, the Bolt is quite competitive against a similarly priced Model 3 — more range, instrument cluster, Apple CarPlay, pedestrian automatic emergency braking (AEB) systems, very strong regeneration based on media reports — though the Model 3 clearly wins on semi-autonomous sensing suite (though one is coming on the Bolt), over-the-air (OTA) updates, and acceleration. Away from one's view around styling, one could argue that the two products each have some pros/cons, particularly at the lower price-point.

Figure 125. Chevy Bolt vs. Tesla Model 3

	Bolt	Model 3
Starting Price	$37,495	$35,000
Fully Loaded	$43,510	$59,500
Base Range	238	220
Top Range	238	310
0-60 MPH (sec)	6.5	5.1-5.6
Center Touch Screen	10.2"	15"
Instrument Cluster?	Yes	No
Apple CarPlay?	Yes	No
Rear Camera Mirror?	Yes	No
Surround Vision?	Yes	No
Autonomous Features?	No	Yes
Supercharging	No	Yes
Vehicle AEB?	Yes	Yes
Pedestrian AEB?	Yes	Not yet
Length	164.0"	184.8"
Wheelbase	102.4"	113.2"

Source: Citi Research, Company Websites

That the Model 3 appears to be gaining far more orders than the Bolt begs a key question: Is the Model 3 success really about "EVs" or is it about Tesla as a brand/product? And to what extent are Tesla-exclusive features like large displays, OTA, and the promise of full self-driving also a factor in demand?

If it's the former, then it's obviously a very bullish sign for future EV penetration and one that every automaker will need to aggressively respond to (some arguably already are). By definition, under this scenario competing vehicles like the Bolt and Leaf would also stand to do better in 2018-19, as would new entries.

But if it's the latter, then the broader EV implications wouldn't be as powerful. That doesn't mean that the EV growth story would subside or that this is 2008–09 all over again, but rather that automakers might reconsider their reaction to Tesla's success — perhaps by accelerating OTA and automated driving functionalities, or by re-thinking other design principles.

Perhaps it'll be a matter of both. If the initial Gen-3 EV enthusiasm is really about Model 3, that would still result in a significant increase in public awareness and word-of-mouth. Such a scenario would probably benefit the other Gen-3 players, so the answer to the question posed above won't necessarily play out concurrently with Tesla's Model 3 production ramp.

Besides demand for Gen-3 EVs, we think another important trend to monitor is the price of battery raw-material costs such as lithium, cobalt, and nickel. In December 2017, Hyundai noted (per Reuters) that rising raw material costs threaten to slow and then maintain a status quo for battery costs by 2020. If this materializes, this too could slow EV demand depending on where battery prices settle at that time. Assuming a $100/KwH battery pack cost, a mid-200 mile EV would likely still sell at a modest price premium to an ICE though the EV would be more compelling on a cost-of-ownership basis. Auto observers have long-debated the selling power of cost-of-ownership vs. sticker price parity, though clearly the latter would be better for EV demand to truly inflect in a disruptive fashion (particularly if range isn't quite at ICE levels in all weather conditions).

In the U.S., the rush of higher-volume EV launches still appears to be more of a 2020+ event, though the next few years will see a handful of important launches, such as the Gen-3 EVs, which will be closely monitored throughout 2018.

Toyota recently unveiled its EV plan that called for an EV "rollout in earnest" starting in 2020 in China (mass-produced vehicle), followed by Japan, India, the U.S. and Europe. By 2030, Toyota's plan called on >50% of its vehicle sales to be electrified (including hybrids) with pure EV (and fuel-cell) representing >10% of Toyota sales. Ford is expected to roll out EVs more aggressively in 2020+. GM, on the other hand, is expected to launch two new EVs in the next ~16 months.

For the U.S., we expect EV penetration to remain <10% through the early 2020s even under somewhat optimistic projections, but the difference is that the industry at that point could be prepared to scale much faster should supply-demand dictate so. Under the most optimistic scenario for battery development as well as autonomous driving (AV) development, the EV penetration story beyond the early/mid-2020s could become a *how fast can they scale it* question at least in major passenger vehicle segments. What's clear is that automakers are investing capital now to prepare for scalable xEV platforms in the 2020+ era.

In the meantime, the next 12 months will prove plenty interesting in shaping the EV narrative. Demand for Gen-3 EVs (Model 3, Bolt EV, Leaf) and launches like the Jaguar I-Pace will answer the following questions:

1. **Whether consumers are purchasing EVs with the total-cost-ownership in mind or sticker price:** Gen-3 EVs are still more expensive than competing ICEs on a sticker price level, but less so on a total-cost-of-ownership. If cost-of-ownership starts to play a major role in the buying decision for Gen-3 EVs, then the pace of disruption in the 2020+ timeframe could accelerate. Of course the automakers selling Gen-3 EVs could benefit from being early with such product.

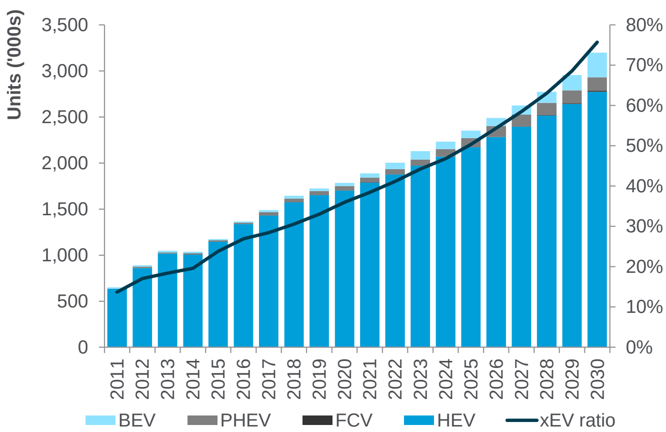
2. **How consumers weigh the cost/benefit of today's EVs:** At a modestly higher cost of ownership, one could argue that consumers would still purchase Gen-3 EVs because of other well-regarded EV benefits — smooth acceleration, greater usable capacity, brake regeneration. But they'd still have to accept modestly less range (200–300 miles, the high-end being the LR Model 3 variant) with the Gen-3 EVs. Will they or won't they? The EV bull argues that EVs are so compelling that consumers will merely adjust lifestyles for the modest range sacrifice. The EV bear argues against that notion by pointing out that U.S. consumers didn't enthusiastically accept 100-mile EVs even though most daily range needs are lower than 100 miles. Past studies done by consultants suggest a desire for the upper-end of the 200–300 mile range, though it's unclear whether such studies are limited by low awareness of EV benefits.

3. **Is this an EV movement or a Tesla movement?** A question that will be answered by gauging Model 3 demand vs. competing Gen-3 EVs, not just initially but throughout 2018–19. If it's ultimately more a Tesla movement, the industry's reaction could shift somewhat towards accelerating the catch-up within other Tesla-leading features like OTA, digital displays, and perhaps standard semi-autonomous hardware. This doesn't mean that automakers would stop investing in EVs, but rather that the perception of what's driving EV penetration (in the near-term) would shift to a Tesla story more than an EV story, at least for some period of time.

Japan

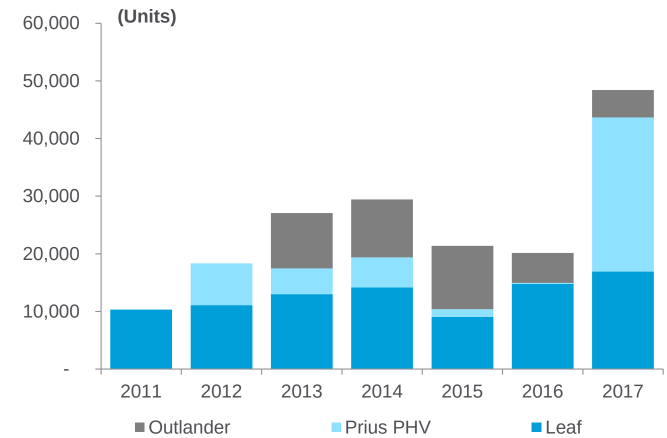
Japan an HEV Leader While Next-Generation Batteries are Key for BEVs. In Japan, the FY16 (FY3/17) weightings for BEV and PHEV sales were extremely low, at 0.3%, respectively. PHEVs and BEVs could hardly be considered to have entered a dissemination phase, as unit sales trends can largely be explained by the model cycle of the Nissan Leaf in the case of BEVs and the Toyota Prius PHV and the MMC Outlander PHEV in the case of PHEVs.

Figure 126. xEV Penetration in Japan



Source: Next Generation Vehicle Promotion Center, FOURIN, Citi Research

Figure 127. Sales in Japan of the Nissan Leaf, the MMC Outlander, PHEV, and the Toyota Prius PHV



Source: Marklines, Citi Research

The market penetration rate for HEVs, meanwhile, has risen sharply, reaching 26% in FY16 and doubling over the past five years. The top three automakers have actively launched HEV models, as in addition to Toyota and Honda, which honed in on HEVs from the outset, Nissan introduced the Note and the e-POWER. In the mini-vehicle space, Suzuki is stepping up the launch of mild hybrid models.

Japan does not have many incentives (i.e., regulatory, subsidies) aimed at promoting BEV or PHEV adoption. We believe automakers are likely to expand their line-ups to keep abreast of overseas regulations, with the effects likely to extend to Japan. However, we expect only a moderately paced market penetration for BEVs and PHEVs in Japan, given the few merits to consumers of switching to such models.

We assume Japan's BEV weighting increases to 2% in 2025 and to 6% in 2030. Leaving aside the impact of radical regulatory changes or subsidies that are not currently under consideration, we think battery cost and performance are likely to have a major impact on BEV penetration rates. Toyota aims to commercialize all solid-state batteries in the first half of the 2020s, but we expect these batteries to be expensive at the outset and therefore we do not think the pace of BEV market penetration will rise. However, we think BEV sales could increase sharply in Japan in the latter half of the next decade, when commercial versions of all-solid-state battery models become available.

We expect Japan's PHEV weighting to inch up to 2% in 2025 and to 3% in 2030. PHEVs tick many regulatory boxes in Europe, the U.S., and China, but there is no clear need for motorists in Japan to make the switch to PHEVs at the moment. However, motorists could shift from HEVs to PHEVs if fuel economy regulations were tightened in a way that would favor PHEVs.

