Electric Vehicles in Europe - 2016

Approaching adolescence

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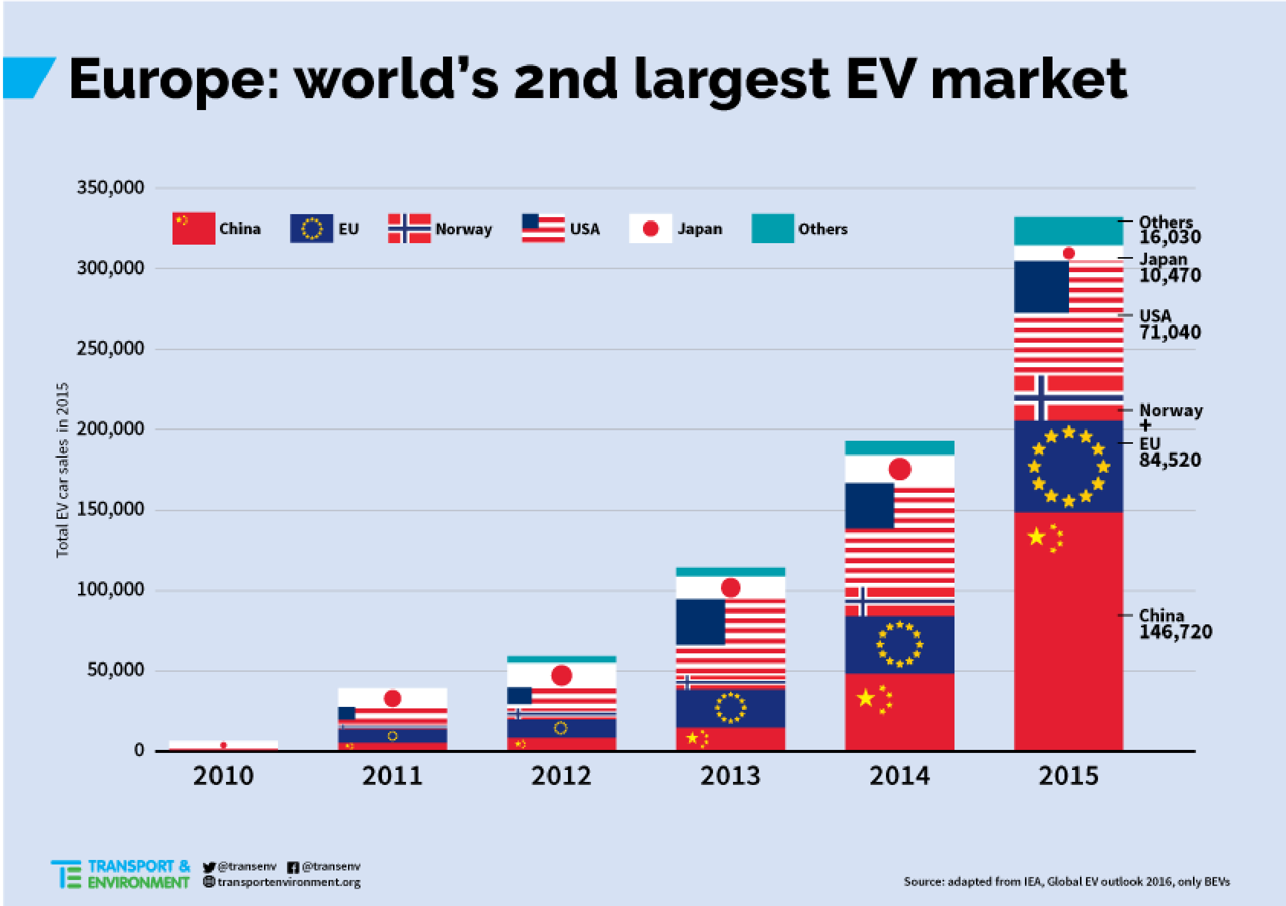
Executive Summary