The HEV still offers the greatest promise in Japan, and we expect the penetration rate to rise to 47% in 2025 and to 66% in 2030. We think HEVs will remain a mainstay at Toyota, which is achieving margins comparable to those of gasoline-powered vehicles in strong hybrids. As a realistic solution, Nissan, which has been focussing on BEVs since the start of this decade, is strengthening its hand with the e-POWER (features a series hybrid system). The internal combustion engine is also evolving thanks to thermal efficiency improvements, and it seems that the superiority of HEVs, which can improve fuel economy and generate profit by combining the internal combustion engine with electrification, will not change.

Appendix 4

Regulation by Region

Europe

There are currently no specific quotas for EVs in Europe but rather a host of regulations that favor low emission vehicles and are generating significant push demand. We summarize the key European regulation in Figure 128 below.

Figure 128. Tougher Testing Standards and Falling CO_2 Limits Give OEMs a Regulatory Headache and Spur on the Need for Powertrain Evolution

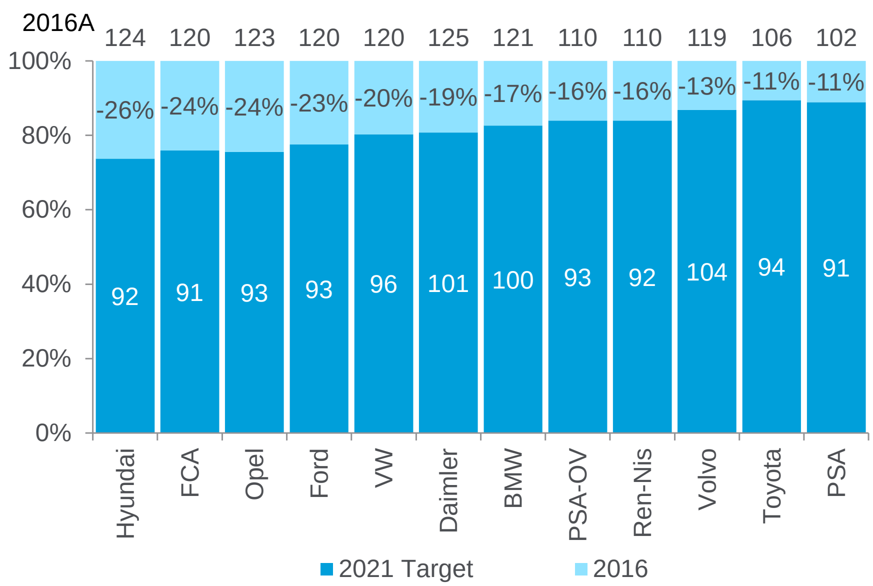
	Overview of European regulatory environment
European Commission CO_2 Targets	2008: In 1998 European OEMs agreed to an optional CO_2 emissions target of 140g/km by 2008, however by 2007 it was clear the hurdle would not be cleared and the voluntary target was scrapped with the intention of replacing it with a mandatory target. 2015: A target of 130g/km was set in 2009, which was comfortably reached according to the European Commission, which reports that in 2016 average emissions were 118.1g/km of CO_2. 2020/21: The current passenger car CO_2 target was set in 2013 and aims for manufacturers to achieve 95g/km by 2021, being phased in from 2020. This would represent a 5.1% annual reduction rate from 2015, considerably faster than the 1.7% rate set by the 2015 target. The targets are currently based on NEDC terms (see Emissions Testing below) and therefore WLTP CO_2 values will be converted back into NEDC terms in order to be compared against the 95g/km target. 2025/2030: The European Commission proposed its post-2020 CO_2 targets in November 2017. CO_2 emissions will need to fall by 15% (2025) and 30% (2030) compared with the 2021 level. Similarly to the current 2020/21 targets, there is a degree of flexibility as targets are partially dependent on the weight of a manufacturer's fleet. Manufacturers that sell more zero-emission and low-emission vehicles (ZLEVs) are also rewarded with a reduction to their average fleet emissions target. The targets are defined in WLTP testing terms and the base against which the reduction is measured (i.e., the OEMs 2020/21 target) will be converted from NEDC terms to WLTP. Super credits: Manufacturers receive super credits for producing low-emission vehicles, which can be used to offset their average fleet emissions. For each low-emission car manufactured, OEMs are able to count that car as 2 vehicles in 2020, 1.67 vehicles in 2021, 1.33 in 2022, and then 1 from 2023 onwards. Super credits were also available to manufacturers when working towards the 2015 CO_2 target.
Euro 6 Emission Limits	Euro 6c/d: The Euro 6 standard was introduced by the European Commission in September 2015 and currently sets the emissions limits with regards to carbon monoxide, NOx, hydrocarbons, and particulates. The standards vary for gasoline and diesel vehicles, which are measured against Euro6c and Euro6d respectively. The most significant departure from Euro5 is in relation to NOx emission limits for diesel vehicles, which were reduced from 0.18g/km to 0.08g/km, a 56% reduction. The rising incremental cost for diesel makes this technology less attractive as a solution to the compliance challenge faced by European manufacturers.
Emissions Testing	New European Driving Cycle (NEDC): Historically the Euro Emission Limits have been applied to vehicles tested using NEDC testing - a laboratory-based drive cycle simulation. However NEDC testing has been criticized for the disparity in results compared to real-world driving, and from September 2018 this will be replaced with the more strenuous WLTP testing. Worldwide Harmonised Light-Vehicle Test Procedure (WLTP): From September 2017 all new models introduced to the market in the EU have had to comply with WLTP testing, and from September 2018 WLTP will apply to all new car registrations, rather than just new models. Unlike NEDC tests, WLTP is designed to better reflect real-driving on-road performance and therefore aims to produce more accurate measurements of fuel consumptions and emissions. Car manufacturers suggest the delta will be an additional 15-20 g/km of CO_2 emissions.[15]. Real Driving Emissions (RDE): Though the WLTP testing conditions are designed to better reflect on-road driving, it is still a laboratory based procedure. Therefore, in order to enhance the accuracy of its results, vehicles will also be subject to Real Driving Emissions (RDE) testing in conjunction with WLTP to come to a final conclusion on the vehicle's emissions and fuel consumption from September 2018. Key differences: Unlike NEDC, testing under WLTP is conducted over four more dynamic phases rather than just two phases as part of a single test cycle. WLTP testing involves driving further (23.25km vs. 11km), for longer (30 vs. 20 minutes) and faster (max. speed 131km/h vs. 120 km/h) than NEDC at a lower test temperate (23°C vs. 20-30°C).
Low Emissions Zones (LEZs)	Europe: Over 200 Low Emission Zones have been implemented across Europe in an attempt to improve air quality in European cities and meet the European Union's Air Quality Standards. By restricting vehicle access, LEZs aim to reduce emission of fine particles, NOx, and indirectly ozone. The most polluting vehicles (classified in accordance with the Euro standards) are regulated within these areas; they are either banned or will have to pay a toll in order to access the area depending on local regulations. London Ultra Low Emission Zone: Transport For London plan on launching an Ultra-Low Emission Zone based on its current Congestion Charge Zone from April 2019. Vehicles entering the zone will have to meet minimum emission standards in order to avoid paying penalty charges. Petrol vehicles will need to comply with Euro 4 standards and diesel will be measured against Euro 6.

Source: Citi Research, ICCT, European Commission, EU WLTP Facts, EU Urban Access Regulations

[15] NEDC – WLTP comparative testing, *TNO*, 10th Oct 16 (link)

Tough regulatory landscape increases significance of EV adoption. The regulatory environment within which European OEMs operate is clearly a catalyst for EV production. Figure 128 provides an overview of the European regulatory environment that we argue is a key driver behind the OEMs' focus on EV and the growing pertinence of electric powertrain in Europe. Manufacturers are being tasked both with significantly reducing their average fleet emissions (see Figure 129) and simultaneously adapting to more stringent testing conditions under both WLTP and RDE. Furthermore, Low Emission Zones provide an example of how European local authorities are responding to the growing concern over air pollution levels and act as a further incentive for consumers to switch to low-emission vehicles.

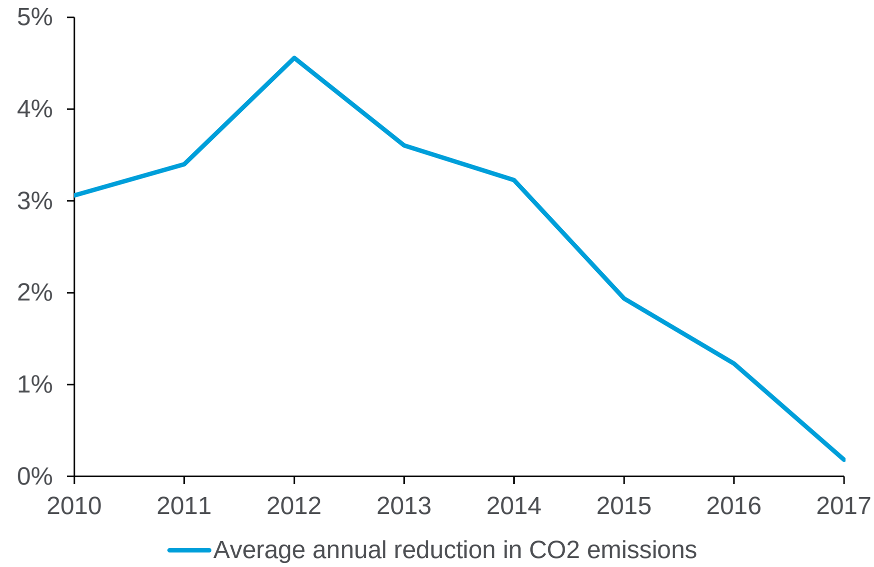
Figure 129. Fleet CO_2 Emissions in 2016 vs. 2020 EU Target



Source: Citi Research, ICCT

CO_2 targets pose headwind to European carmakers. In order to meet EU CO_2 targets OEMs will have to reduce average fleet emissions to 95g/km by 2020 with a phase-in to 2021. Specific targets will vary depending on the average mass of the fleet (heavier cars are permitted higher emissions). The headwind that manufacturers face ranges between 11% and 26% (see Figure 129) and worryingly the pace at which average CO_2 emissions are declining appears to be slowing (see Figure 130). Given the rising popularity of SUVs and declining penetration of diesel, it's a possibility that the CO_2 count could get worse before it gets better. Increasingly the OEMs are being compelled to produce low or zero emission vehicles.

Figure 130. The Average Pace of CO_2 Reduction by OEMs is Slowing



Source: Citi Research, ICCT, Company Data

At first glance targets set for 2025 and 2030 seem less strenuous… The EU's proposals of further CO_2 limits in 2025 and 2030 will require passenger car fleets to achieve a 15% reduction by 2025 and 30% by 2030 vs. 2021. This suggests a slowdown in the pace of improvements required by the EU. In theory, to meet 2021 targets, fleet CO_2 emissions need to improve 5.1% per year (2015–21), but under these proposals that rate is 4% per year (2022–25) and 3.8% per year 2026–30.

…but WLTP testing will make the task more challenging. The targets for 2025 and 2030 will be defined in WLTP testing terms, and the 2020/21 base will be converted from NEDC terms to WLTP. Therefore, although the annual rate of reduction may be slower, the introduction of more stringent testing criteria (WLTP and RDE) makes comparing the difficulty of meeting the 2015 CO_2 targets with 2025/2030 tricky.

Diesel decline means OEMs relying increasingly on EV to meet CO_2 targets. Diesel vehicles being ~20% more fuel-efficient than gasoline equivalents means they play a vital role in reducing average fleet CO_2 emissions (see here). However, the falling diesel penetration (Western European diesel share of new car sales was down 800bps in January 2017) has limited its dilutive effect on fleet CO_2 emissions. We assume this and the rising popularity of SUVs contributed to the slowdown in CO_2 reduction shown in Figure 130. Consequently, the speed of transition from ICE to electric powertrain has become increasingly pertinent to OEM efforts to meet forthcoming CO_2 targets. Presumably manufacturers will rely increasingly on EV volumes to reduce their average emissions.

Figure 131. EU Super Credits: Extra Incentive to Produce Low Emission (<50g/km) Vehicles

	First stage of emission reductions (2015 CO_2 target)								Second stage of emission reductions*			
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
No. of vehicles each low-emitting (<50g/km) car is counted as	3.50	3.50	2.50	1.50	1.00	1.00	1.00	1.00	2.00	1.67	1.33	1.00

*super credit scheme's contribution to the target will be capped at 7.5g/km per manufacturer over the three years during second stage of emission reductions

Source: Citi Research, European Commission

Super credits add extra incentive to produce electric. To help reach the 2015 CO_2 target, the European Commission introduced a "super credit" scheme. Between 2012 and 2015 every vehicle produced emitting below 50g/km CO_2 earned manufacturers "super credits" that could be used to reduce their average fleet emissions (see Figure 131). Each low or zero-emission vehicle would be counted as higher number of vehicles in accordance with the table shown in Figure 131. This scheme is set to restart in 2020 to support OEM efforts to reach the 2020/21 targets. Though the scheme is currently set to phase out by 2023, the EU has suggested a credit system will be available in relation to 2025 and 2030 targets. The details of this system are not yet clear, but we assume it will be a continuation of the super credit scheme.

Government Bans and Incentives

European cities and nations announce bans on ICE powertrain. Regulation of the ICE powertrain is tightening across Europe. Bans on new gasoline and diesel sales have been proposed in the Netherlands by 2030, plus in France and the U.K. by 2040, and Norway wants all new cars sold by 2025 to be zero emission (see Figure 133). Also, a number of European cities have already introduced restrictions and bans on the use of diesel vehicles. Therefore, although the pace at which EV penetration will grow is less certain, it appears to only be a matter of time before almost all new cars sold come with an electrified powertrain of some description.

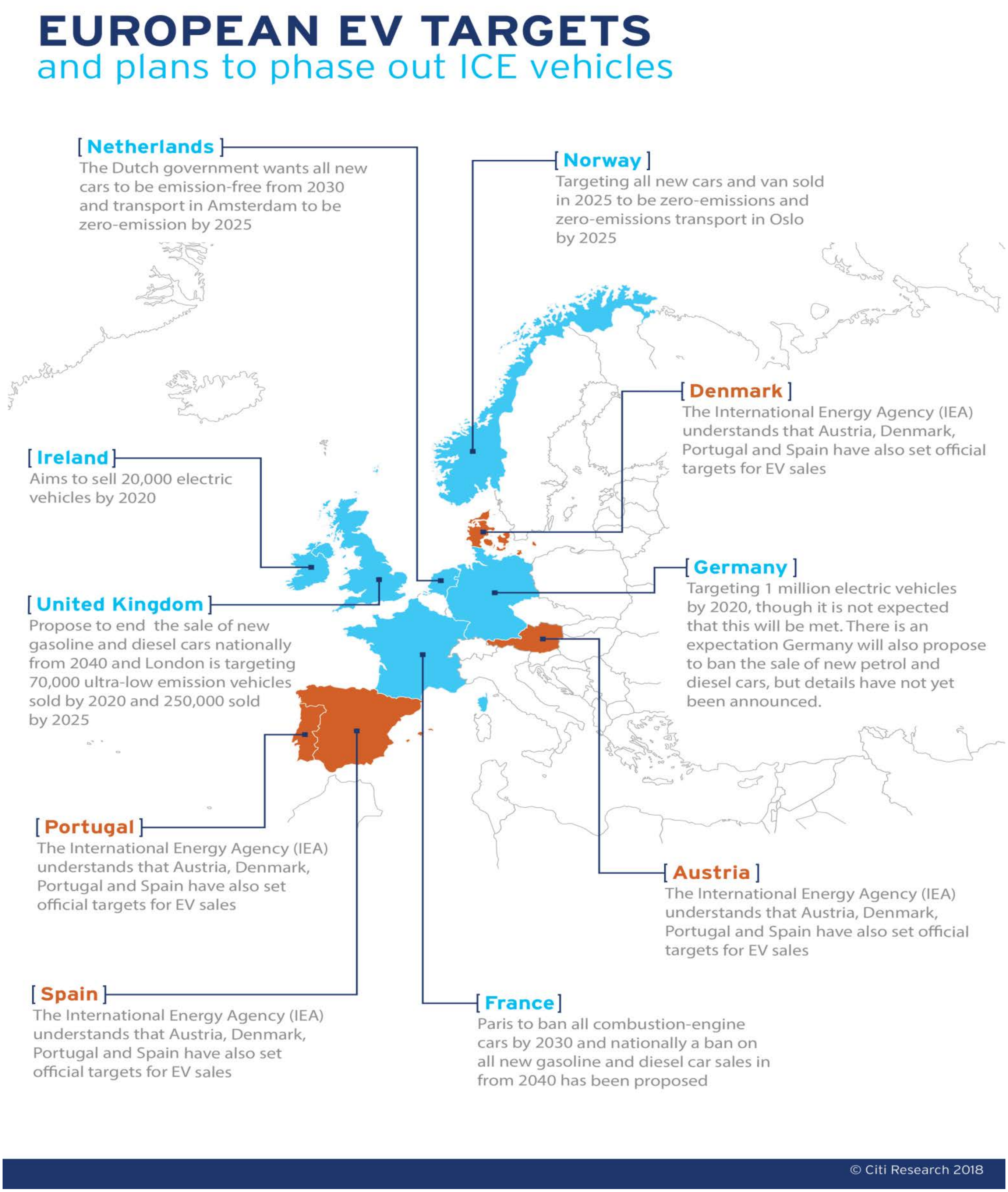
Incentives encourage EV adoption by reducing total cost of ownership. In order to encourage the powertrain transition from ICE to electric and to support demand for EVs, European governments and cities have introduced a swathe of incentives for both individuals and companies (see Figure 132). Purchase subsidies and tax benefits help reduce the total cost of ownership of an EV, which is a key barrier to entry for many consumers. For example, the boom in EV stock in Norway (from 5,380 in 2011 to 133,260 in 2016) has been largely driven by generous subsidies. In Norway, a BEV is exempt from purchase tax, VAT, and toll road fees, and in the capital city Oslo EVs enjoy free charging, free parking facilities, and access to the bus lane.

Figure 132. Incentives for Europe's Ten Largest EV Markets

	Purchase Subsidies	Registration Tax Benefits	Ownership Tax Benefits	Company Tax Benefits	VAT Benefits	Other Financial Benefits	Local Incentives	Infrastructure Incentives
Austria	✓	✓	✓	✓	✓		✓	
Belgium	✓	✓	✓	✓				
France	✓	✓	✓	✓			✓	
Germany	✓		✓	✓		✓	✓	
Netherlands		✓	✓	✓				
Norway		✓	✓	✓	✓	✓	✓	✓
Spain	✓	✓	✓		✓	✓	✓	✓
Sweden	✓		✓	✓				
Switzerland			✓			✓		
UK	✓	✓	✓	✓			✓	✓

Source: Citi Research, EAFO

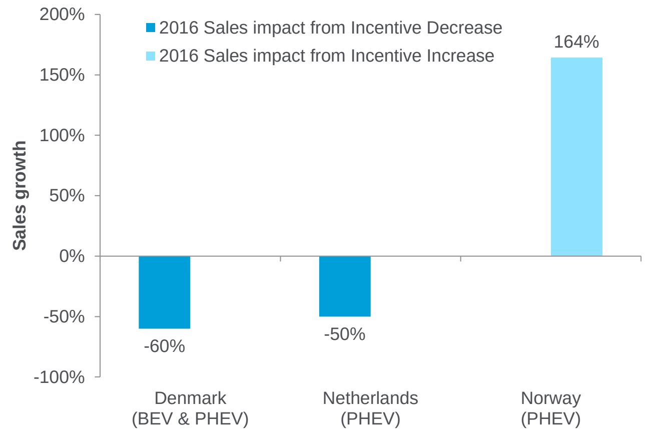
Figure 133. European Governments are Planning for Life After ICE and Setting Themselves Targets for EV Adoption