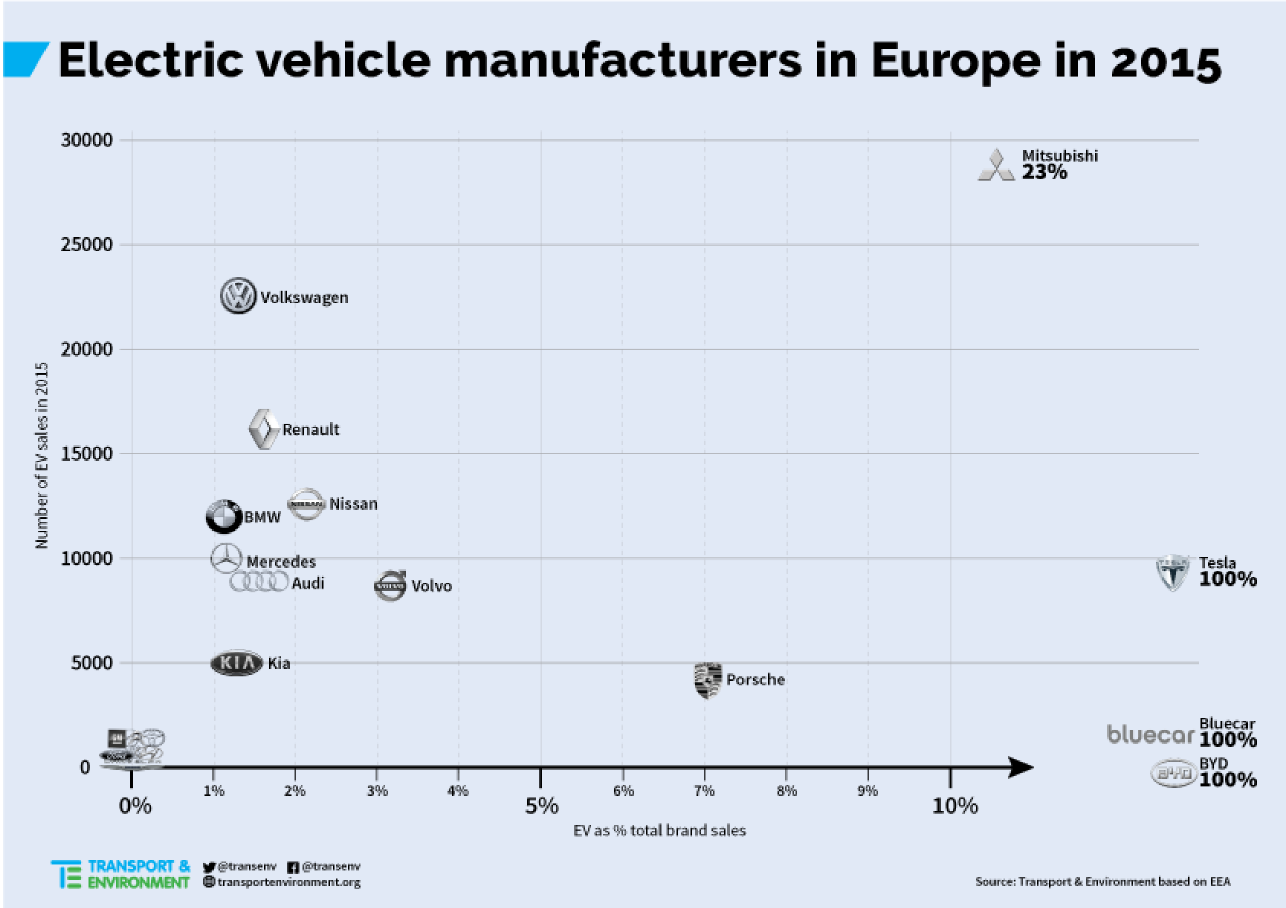
Electro-mobility offers an unequalled solution to make Europe's transport more efficient and less polluting. But the market for electric vehicles (EVs - both battery and plug-in hybrids) has had several false dawns. Finally in 2015, sales of electric cars reached the important milestone of a 1% market share. Overall electric car sales doubled in 2015 to at least 144,000. The most recent data in 2016 suggests further growth in 2016. Sales year to date suggest significantly more than 200,000 plug-in vehicles will be sold in Europe this year taking the total number of EVs on the road to more than 500,000.

Europe is the world's second biggest market, aided by strong sales in Norway and the Netherlands. But there is no single market for electric cars in Europe, with virtually no sales or recharging infrastructure in most EU countries because policy and political support is lacking. This needs to change if Europe is to become a leader in electromobility and in particular compete with China.

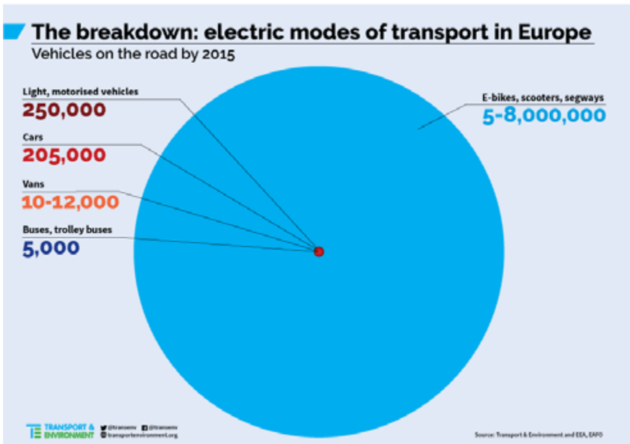


With the notable exception of Nissan-Renault, the world's biggest producer of electric cars, and Mitsubishi the dominant supplier of plug-in hybrid vehicles in Europe, most European carmakers have until recently been keen to talk down the prospects for electric cars and vans. This is now changing with a raft of recent new announcements including at the 2016 Paris Motor Show. This paradigm shift is underpinned by a rapidly falling price and improving performance of batteries that suggests by the mid-2020s the lease price for battery and conventional vehicles will be similar.

Contrary to rhetoric, the shift to EVs need not lead to the destruction of value in the European automotive industry with batteries imported from the Far East or the US. Instead, there are a number of planned new production facilities in Germany, Hungary and Poland; whilst research indicates the transition will create 0.5-1 million jobs.



However, there remains a serious lack of choice in the electric vehicle market particularly for vans. This grossly neglected market is one rich in opportunities, particularly for city deliveries. The European Commission must act, and the forthcoming car and van CO_2 regulations provides the opportunity to encourage manufacturers to supply new models and build choice for customers through the adoption of a California-style ultra-low carbon vehicle target for all manufacturers.



Electric cars and vans are part of a much wider electromobility revolution. Light electric vehicles offer an alternative vehicle for short trips for individuals, but remain largely ignored by policy makers. Even more important are the growing numbers of electric bikes and scooters that make it easier for longer distance commuting than conventional pedal cycles.

Electromobility including electric trains and trams provides the opportunity for a clean, green mobility future that assigns dirty diesel cars and trains that choke cities and commuters to the dustbin of obsolescence. The outstanding question is not if, but how quickly the disruption occurs and to what extent Europe captures the economic opportunities from this shift. Electric vehicles are in their adolescents, and about to be highly disruptive. Through constructive policy interventions at an EU, national and local level the technology and market can quickly mature and our mobility become quieter, cleaner and its contribution to climate change drastically reduced.