Source: Citi Research

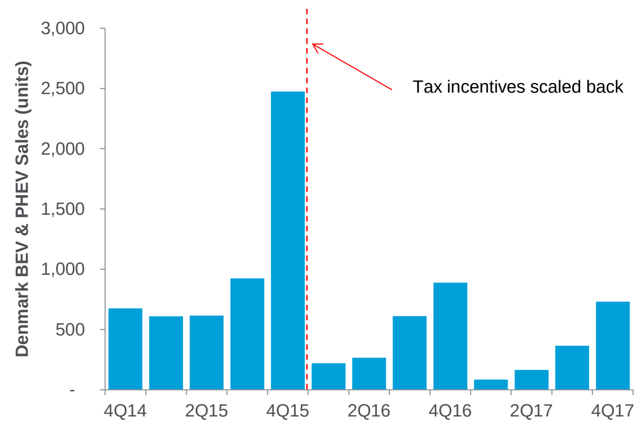
EV demand appears to be highly sensitive to changes to incentives. This raises the question of how EV demand will react when/if generous incentives currently in place are withdrawn. Figure 134 below shows the impact increasing and decreasing EV support incentives had on sales growth in 2016 and suggests demand is highly sensitive to such changes.[16]

Figure 134. EVs Highly Sensitive to Changes to Incentives



Source: Citi Research, IEA

Figure 135. Danish EV Market Shrinks Following Subsidy Withdrawal



Source: Citi Research, ACEA

We see an example of this in Denmark, where the scaling back of the Danish tax incentives that began in the first quarter of 2016, led to a 60% decrease in EV sales that year. As a result, the Danish state chose to stall its intended subsidy cuts in order to prevent the market collapsing. Instead of 40% of the full registration tax in 2017, this rate has been capped at 20% until an additional 5,000 EVs are sold or 1 January 2019 is reached, at which point it will rise to 40%. The tax will increase to 65% in 2020, 90% in 2021, and 100% in 2022 (2 years later than originally planned).

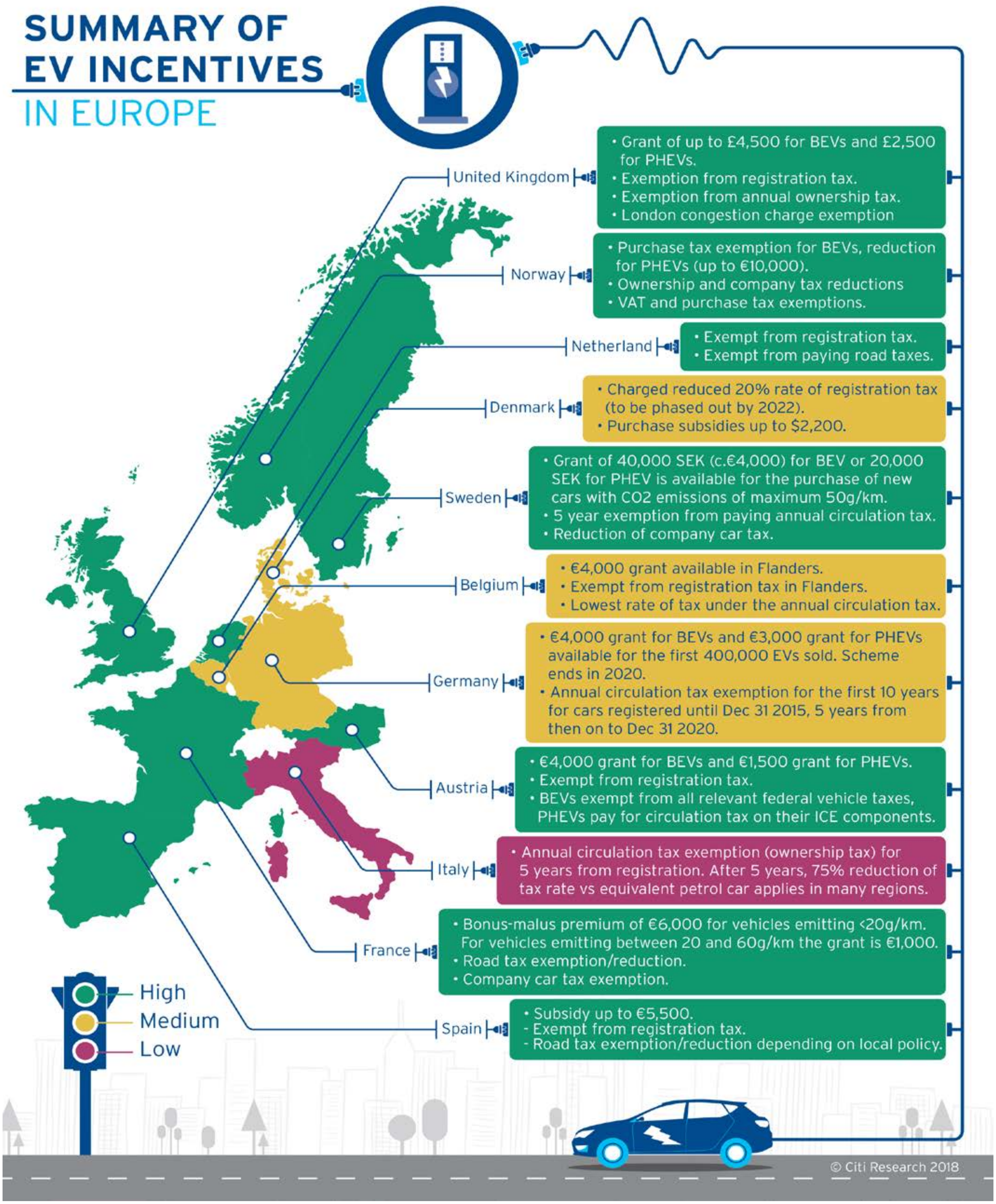
Announced in April 2017, plans to slow the pace of subsidy withdrawal have had a mixed impact on the EV market in Denmark. Although Q2 and Q3 sales in 2017 are up 94% and 112% month over month, respectively, they remain down 38% and 40% year over year, and sales for the first three quarters are down 68% since 2015, when the tax exemption still applied in full. This volatility is not helpful to carmakers or those involved in the EV supply chain.

Norway's EV market economics are being questioned. In contrast to Denmark's collapse and the 50% decline in the Netherlands following a rise in PHEV tax rates, Norway's PHEV sales more than doubled, growing 164%, after Norway increased its their purchase subsidies and tax exemptions in 2016. This led to some Norwegian politicians questioning the justification for the extent of their incentive provisions: Despite the subsidized BEVs accounting for only 5% of daily commutes, Oslo's incentives for BEVs amounted to over half as much as the total city public transport bill.

The dependence on temporary subsidies for the creation of demand creates substantial uncertainty regarding activity post the expiry of these incentives. While of course governments could sustain/increase subsidies to sustain growth, the cost to the state as EV sales penetration grows would not in our view be sustainable financially as a long-term solution.

[16] In 2016 tax incentives were scaled back in Denmark, PHEV tax rates increased in the Netherlands, and purchase subsidies and tax exemptions increased in Norway.

Figure 136. European Incentives Are Key to Driving EV Adoption



Source: Citi Research

China

The boom in China, which started a few years ago, was largely triggered by generous government subsidies on NEV for both manufacturers and customers. Subsidy will continue to play a major role in stimulating NEV deployment in China. Besides, China announced a dual credit management system in September 2017 to encourage the development of NEV under a more market-oriented approach, which we believe would give a strong push to NEV sales in 2019–2020E, with a requirement for manufacturers to reach 10%/12% NEV credit based on their conventional vehicle sales volume. Details of the latest 2018 NEV subsidy policy can be found in Figure 137.

Figure 137. Details of 2018 Final EV Subsidy Policy

	2017	2018 Draft version 1	2018 Draft Version 2	2018 Final Policy	vs. Draft Policy
Passenger Vehicles					
Cap subsidy amount (Rmb/kwh)	1,100	1,100			J
Subsidy per vehicle (Rmb/unit)					
By driving range:					
100-150km	20,000	-	-	-	--
150-200km	36,000	10,000	15,000	15,000	--
200-250km	36,000	25,000	25,000	25,000	L
250-300km	44,000	34,000	34,000	34,000	--
300-400km	44,000	45,000	45,000	45,000	--
≥ 400 km	44,000	50,000	50,000	50,000	--
Subsidy multiplier					
Battery energy density (wh/kg)					
<90	--	--	--	--	--
90-105	1.0x	--	--	--	--
105-120	1.0x	0.5x	0.5x	0.6x	J
120-140	1.1x	1.0x	1.0x	1.0x	--
140-160	1.1x	1.1x	1.1x	1.1x	--
>60	1.1x	1.1x	1.1x	1.2x	J
Electric bus					
Subsidy amount (Rmb/kwh)	1,800	1,100	1,440	1,200	middle
Cap subsidy per vehicle (Rmb/unit)					
6-8m	90,000	50,000	72,000	55,000	middle
8-10m	200,000	120,000	120,000	120,000	--
>10	300,000	180,000	240,000	180,000	--
Subsidy multiplier					
Battery energy density (wh/kg)					
<85	--	--	--	--	--
85-95	0.8x	--	--	--	--
95-110	1.0x	--	--	--	--
110-115	1.0x	0.8x	0.8x	--	L
115-120	1.2x	0.8x	0.8x	1.0x	J
120-135	1.2x	1.0x	1.0x	1.0x	--
135-140	1.2x	1.0x	1.0x	1.1x	J
>140	1.2x	1.2x	1.2x	1.1x	L
Special Vehicle					
Cap subsidy amount (Rmb/unit)	150,000	100,000	100,000	100,000	--
Subsidy per battery capacity (Rmb/kwh)					
≤ 30kwh	1,500	900	850	850	--
30-50kwh	1,200	750	750	750	--
>50kwh	1,000	650	650	650	--

Source: Ministry of Finance, Ofweek, Citi Research; Note: EV subsidy amount = base subsidy amount x energy density multiplier x energy efficiency adjustment factor

Phasing Out Subsidy Accelerate Industry Consolidation

The Chinese government started subsidizing NEVs in 2009. By implementing a series of actions to plug subsidy leakages and by introducing a set of requirements on battery size, energy density, pure electric range, etc., the government now focuses on subsidies for high-quality NEVs.

According to news reports over the past two months, the potential 2018 NEV subsidy adjustment appears to be much stricter on pure-electricity range (R) and battery-energy density than the previous ones, potentially with -100% to +14% changes for BEV PV, -8% changes for PHEV PV, and -100% to -40% changes for BEV bus. This, in our view, will further enlarge the gap between high- and low-quality NEV makers' subsidy, thus accelerating industry consolidation. We think this also shows the strong government determination to make the NEV industry lean — with no "fat" but "muscle." The Chinese government started subsidizing NEVs in 2009. By implementing a series of actions to plug subsidy leakages and by introducing a set of requirements on battery size, energy density, pure electric range, etc., the government now focuses on subsidies for high-quality NEVs.

We show the latest 2018 NEV subsidy policy in Figure 137. The magnitude of subsidy cut is generally in line with draft policies circulated in the market previously.

Key interpretations from the materials demand point of view:

Higher-energy density requirement to support NMC battery and cobalt demand. Government adopts differentiated treatment in the passenger vehicle sub-sector: incentive is cut for short-driving-range cars (<400km) and low-energy-density batteries (<140wh/kg), but subsidies for high-end ones are increased. During 2017, there is no incentive for producers to produce driving-range >400km & energy-density >160wh/kg batteries because they could already enjoy the highest subsidies once they reach 300km and 120wh/kg. The new policy encourages producers to develop even further.

Magnitude of cut is lower than the market expectation. Final 2018 subsidy per kwh reached Rmb1,200/kwh vs. Rmb1,100/kwh in the draft policies for both e-bus and e-PV. Subsidy policy of SPV is generally in line.

More measures introduced to resolve cash flow pressure resulting from lengthy time to collect subsidy. Required accumulated driving mileage for non-private NEVs is reduced from 30,000km to 20,000km. A portion of the subsidy will be granted when the vehicle is sold; the rest is paid when the mileage meets requirement. This could lead to healthier cash flow along the EV supply chain.

The new policy will be implemented from June 12. From Feb 12 to June 11, a temporary subsidy policy will be applied for the transition period: ePV and e-bus will get 0.7x 2017 subsidy amount and special vehicles will get 0.4x 2017 subsidy amount. Most ePv and eBus will enjoy a higher subsidy in transition period, compared with after June. Therefore, we think a moderate level of rushing sales and installation will continue to take place, to support demand in the next few months.

Dual Credit System Stimulates NEV Production

China introduced the dual credit system in September 2017. This management system consists of corporate average fuel consumption (CAFC) credit and NEV credit, and its aim is to push down average fuel consumption for gasoline cars and push up the production for NEVs. The policy came into effect on April 1, 2018, and is practically applicable to all nameable passenger vehicle OEMs in China.

CAFC credit is calculated by the OEM's annual production volume times the difference between its actual and target CAFC. Positive credits can be carried forward for no more than three years at a conversion ratio of 80% for credits earned in 2018 and before or 90% thereafter. Credit can also be transferred within related companies, defined by shareholding at or more than 25%. Negative credits should be offset by those from previous years or from related corporates, and, if not enough, by NEV points on a 1:1 basis. CAFC credit must be at a non-negative balance for each year; otherwise, the government will suspend the OEM from launching new models or implement a partial production suspension of its models with high fuel consumption.

NEV credit is calculated by the OEM's annual production volume times the respective point for each model; PHEVs get 2 points, and BEVs can earn up to 5 points based on their range per charge under the formula 0.012R+0.8 (i.e. BEV with range at 350km or above can earn full score at 5). NEV credit cannot be carried forward (except 2016 when a 1-year carry forward is allowed), and cannot be transferred with related companies; it can, however, be traded freely through MIIT's platform. NEV insufficient credit can only be balanced by NEV credits purchased from others. Depending on the number of gasoline vehicles produced, OEMs are required to generate NEV credit up to 10%/12% of that volume in 2019/20E. Failure in achieving the requirement can result in production suspension of ICE vehicles.

In short, the big producers of conventional vehicles will be compelled to subsidize NEV manufacturers if they aren't able to ramp up their NEV products in time, thus effectively forcing the auto industry to take on the financial burden for NEV to reduce the Chinese treasury's involvement in order to foster long-term development for the sector. In answer to this, many conventional car makers have set up partnership with NEV producers to leverage their NEV credits as an answer to the NEV credit requirement over the past year.

Figure 138. Duel-credit Management System

Regulatory authority	Ministry of Industry and Information Technology (MIIT)	
Two parallel system	CAFC credit	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 2016-17/2018-19/2020 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 0.012 + 0.8 (cap at 5) NEV point per PHEV = 2
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 80% conversion ratio in 2018 and 90% in 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 be trade freely on MIIT's platform, but cannot be re-sold. - NEV credit is not allowed to be carried forward - The 2019/20 NEV balance will be examined together
Assessment companies	All PV OEMs selling in China (including import)	All PV OEMs with annual production volume or import volume greater than 30k 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%
Assessment period	2016+2017, 2018, 2019, 2020	2019+2020
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 ICE models

Source: MIIT, Citi Research

In the table below, we present our calculation on the industry's positioning under the dual credit system. Based on our forecast for NEV sales volume reaching 1.5m units by 2020E from 0.3 million units in 2016, and assuming average range for BEV to progressively increase to 300km in 2020E from 150km in 2016, the total NEV points earned for all the NEV makers in China will be 3.8/5.5m points in 2019/20E. Compared with the 2.6/3.4m points NEV credit requirement in 2019/20E, derived based on the 10%/12% NEV point to conventional vehicle volume ratio as required by the MIIT, NEV credit surplus for the auto industry as a whole will be 1.1/2.1m points in 2019/20E, according to our calculation.

Figure 139. Estimation of NEV Credit and CAFC Credit for the Auto Industry in 2017-20E

	2016	2017E	2018E	2019E	2020E
NEV credit (mn points)	0.83	1.23	2.11	3.76	5.50
BEV	0.67	1.04	1.78	3.19	4.56
PHEV	0.16	0.20	0.33	0.57	0.94
NEV credit to conventional vehicle ratio	-	-	-	10%	12%
NEV credit requirement (mn points)	-	-	-	2.63	3.39
NEV credit surplus (mn points)	0.83	1.23	2.11	1.13	2.11
CAFC deficit after intra-group offset (mn points)	(0.70)	(0.72)	(0.76)	(0.80)	(0.87)
PV sales volume (mn units)	23.7	24.4	25.9	27.3	29.8
Conventional vehicle	23.3	23.9	25.2	26.3	28.3
New energy vehicle	0.3	0.5	0.7	1.0	1.5
BEV	0.3	0.4	0.6	0.7	1.0
PHEV	0.1	0.1	0.2	0.3	0.5
Proportion(as % of total volume)					
Conventional vehicle	99%	98%	97%	96%	95%
NEV	1.4%	2.0%	2.8%	3.7%	5.1%
PHEV	1.1%	1.6%	2.2%	2.7%	3.5%
BEV	0.3%	0.4%	0.6%	1.0%	1.6%

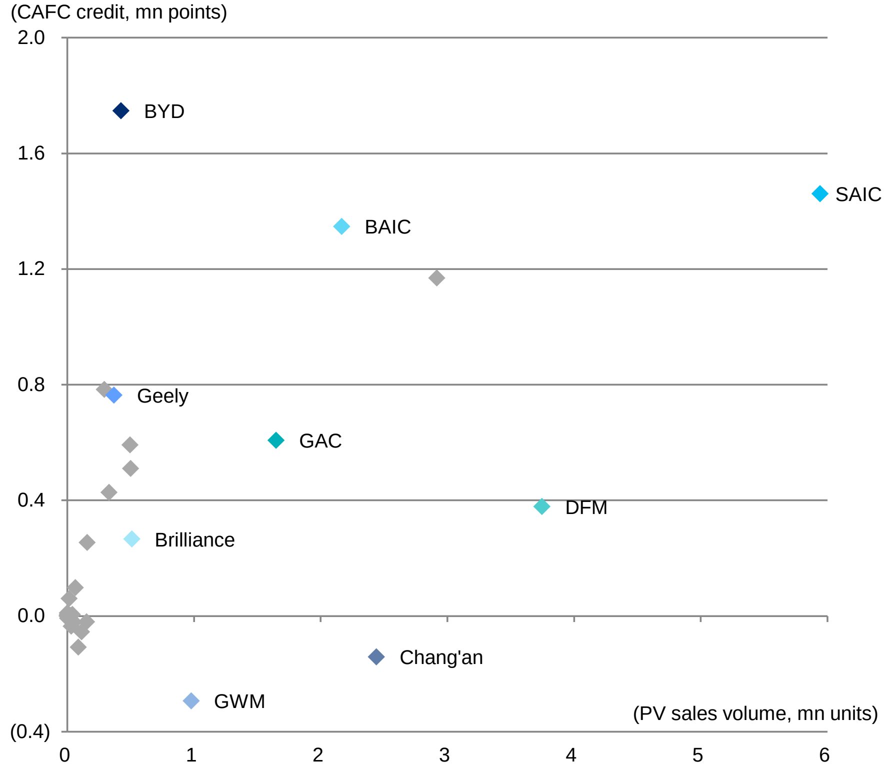
Source: Citi Research estimates

Intensified CAFC pressure under the industry's upsizing trend. According to MIIT's release and based on our calculation, among the 42 auto groups in China, 29% of them or 12 groups recorded a CAFC point deficit in 2016 (after considering intra-group point off-set), topped by GWM with -0.3m points and Changan with -0.1m points. Total negative CAFC balance for the industry was at -1.37m points, and after intra-group off-set at -0.7m points.

Top performers are BYD with +1.7m points, SAIC group with +1.5m points, and BAIC group with +1.4m points, followed by Geely and GAC group. For most of them, the high credit is thanks primarily to their engagement in NEV, which helped lower its CAFC (as BEV is considered to have 0 fuel consumption and have a multiplier impact of 5x/3x/2x in 2016–17/2018–19/2020 and PHEV's fuel consumption is also substantially lower than that of a gasoline vehicle with similar multiplier impact of 3.5x/2.5x/1.5x in 2016–17/2018–19/2020), especially given most of them recorded negative balance back in 2015.