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1. Introduction

Electro-mobility offers an unequalled solution to make Europe's transport more efficient and less polluting. The electrification of transport is needed to realise the Energy Union's aim to "decarbonise … road … and rail transport" (Energy Union package 2015)[1], in addition to improving noise levels and air quality in urban areas where this is a chronic problem. In a recent communication, the European Commission (EC) stated that "*Emissions from conventional combustion engines will need to further reduce after 2020. Zero- and low emission vehicles will need to be deployed and gain significant market share by 2030.*"[2] The EC has confirmed their intention to set post-2020 CO_2 standards for cars and vans in the mid of the next decade, as well to investigate ways to incentivise low and zero-emissions vehicle technology, such as electrified powertrains and hydrogen.

Zero-emission at tailpipe, Electric vehicles offer a double benefit of tackling air quality problems and climate change. Whilst there are still ways to improve and optimisation the internal combustion engine this is becoming increasingly cost-intensive for car makers and likely to have reached its practical limit by the mid-2020s. First generation, food based, biofuels have been shown to have minimal or no greenhouse gas benefits when the full lifecycle is calculated including the effects of indirect land use change.[3] Advanced biofuels and power to liquids or gas solutions are technically immature, expensive and unable to meet the large demand for liquid fuels from cars (but may play in a role in decarbonising aviation, shipping or trucks). Natural gas is a fossil fuel and bio-methane from waste only available for niche markets. It is therefore electromobility that is required to decarbonise passenger cars from around 2025 onwards.

As prices for renewable electricity are falling, a European EV market shifts the energy supply from imported, politically instable, fossil fuels to domestically sourced, secure, clean and cheaper sources. Half of the European power mix is already decarbonized today and by 2030 this will be the case for about 75 percent of the generation.

Economic benefits of vehicle electrification are substantial for customers and the economy: For example, the owner of an average new car in 2020 will save around €300 to €400 on fuel each year compared to an owner of an average 2010-manufactured car. The transport sector is the biggest driver of oil demand at EU level – two-thirds of final demand for oil comes from transport, and this amount has been increasing. In 2015, a year of historically low oil prices, total spending on crude oil imports in the EU was €187 billion. Russia accounts for 30% of our oil imports, while often geopolitically unstable regions in Africa and Middle East account for an additional 31%. The shift from fossil to hybrid and electric vehicles would allow Europe to save €47 billion by 2030 on imported crude oil or oil products.[4]

Analysing recent market developments, this report shows why sustainable electro-mobility is the most promising medium term option for most European passenger transport and local freight distribution and

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[1] European Commission 2015, Energy Union package, COM(2015) 80 final, p.24 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2015%3A80%3AFIN

[2] Brussels, 20.7.2016, COM(2016) 501 final, A European Strategy for Low-Emission Mobility

[3] https://www.transportenvironment.org/publications/globiom-basis-biofuel-policy-post-2020

[4] European Climate Foundation, Fuelling Europe's Future, http://www.camecon.com/Libraries/Downloadable_Files/Fuelling_Europe_s_Future-_How_auto_innovation_leads_to_EU_jobs.sflb.ashx

explains what Europe needs to do to accelerate the shift towards a single market for electric vehicles in Europe.

2. Scope and Definitions

What is an Electric Vehicle?

This report focuses on cars (certified in the EU as category M1 vehicles) but also covers sales of vans (certified as category N1) and smaller electric quadricycles, scooters etc. (L call vehicles). We define the following types of electric vehicles:

- ***Battery Electric Vehicles (BEVs)*** are 'pure' electric vehicles in that all of their power is derived from mains electricity, supplied to an on-board battery which then drives an electric motor(s). These vehicles produce zero emissions at the point of use, although they will still give rise to emissions in a well to wheel perspective if the power that they use comes all or in part from fossil-fuelled power plants, as well as over their lifetime when battery and material production and recycling is taken into account.
- ***Plug-in Hybrids (PHEVs)*** are also powered primarily by electricity and can operate in an 'all-electric' mode similar to a BEV, but in addition they have a small conventional internal combustion engine (ICE) which is used to enhance their performance or extend the available range of the vehicle between charges, or both. These vehicles do produce emissions of CO_2 and other pollutants while the ICE is in operation, but generally at a low level (with CO_2 emissions typically of less than 50g/km on the official test).
- **Range-extender electric vehicles (REEVs)**, of which the BMW i3 is currently the most popular example, are primarily powered by a battery-electric motor, but also have a small conventional internal combustion engine and fuel tank. Typically the latter are used purely to top up the battery to give greater range between electric charges, and does not drive the wheels directly.
- A **hydrogen fuel cell electric vehicle (FCEV)** is also a form of EV as it is powered by an electric motor, although it does not derive its power from mains electricity. However in 2015 sales of FCEVs remained negligible. The costs of FCEVs remains significantly higher than BEV & PHEV models and cost forecasts suggest FCEVs will be unable to close this gap before 2030. By this time T&E believe the BEV will be a mature and cost-effective technology and vehicles have a sufficient range to offset the benefits of FCEV technology. T&E will keep the issue under review but for the present consider BEV and PHEV to be on the cusp of a technology and market breakthrough unlike FCEVs.

Note that other types of 'milder' non-plug-in hybrids, which derive their motive power exclusively from petrol or diesel fuel but use an auxiliary electric motor to enhance efficiency or performance (such as the original Toyota Prius), are not considered as EVs for the purpose of this report.

Category L Vehicles

Category L is the EU definition for a wide range of light motorised vehicles that fall below the threshold for light passenger or goods vehicles in categories M or N. Historically most vehicles in the category have had only two wheels - traditional motorbikes, scooters or mopeds. Recently, there has been a proliferating range of novel forms of light vehicles with two, three or four wheels. These range from the largest powered bicycles (although most remain in the separate e-bike category discussed below) up to large motorcycles and quite substantial four-wheeled vehicles. Some of the largest in class are four-wheelers ("heavy" quadricycles in Category L7) up to 400 kg in weight (or 550 kg for vehicles intended for carrying goods)[5].