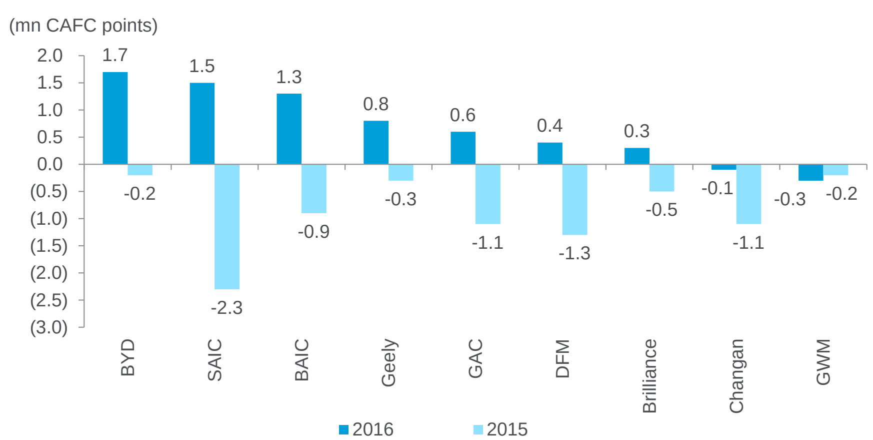
While CAFC credit is not a problem for most of the OEMs as of now, it is important to note that (1) when NEV credit assessment commences in 2019–20, a company that has no other way but to use NEV points to offset CAFC negative credit will face higher pressure in achieving the 10/12% NEV credit requirement, and (2) OEMs with abundant CAFC credit will have a much larger room to seize the vehicle upsizing trend in the coming few years (from class A or below to class B or above, and from sedan to SUV, as we discussed in the previous sections) to gain market share. In other words, we think NEV is not only essentially for the OEMs in meeting the NEV credit requirement, but also helpful in lowering the CAFC to give room for gasoline vehicle upsizing.

Figure 140. Comparison of CAFC Credit for Leading Auto OEM Groups vs. Others in 2016



Source: MIIT, Citi Research

Figure 141. CAFC Balance for Auto OEMs in 2016 vs. 2015



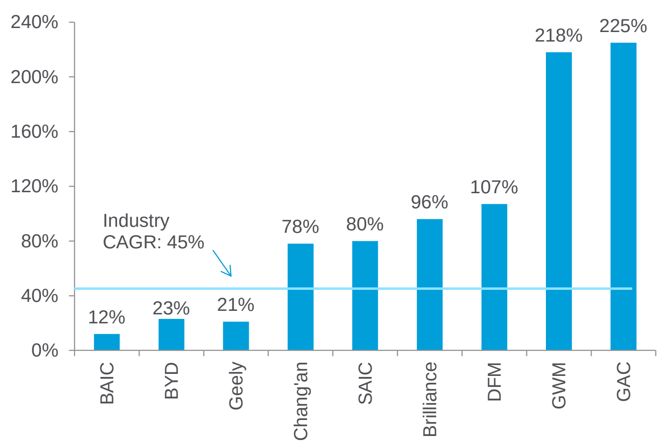
Source: MIIT, Citi Research

In addition to the sector top-down analysis on the dual credit system, in this section, we present a more detailed bottom-up analysis. Our core conclusion is that the NEV credit requirement, as stretched as it may seem, is easily achievable for the majority of the OEMs.

In conjunction with the core conclusion, given possible a NEV credit surplus in 2019/20E, we find that (1) BEV (that can earn as much as 5 points/ vehicle if the range is longer than 350km) is not a must, that our expectation for PHEV to surge faster than BEV in 2019–2020E is reasonable, and (2) should vehicle upsizing result in a negative CAFC balance (which will happen according to our estimation), NEV credit can offset it.

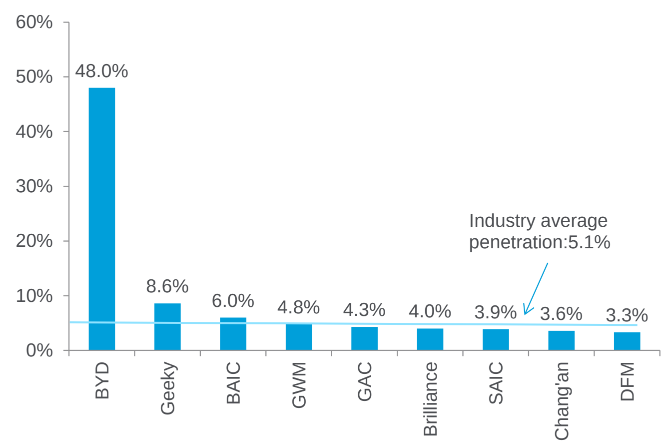
To measure each OEM's positioning, we assume a conservative case where OEMs either maintain their NEV volume proportion status quo or ramp up to a minimal level to meet the requirement. Under this methodology, the NEV volume CAGR for the OEMs will hugely diversify, ranging from 10% for BYD to over 200% for GAC and GWM. NEV's share of total vehicle sales ranges from 2.7% for DFM to 32% for BYD, after taking into account a different mix for BEV/PHEV. The majority of the OEMs can easily achieve the NEV point requirement by 2020E based on our forecasts, the volume of which is lower than some of the internal targets, according to news reports.

Figure 142. NEV Volume CAGR in 2017-20E for Major OEMs



Source: Citi Research estimates

Figure 143. NEV's Share of Total Vehicle Sales Volume in 2020E for Major OEMs (status quo or raised to meet the minimum credit requirement)



Source: Citi Research estimates

U.S.

U.S. Regulatory Landscape: Agnostic at the Core

Looking back historically at U.S. vehicle regulations highlights a proactive approach to achieving road safety and environmental benefits for all stakeholders involved. Regulations help these stakeholders by: setting standards for a vehicle to be considered road worthy (FMVSS); introduction of emission and fuel efficiency targets; and the passing of new safety requirements, to just name a few. A commonality across these regulations, from what we've noticed historically, is that they are structured to be agnostic from a technological perspective. This means that many different types of technology may be used to achieve the desired result.

Explanatory Example

Let's take rear-vision safety as an example. In 2007 the U.S. Congress passed legislation requiring vehicles to have rearward visibility – meant to detect areas behind the motor vehicle to reduce death and injury resulting from backing incidents, particularly incidents involving small children and disabled persons. The law stated that this may be achieved by the provision of additional mirrors, sensors, cameras, or other technology to expand the driver's field of view. This law was completely technology agnostic and as such OEMs were at liberty to use whatever technology they deemed most successful.

CAFE Standards

U.S. fuel efficiency regulations (CAFE standards) have been in a state of political flux as of late. Regulatory targets for 2022+, which were previously set following the mid-term review under the Obama administration, are now once again being reviewed by the current administration and it seems likely these will be rolled back.

The Impact on Propulsion Technology in the U.S.

However, we don't believe a scrapping or reduction in fuel efficiency targets really slows down the powertrain electrification (hybrids & EVs) push that OEMs have in place, in order to help them reach the prior or potentially new CAFE targets. In our discussions with suppliers we hear that OEMs simply aren't waiting for regulations to be set, rather they are proactively moving at electrified powertrains and other fuel efficiency technologies (i.e., lightweighting) in order to reach targets. This reinforces our prior comment on regulations being technology agnostic. In this instance we can see OEMs deploying different powertrain technology (more fuel efficient ICEs, hybrids, EVs) and other technologies. While some technologies, such as EVs, do offer greater flexibility based on MPG/range calculations (as it pertains to the vehicles footprint), we believe that this flexibility isn't primary driver of EV penetration/adoption here in the US. Rather, we believe that the driver of EV demand will stem more from consumer pull vs. a regulatory push

Japan

In 2015, Japan submitted an action plan ahead of the Paris Agreement which targeted a 26% reduction in greenhouse gas emissions relative to 2013 by 2030. As part of this it set a fuel efficiency target of 20.3km/L by 2020, compared with 17.0km/L in 2015.

The Japanese government has announced a number of policies to promote uptake of next-generation vehicles over the past several years.

2009 – Next-generation vehicles, including hybrids, are exempted from the acquisition and weight taxes (the latter is determined by vehicle weight) from 2009. The tax rate was decreased for traditional vehicles as well that meet stipulated emission reduction standards.

2010 – METI (Ministry of Economy, Trade and Industry) announces its "Next-generation Vehicles Strategy 2010", comprising six main policies (Figure 144).

Figure 144. Six Key Policies in the "Next-generation Vehicles Strategy 2010"

	Targets	Action Plan
Overall Plan	Next Gen vehicle development and production	Next gen vehicles account for up to 50% in 2020 Promote the use of various fuels Promote the siting of low-emission industries
Batteries	Secure battery technology by R&D	Improve performance of LiB Develop post-LiB Achieve economies of scale by promoting EVs
Rare Metals	Secure rare metals and build recycling systems	Strategically secure rare metals Develop batteries and motors free of rare metals Establish battery recycling system
Infrastructure	Install 2 million normal chargers and 5,000 quick chargers	Build infrastructure during market preparation phase Collaborate with the private sector for further penetration
Systems	systemize the vehicles	Establish new business model Verify the system in the social demonstration program Promote global standardization
Global Standards	strategic global standardization	Establish global standards for battery performance and safety level Set a global standards for charging connectors/systems Promote collaboration of public-private organization

Source: Citi Research.

2014 – The "Automobile Strategy 2014" shares similar goals to the "Next-generation Vehicles Strategy 2010," and added more detailed plans regarding the global market and further development of the market and industry. The country is aiming to increase the next-generation vehicle rate to 70%, compared with less than 30% as of 2015. We think this is an attainable target for HEVs in 2030. We note that BEVs and PHEVs were not broken out in the plan.

Figure 145. Next-generation Vehicles Promotion Plan in the "Automobile Strategy 2014"

	2015 (actual)	2020 (goal)	2030 (goal)
Traditional gasoline	73.5%	50~80%	30~50%
HEV	22.2%	20~30%	30~40%
BEV/PHEV	0.6%	15~20%	20~30%
FCV	0.01%	~1%	~3%
CDV	3.6%	~5%	5~10%

Source: METI, Citi Research.

2015 – METI allocates funds to EV-related projects: ¥30 billion for EV charging facilities (2014), ¥30 billion for EV purchase subsidies (2015), ¥2.5 billion for lithium-ion battery R&D (2015), and ¥3.1 billion for fundamental new battery research (2015).