Most vehicles in Category L are designed primarily as lightweight passenger vehicles, but a few are intended to carry goods, and these are now developing to offer important new applications for local deliveries and maintenance in urban areas.

Many of these subcategories are becoming increasingly popular around the world, as they offer a substantial part of the functionality of a fully-fledged car or light van, but at a much lower cost and with a far smaller footprint. Electric versions are also becoming increasingly widespread and popular. Owing to their lightweight and light duty cycles, these small vehicles are easy to build with electric power units, and the smallest do not even require the most sophisticated and expensive types of battery. These offer huge environmental benefits by comparison to conventional two-wheelers with engines in terms of CO_2, air quality and noise.

Approximately 20,000 Category LEVs were sold in 2012 in the EU, as against 22,700 in Category M1, illustrating that sales of EVs in these two categories are of a broadly similar magnitude. Since then sales of cars have grown rapidly but those of L class vehicles have been far more modest as policy has not incentivised their purchase of use.

Scooters, e-bikes etc.

Category L specifically excludes electrically-assisted pedal cycles (EAPCs or e-bikes) and kick-scooters, self-balancing vehicles such as Segways, and electric mobility scooters intended for use by mobility-impaired people. These remain in a separate category. Again, electric versions of many of these vehicles are now commonly available, either to substitute for human 'pedal power' or to supplement it for greater speed, longer journeys, or extra help with steep hills. These are collectively referred to as LEVs (light electric vehicles) to distinguish them from the larger Light Duty Vehicles that are the main subject of this report.

In contrast to the larger classes of vehicle, around 854,000 e-bikes were estimated to be sold across Europe in 2012, with more than 400,000 in Germany alone. However, with an import level of 550,000 units the true figure may be even higher, at well over a million Europe-wide. The numbers also appear to be increasing over time. The graphic below illustrates the relative magnitude of the stock of electric e-bikes and other LEVs in Europe by comparison to the larger EVs in categories L, M, and N. These small vehicles are actually far more numerous than the Category L, M and N EVs that are the main subject of this report – as the graphic above illustrates.

Electromobility is not therefore limited to electric cars but encompasses a much wider range of electrically powered vehicles - including trains and trams.

[5] These limits exclude the weight of the batteries in the case of electric-powered vehicles, giving these vehicles an important technical advantage.

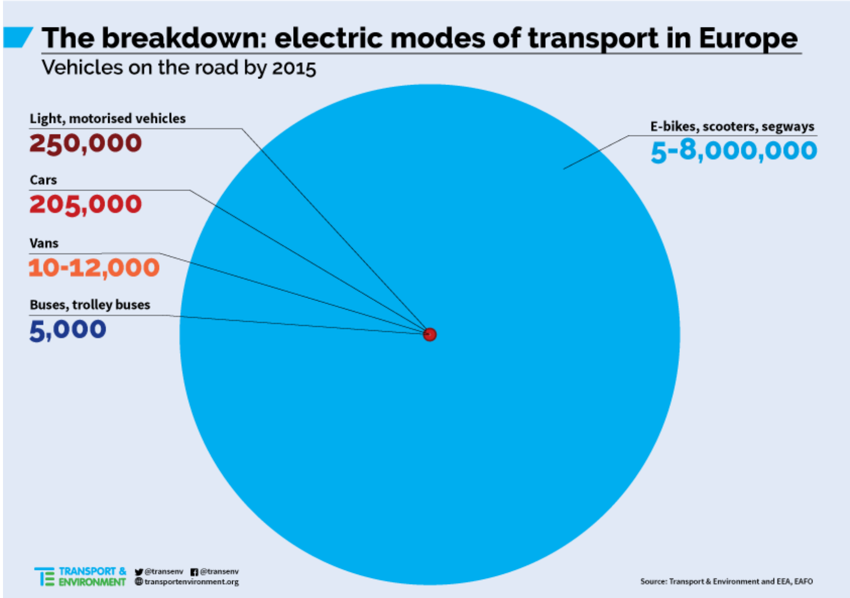

Figure 1: Estimated size of e-vehicle fleets in the EU

How many LEVs are there in Europe?

The only sensible answers to this question are "definitely several million" and "we don't really know with any accuracy". This is because the market for LEVs is large, varied, fragmented and poorly regulated. Also, a large proportion of the LEVs sold (especially the cheaper ones) are imported, making them more difficult to track. In order to improve this important market and our understanding of it, we argue that three key developments are urgently needed:

- Better basic standards to ensure the safety and integrity of LEV electrical and mechanical systems, which will allow the market to work better and consumers to have greater confidence in the quality of all LEVs sold;
- Labelling and enforcement to reinforce these standards;
- Establishment of a simple market surveillance system to allow us to better understand the scale of annual sales, and the basic types and country of origin of the vehicles sold.
- Reform of Type approval system to simplify the market access for innovative vehicles in the segment and lower prices to accelerate sales

Heavy Duty Vehicles

The weight, price and performance of batteries currently make these unrealistic for most of the larger vehicles such as large vans and trucks (Categories N2 and N3). However, solutions to decarbonise heavy duty vehicles (HDVs) are urgently needed as emissions increased by 36% between 1990 and 2010 and continue to grow with HDVs currently representing around 30% of all road transport CO_2 emissions, a figure that is expected to grow to 40% by 2030[6].

[6] https://www.transportenvironment.org/publications/too-big-ignore-%E2%80%93-truck-co2-emissions-2030

Although at an earlier stage of market development truck makers and technology companies are now investing in electric solutions such as Siemens and Scania that are testing electric trucks with catenary lines on highways[7]. Tesla, envisages moving into heavy duty trucks and high passenger-density urban transport once it has consolidated its position in the passenger car market. Renault Trucks has developed and is testing electric trucks for urban and interurban logistics as well as electric waste collection trucks[8]. Nissan launched an electric truck concept in 2012. With increasing access restrictions to diesel vans and trucks in cities, electric vehicles are seen as a significant new market opportunity made possible through advances in battery technology particularly where loads are not heavy and distances are limited to a defined urban delivery circuit of up to 150km per day.

Electric version of some municipal applications, such as waste collection vehicles, are also being tested. However, it is buses where electric solutions are being adopted most quickly offering clean, quiet operation in city centres in particular. Most established models still come from the Far East (notably BYD), but low-carbon bus initiatives are now also emerging in Europe, for example by bus makers such as VDL and Solaris. With charging possible through in-road induction or cables at the end of the route battery sizes and costs can be limited. By 2016, 556 battery, fuel cell and PHEV buses are running in European cities, and another 4493 trolley buses equipped with a combustion engine if not running electrically.[9]

Electric vehicle sales in Europe in 2015

A note on data quality

Data on sales of electric cars and vans presented in this section is derived primarily from data collated by the European Environment Agency's provisional 2015 CO_2 registration database. The provisional car and van sales data have been collated by the European Environment Agency from data supplied by national administrations responsible for car registrations in each of the 28 Member States. At the time of writing these data are under review by carmakers, and could therefore change as a result.

Whilst sales figures for the total car or van data figures contains a low proportion of errors and makes no significant impact upon the final trends and analysis, the EV sales have many fewer data points, so that errors or omissions have more influence on the results. In fact, analysis has shown that there is a serious anomaly in the raw data that needs to be addressed. This could potentially affect the calculation of supercredits given to ULCVs.

Estimates for sales from years prior to 2015 have been aligned with the detailed reconciliation exercise undertaken by the Joint Research Council (JRC) in 2015. The JRC report highlights the challenges of estimating sales of EVs. For example, the names of novel vehicle models are

[7] https://www.scania.com/group/en/worlds-first-electric-road-opens-in-sweden/

[8] see for example http://corporate.renault-trucks.com/en/press-releases/2013-12-09-the-maxity-electric-vehicle-equipped-with-a-small-residential.html and http://www.nissan-global.com/EN/NEWS/2011/_STORY/111025-01-e.html

[9] http://www.eafo.eu/vehicle-statistics/buses/cities

sometimes miscoded. In particular, it appears that significant numbers of non-plug-in hybrids (which are outside the scope of this report) are wrongly coded.

As a result, the EEA initially estimated that approximately 1.3% of all new cars sold in the EU were electric in 2015, corresponding to somewhere between 171,000 and 185,000 vehicles. However, this figure appears significantly too high. In contrast, the manufacturers' association ACEA gives an estimate of 146,000, while our own careful screening of the EEA database gives a robust lower bound estimate of just under 145,000 - only slightly below the ACEA figure and representing just over 1% of EU car sales.

Trajectory of sales 2010-2015

In terms of the total number of electric cars sold, there is a constant **and strong upward trend, with sales more than doubling to at least 144,000 in 2015**. This is the largest increase in total for any year to date, and compensates for a relatively modest rise in 2014.

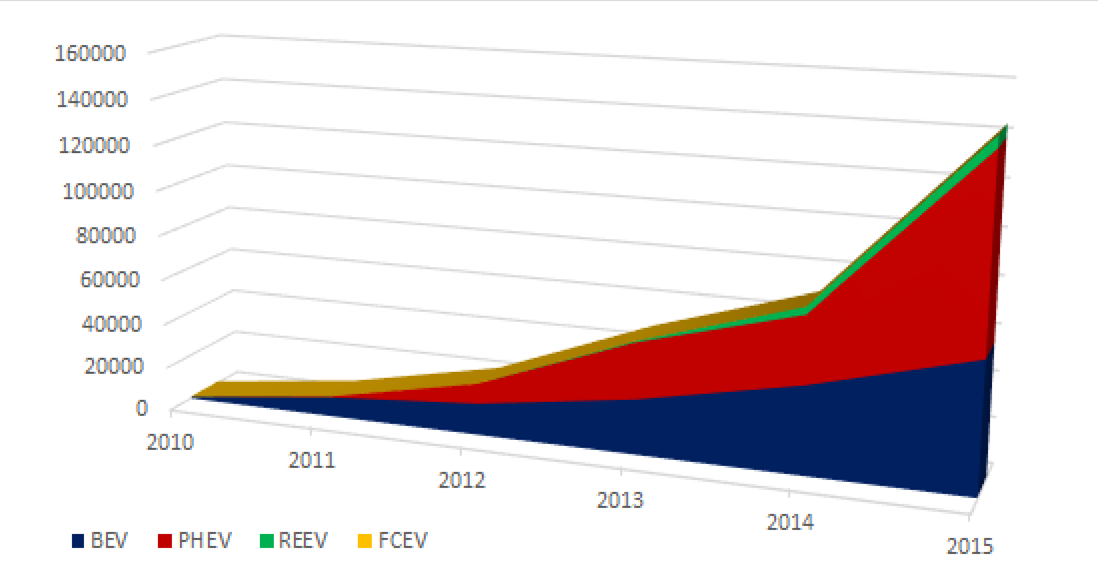

Figure 2: EV sales per year in the EU

Analysis of cumulative sales in the EU plus EFTA (Norway and Switzerland) suggests that by the end of 2016 there will have been approaching 600,000 plug-in cars sold in Europe. This is based upon ACEA data for the EFTA region and for 2016 combined with the information from the European Environment Agency. T&E has projected that sales in the second half of 2016 will be 20% higher than in 2015 (and this is likely to be a conservative estimate). Even accounting for some cars being removed from the road by the end of 2016 there will be significantly more than 500 thousand electric cars on Europe's roads.