Figure 146 shows what subsidies a buyer gets when purchasing different EV models. These amounts are not significant relative to the total price of the vehicle in question, so we do not think this will do a lot to stimulate EV uptake.

Figure 146. Subsidy Amount by Model

Category	Maker	Model	Subsidy ('000 Yen)	Subsidy ($, as of 1/19/2018)
BEV	Tesla	Model S/ ModelX	400	3,611
	Nissan	Leaf	228-400	2,058-3,611
	BMW	i3	390	3,521
	VW	e-golf	301	2,718
	Mitsubishi	i-MiEV	120-172	1,083-1,553
PHEV	Toyota	Prius PHV	200	1,806
	BMW	330e/530e/740e	200	1,806
	VW	Passat GTE	200	1,806
	Porche	Panamera4 E-hybrid	200	1,806
	Volvo	V90/XC60/XC90	200	1,806
FCV	Toyota	MIRAI	2,020	18,238
	Honda	CLARITY	2,080	18,779

Source: Citi Research.

FCVs are another category of next-generation vehicles that the Japanese government is interested in developing. The government targets FCV ownership of 40,000 units by 2020 and 800,000 by 2030, which looks a high hurdle. FCVs are more energy-efficient than EVs and do not need charging, and they also do not release any harmful emissions. Moreover, the government expects to generate synergies with fuel cell supply chain companies in Japan. On the other hand, the lack of hydrogen infrastructure is likely the biggest obstacle to FCV popularization. We think there is still a chance FCVs could gain market share if improvement in lithium-ion batteries and next-generation batteries take longer than expected (or their efficiency reaches its limits).

Japan is not the one of the most aggressive participants in BEV market. The government does have a plan for BEV promotion, but it lacks teeth. We think Toyota, one of the world's largest automakers, may be one reason for this. The Toyota Prius is the most successful HEV, having sold more than 10 million units worldwide (and cut a total of 77 million MT of carbon dioxide emissions thus far). There seems little motivation to promote BEVs, due to Toyota's dominant position in HEVs.

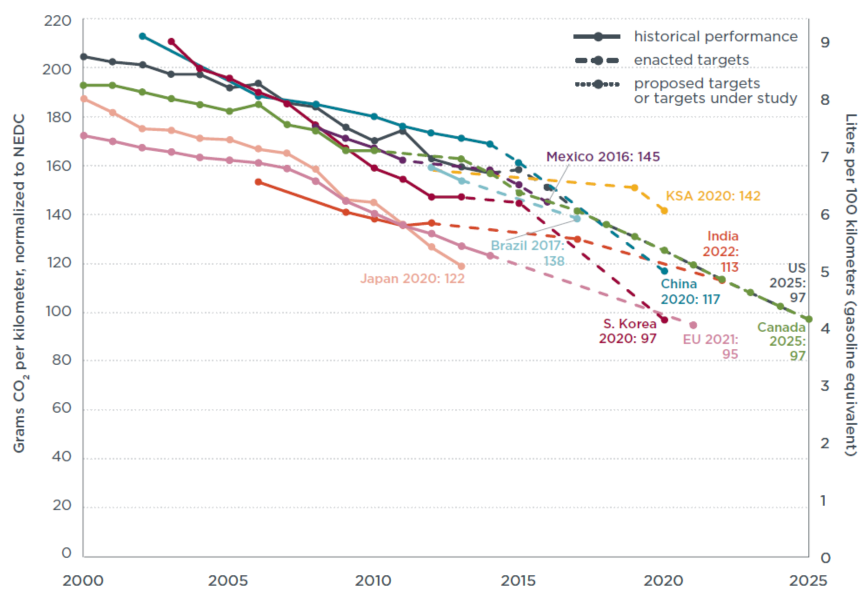
Rest of World

Korea: No Exception for Car Electrification via Stringent Regulations

Just as in other countries, Korea is setting more stringent standards for fuel-efficiency and gas-emissions; automakers in Korea (for their domestic sales) should improve average fuel-economy to 24.3km / liter by 2020 (from 17km/ liter in 2015), while CO_2 emission standards will be tightened to 97g/ km by 2020 (from 140g/ km in 2015). That said, the Korean government has introduced various subsidy programs in order to stimulate demand for NEV or xEV; both national and local governments provide subsidies in the form of tax-benefits and cash incentives.

Figure 147. Fuel-Efficiency Standards in Key Markets

Region	Fuel economy Standard
Europe	Fuel efficiency 17.9km/l, CO_2 emission 130g/km by 2015
	Fuel efficiency 24.4km/l, CO_2 emission 95g/km by 2020
U.S.	Fuel efficiency 15.1km/l, CO_2 emission 155g/km by 2016
	Fuel efficiency 23.2km/l, CO_2 emission 97g/km by 2025
China	Fuel efficiency 14.5km/l, CO_2 emission 161g/km by 2015
	Fuel efficiency 20km/l, CO_2 emission 117g/km by 2020
Japan	Fuel efficiency 16.8km/l, CO_2 emission 130g/km by 2015
	Fuel efficiency 17.9km/l, CO_2 emission 122g/km by 2020
Korea	Fuel efficiency 17km/l, CO_2 emission 140g/km by 2015
	Fuel efficiency 24.3km/l, CO_2 emission 97g/km by 2020



Source: ICCT, Citi Research

Figure 148. Korea: Government Subsidies for NEV

Frequency	Area	Tax/ fee Type	Regular Tax	Incentive for BEV
One Time	National	Individual consumption (a)	5% of vehicle base price	Max W2mn reduction
		Education (b)	30% of base price	Max W0.6mn reduction
		VAT	10% of (base price+a+b)	n.a.
	Local	Acquisition	7% of (base price+a+b)	Max W1.2mn reduction
		Public Bond	9-20% of (base price+a+b)	Max W0.7mn reduction
Annual	Local	Vehicle	KRW80-200/cc	Exempt
		Education	30% of annual vehicle tax	Exempt

*BEV: Battery Electric Vehicles

Source: MOLIT, Citi Research

Appendix 5

Product Pipeline by Manufacturer

Figure 149. Germany's 'Big Three' BEV Product Pipeline by Segment

	A Segment	B Segment	C Segment and above	SUV	Unclassified
BMW			i8 (2022) 3 Series (2020) I5 (2021) iNext (2021)	X3 (2019)	Other (2020)
Mini		Mini One (2019)			
Rolls Royce			Phantom (2020) Ghost (2021)		
BMW Group 2021e BEV Volumes	-	11,656 (18%)		9,689 (15%)	3,638 (6%)
Mercedes		EQ A (2020)	EQ D Sedan (2019) EQ E Sedan (2019) EQ F Sedan (2021) EQ C (2022)	EQ D SUV (2018) EQ E SUV (2019) EQ C SUV (2022) EQ F SUV (2021)	Other (2020)
Smart		Smart forfour (2018) Smart BSUV (2022)			
Daimler 2021e BEV Volumes	15,094 (16%)	19,535 (21%)	24,528 (26%)	22,873 (24%)	11,856 (13%)
Audi		Q2 (2019)	A9 E-Tron (2020) Compact EV (2020) A5 (2021) R8 (2021)	Q E-Tron (2018) Q5 BEV (2021) Q6 BEV (2018) D SUV (2021) & D SUV Sportback (2022) Q8 BEV (2022)	Other (2019)
Bentley			Other (2020) Speed 6e (2022)	Bentley SUV (2021) Bentayga (2022)	
Lamborghini				Urus (2022)	
Porsche			Mission E (2019)	D-SUV (2021) Macan (2021)	Other (2020)
Seat	Mii (2019)		SUV EV (2020) Compact EV (2021)		Other (2020)
Skoda	Citigo (2019)		Octavia (2019) Coupe SUV (2020) Compact EV (2021)		Other (2020)
VW Brand			Golf (2018) New Bora (2018) ID (2019) Lavida (2020) ID AEROe (2021) T-Roc (2021)	I.D. Crozz (2020) I.D. Lounge (2021) X BEV (2021)	Other (2019)
VW Group 2021e BEV Volumes	10,385 (2%)	1,477 (0%)	179,867 (41%)	85,796 (20%)	160,040 (37%)

Source: Citi Research, LMC

Figure 150. PSA and Renault BEV Product Pipeline by Segment

	A Segment	B Segment	C Segment and above	SUV	Unclassified
Citroen		C3 (2020)	C4 Cactus (2021)		Other (2019)
DS		DS3 SUV (2019)	DS7 Crossback (2021)		Other (2020)
Opel		City EV (2021) Corsa (2019)			Other (2020)
Peugeot		208 (2019) 2008 (2020)			Other (2020)
PSA Group 2021e BEV Volumes	2,683 (4%)	45,848 (71%)	9,174 (14%)	-	6,420 (10%)
Dacia		Duster (2022)	LE (2019)		Other (2019)
Infiniti			LE (2019) Infiniti EV (2021)		Other (2019)
Mitsubishi	eK Wagon (2020)	Xpander (2022)	SUV EV (2020)	ASX (2019)	
Nissan	DAYZ (2020)		SUV EV (2020)		Other (2019)
Renault	Zoe (2019) Kwid (2020)		SUV EV (2020)		Other (2020)
Renault-Nissan 2021e BEV Volumes	38,636 (16%)	7,172 (3%)	129,043 (54%)	2,245 (1%)	63,853 (27%)

Source: Citi Research, LMC

Figure 151. U.S. Manufacturers BEV Product Pipeline by Segment

	A Segment	B Segment	C Segment and above	SUV	Unclassified
Ford		Small SUV (2020)	C-SUV (2020) Focus (2020)		Other (2021)
Ford 2021e BEV Volumes	-	4,195 (13%)	21,042 (67%)	-	5,962 (19%)
Buick		Encore (2019)	Compact MPV (2019) Midsize Car (2019)		Other (2020)
Cadillac			XT4 (2020)		
Chevrolet		Bolt (2020)			Other (2020)
GM 2021e BEV Volumes	-	41,139 (41%)	11,092 (11%)	-	47,120 (47%)
Tesla			Model 3 (2018) Model Y (2020) Roadster (2020)	Model X (2018)	
Tesla 2021e BEV Volumes	-	-	210,547 (86%)	33,265 (14%)	-