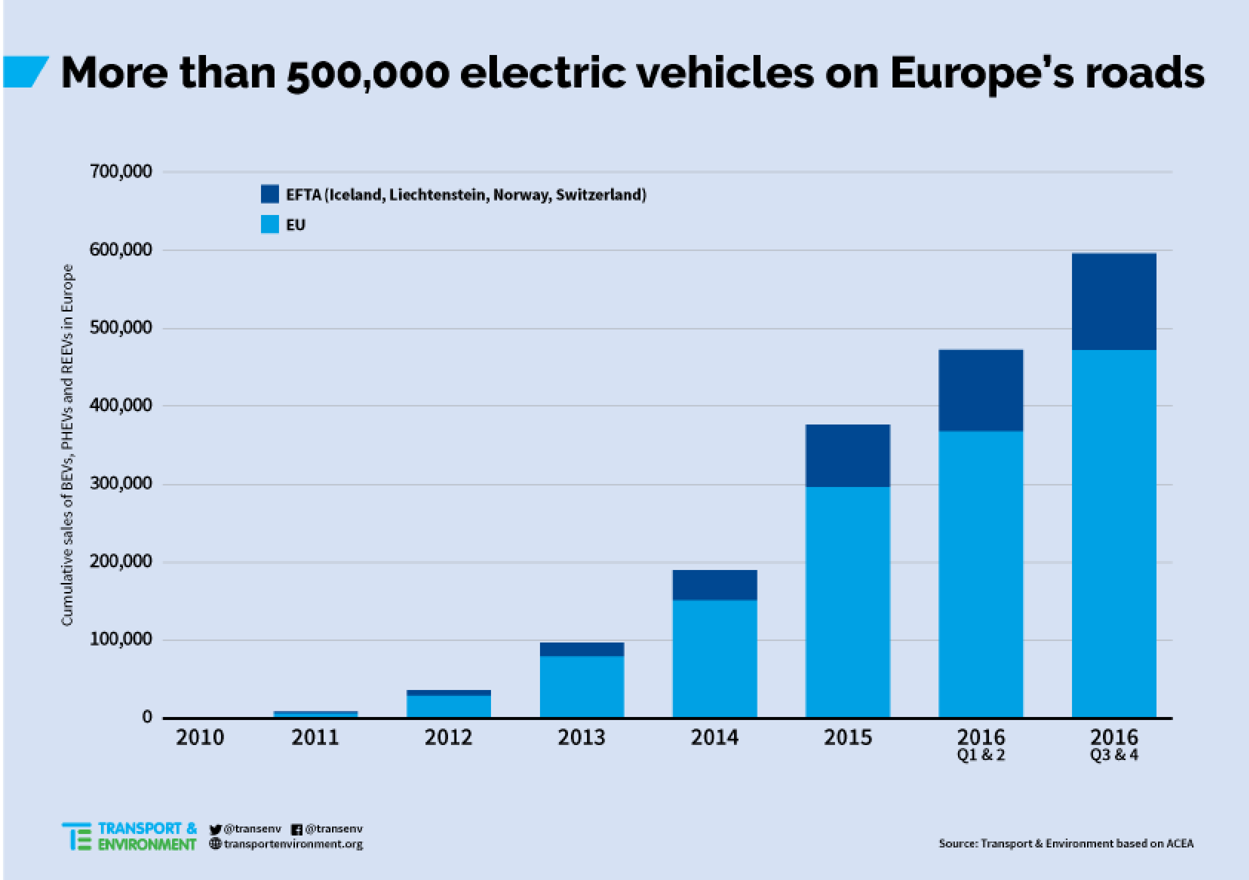

Figure 3: Cumulative sales of plug-in cars in Europe (BEV, PHEV and REEV), source: T&E based on ACEA

2015 saw an **upsurge in the numbers of plug-in hybrids which in 2015 exceeded battery electric car sales for the first time but BEV sales also grew.** Range extenders are now also being bought in significant numbers, thanks almost entirely to the popularity of the BMW i3. A steady trickle of fuel cell electric vehicles have been purchased in each of the past four years, but these appear to be mainly for experimental purposes and amount to fewer than 200 vehicles in total.

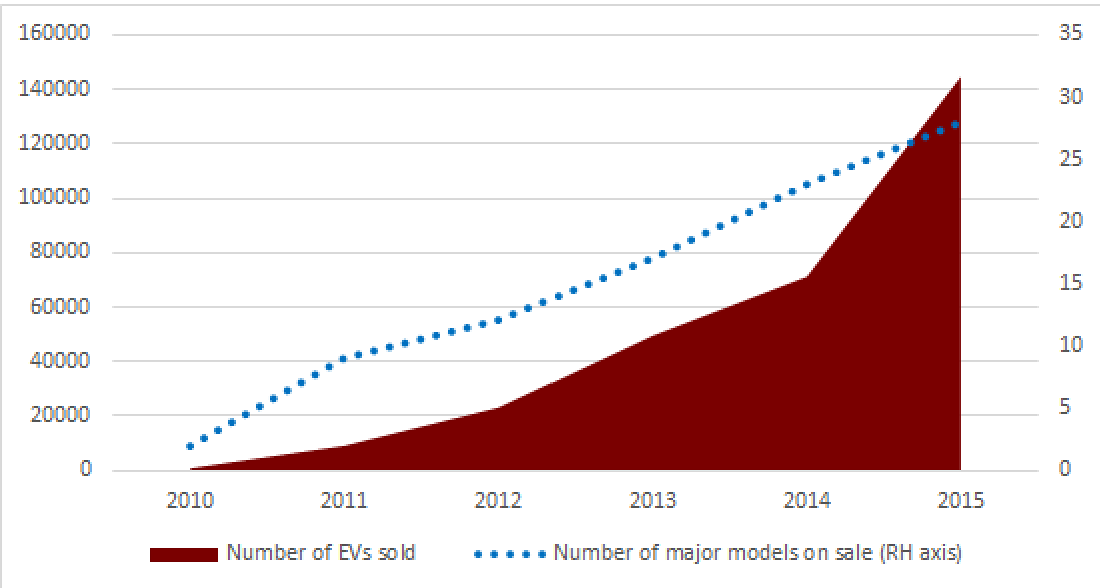

Figure 4: Development of EU EV sales and major models available

The growth in sales is matched by an increase in choice with nearly 30 models on the market (with over 100 vehicles sold in each year). However this represents a tiny fraction of the the total models on sale and more supply is needed to boost demand. Nevertheless these is now some availability of models in most segments of the market (including SUVs, executive cars and sports cars alongside smaller family and compact models).

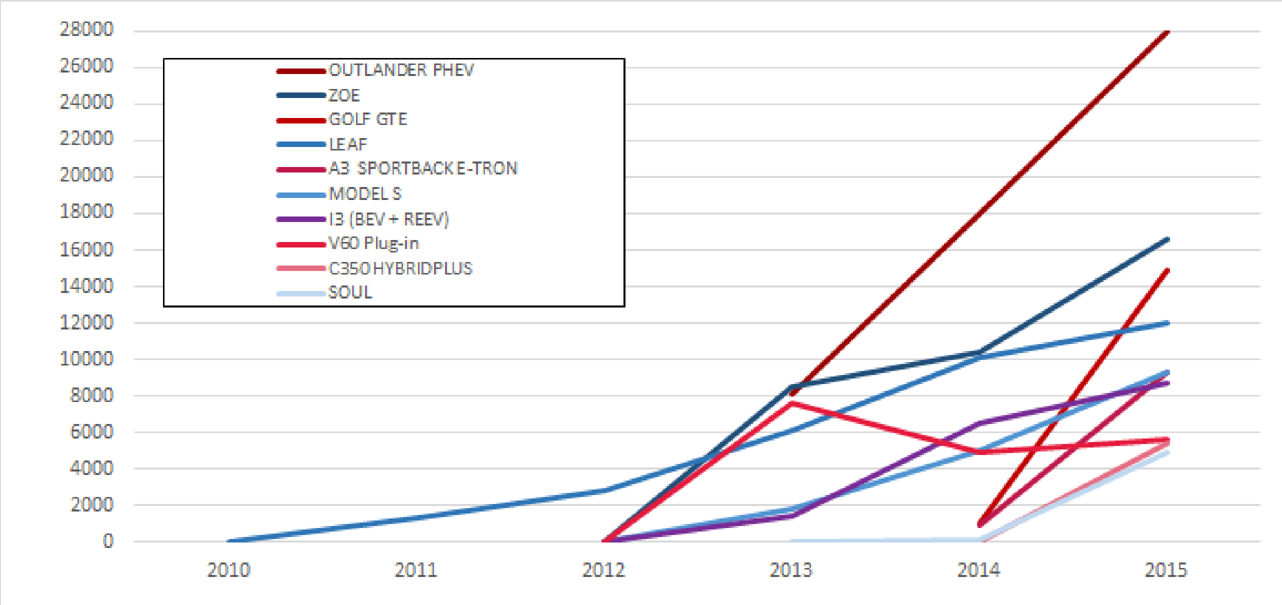

Figure 5: Development of sales of the most popular EV car models

		2010	2011	2012	2013	2014	2015
OUTLANDER PHEV	PHEV	0	0	0	8165	18024	27977
ZOE	BEV	0	0	41	8539	10378	16621
GOLF GTE	PHEV	0	0	0	0	1010	14931
LEAF	BEV	36	1311	2835	6162	10142	11977
A3 SPORTBACK E-TRON	PHEV	0	0	0	0	908	9353
MODEL S	BEV	0	0	3	1823	5032	9318
I3 (BEV + REEV)	BEV/REEV	0	0	14	1402	6496	8702
V60 Plug-in	PHEV	0	0	37	7571	4926	5657
C350 HYBRIDPLUS	PHEV	0	0	0	0	51	5425
SOUL	BEV	0	0	0	6	156	4923

Table 1: Sales of most popular EV models in numbers

The top-selling battery models (in blue) are the Zoe and the Leaf, and these have made steady progress going back several years. The plug-in hybrids (shown in red) are generally more recent and are showing strong growth, particularly the Mitsubishi Outlander, now the most popular electric car choice by quite some margin. The Golf GTE plug-in is also proving popular, and has overtaken the Leaf in 2015 sales. This, however, might be closely linked to purchase subsidy schemes in some Member States such as the Netherlands (discussed below).

Sales by brand in 2015 – the key players in EV manufacturing

The figure below illustrates the **positions of the main brands active in the EV market**, plotting the number of new cars sold in 2015 on the vertical axis against the percentage of sales that were electric on the horizontal axis. From this chart it is possible to map out a number of different groups that are characterised by their market strategy towards EVs, as follows:

1. In the bottom left-hand corner are a group of brands that have sold only a negligible number of electric vehicles, in either absolute or percentage terms. Some of these are very small specialist companies that make very little impact on the overall market; but others are major manufacturers that have shown little or no interest in EV manufacturing to date or have had limited success. In contrast to the above, there are a number of brands that appear to have engaged very little or not at all with the emerging EV market.