Source: Citi Research, LMC

Figure 152. Japanese Manufacturers BEV Product Pipeline by Segment

	A Segment	B Segment	C Segment and above	SUV	Unclassified
Honda		DF HR-V (2018) Fit/Jazz (2020)	Clarity (2018) Urban EV (2019) Sports EV (2020)		Other (2020)
Honda 2021 BEV Volumes	-	11,997 (14%)	32,973 (38%)	-	41,652 (48%)
Genesis			Compact EV (2022) G80 (2020)		Other (2021)
Hyundai		Kona (2018)	Elantra/Avante (2020)		Other (2020)
Kia		Stonic (2019)	Niro (2018) K3 (2020)		Other (2019)
Hyundai Group 2021e BEV Volumes	-	32,384 (21%)	32,973 (38%)	-	41,652 (48%)

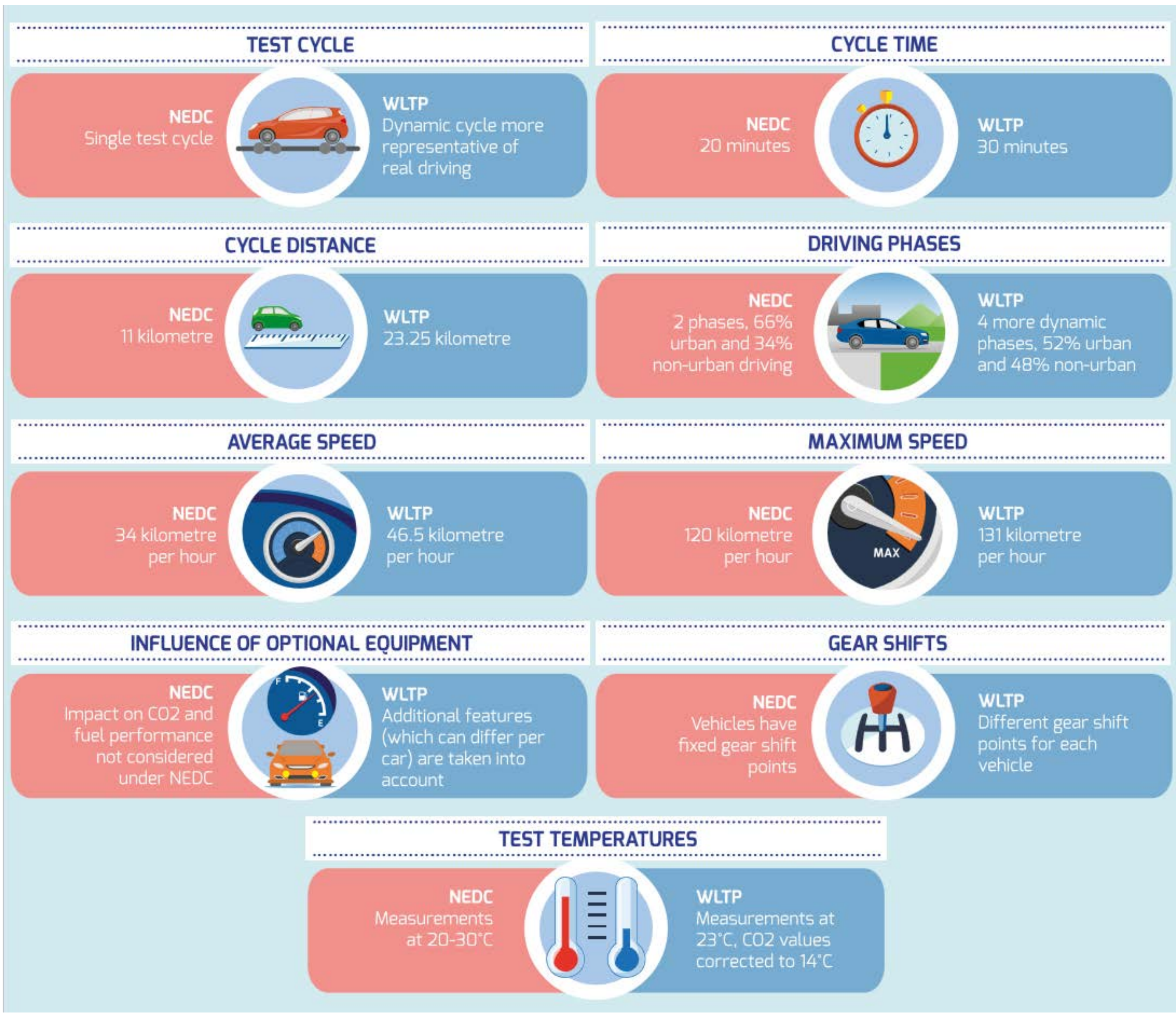
Source: Citi Research, LMC

Appendix 6

Navigating the Shift from NEDC to WLTP

The existing lab-test for vehicles, NEDC (New European Driving Cycle), which was designed in the 1980s, was superseded by a new test; namely WLTP (Worldwide-harmonized Light-vehicle Test Procedure) in September 2017. The rationale for the move to WLTP was the previous test was seen as outdated, given it had not evolved with the technological advancement of vehicles. WLTP provides a more accurate representation of vehicle emissions and fuel-efficiency.

Figure 153. Summary of What Changes from NEDC to WLTP



Source: wltpfacts.eu

Timeline for Transition from NEDC to WLTP

The new test will be enforced gradually; it started with all 'new-type' cars (i.e. newly introduced models) that were tested as of September 2017. From September 2018 WLTP will apply to all newly registered cars (i.e., cars physically on the road). Until the end of 2018, the NEDC-CO_2 value will be used to calculate the tax-band for the vehicle, however from the January 1, 2019 all cars in dealerships will quote WLTP-CO_2 values (there will be a year's grace for outgoing models i.e. those approved under the NEDC test). **It is worth noting the CO_2 targets for 2021 will continue to be based on the NEDC test.** Given the increased rigor of the WLTP test it will result in a higher CO_2 emission figure than under NEDC (c15% more as a rule-of-thumb).

Real Driving Emissions Testing Is Also Being Conducted

On top of the change from NEDC to WLTP, an additional test, RDE (Real Driving Emissions), was implemented from September 2017. This does exactly what it says on the tin; that is to measure car emissions/ pollutants (e.g. NOx) of a car when driven on a road. The automotive industry has come under increased scrutiny in recent years, this heightened after VW's use of 'cheating-devices' came to light in September 2015, and the objective of RDE is to ensure vehicles are as efficient in real-driving conditions (i.e. on the road) as when being tested in a lab. An RDE test uses a 'portable emissions measurement system' (PEMS), which is attached to the vehicle during an on-road test. As of September 2017, all new car models must comply with a 'not to exceed' (NTE) limit of 2.1x permissible NOx emissions (which under Euro 6 is 80mg/km). From September 2019 the same conformity factor (2.1x) will apply to all newly registered vehicles. The conformity factor reduces to 1.5x from January 2021 on all newly registered vehicles.

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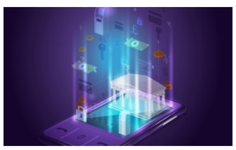

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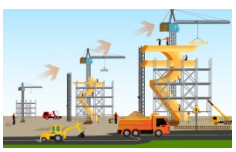

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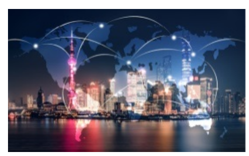

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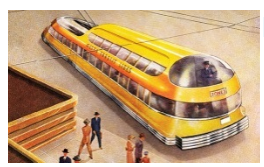

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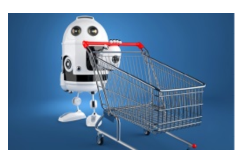

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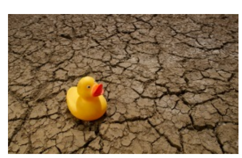

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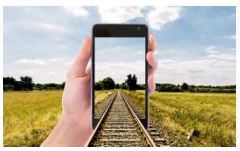

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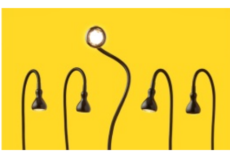

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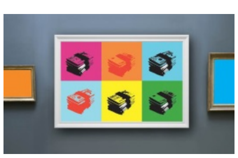

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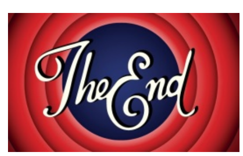

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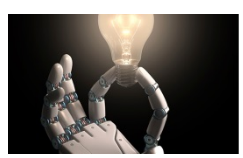

Disruptive Innovations III
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IMPORTANT DISCLOSURES

NOW / NEXT

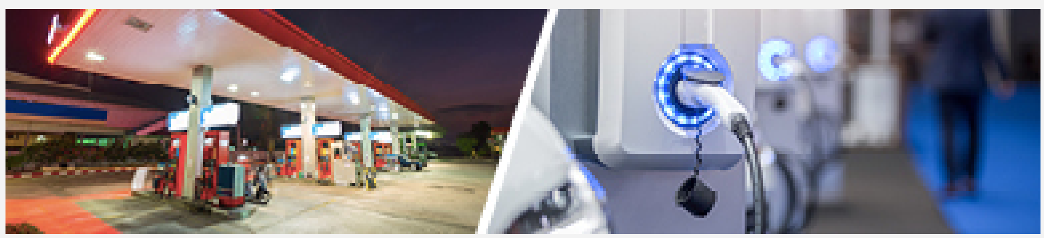
Key Insights regarding the future of Electric Vehicles

REGULATION

In the near term, we expect EV demand to be largely propelled by a combination of regulatory and government incentives to force auto manufacturers to comply with emission targets. / Regulation to reduce CO_2 emissions continue to evolve and will be a driving force behind OEM R&D and capital decisions going forward.

INFRASTRUCTURE

Charging infrastructure is consistently seen as a barrier to broader adoption of EVs as the availability of public charge points for EVs still significantly lags. / Global charging points are expected to rise to 13 million units in 2020 from just 2 million in 2020, a 51% CAGR.



TECHNOLOGY

Battery degradation continues to weigh on consumer confidence while battery costs continue to weigh on vehicle range ad total cost of ownership. / Battery costs are continuing to fall and solid-state batteries are a leading candidate for mainstream next-generation battery technology.