- **Citroen**, **Peugeot**, **Chrysler**, **Ford**, **GM/Opel**, **Honda** and **Hyundai** have each sold quite negligible numbers of EVs in 2015 (group 1 in graph above)
- The **Fiat**, **Mercedes**, **Seat**, **Skoda**, and **Suzuki** brands appear as yet to have no EV offerings.
- **Toyota** was an early and very visible entrant into the (non-plug-in) hybrid market with the Prius launched back in 1997. This has now sold more than 3.5 million units worldwide and continues to evolve. Disappointingly, however, the plug-in version (which has a very limited electric range) has very weak sales of just above 1000 per year. Toyota is presently focussing its efforts in the US market and in developing hydrogen fuel cells, as these are expected to receive greater acceptance in the US.

2. Higher up on the left-hand axis are **Kia** and **Porsche**, selling just short of 5000 electric cars each in 2015. For Kia this is still barely more than 1% of its total sales; but for Porsche it is above 7%, reflecting the fact that Porsche now offers plug-in hybrid versions of a number of its high-end models, and that these are growing in popularity.

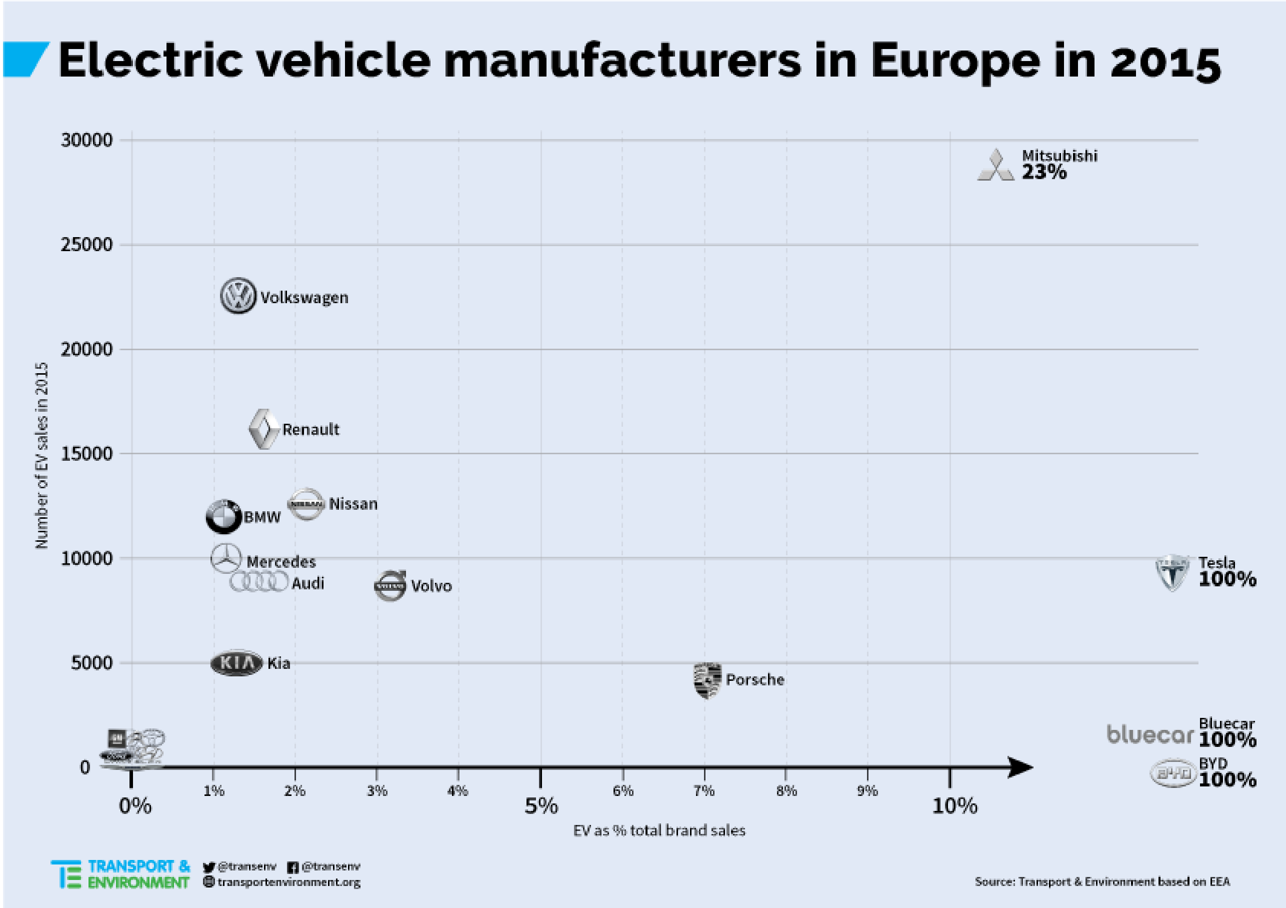

Figure 6: Market position of major manufacturers in the EU EV market in 2015

3. Higher still come **Daimler**, **Audi** and **Volvo**, each of which sold just below 10,000 electric models in 2015, most of which were plug-in hybrid versions of their existing models. Daimler also sold a substantial share of BEVs in 2015 however. Note that these are all very large and successful brands, so the electric vehicles still amounted to only a small share of their total sales, ranging from 1.2% in the case of Daimler up to 3.2% for Volvo.

4. Above these come **Renault**, **Nissan**, **and BMW** with electric car sales of between 10,000 and 20,000 in 2015 and **Volkswagen** with sales of nearly 23,000, including a mix of battery and plug-in hybrid models. These are all very large and popular brands, so EVs still account for only a very small share of their total sales — between 1.3 and 2.4% in each case.

5. Out on its own at the top edge of the chart is **Mitsubishi**, almost exclusively reflecting sales of its extremely popular Outlander plug-in hybrid version. Aside from the all-electric brands discussed below, Mitsubishi is the only major manufacturer for which electric cars account (at 23%) for more than a few percent of total sales.

6. Away to the right-hand edge of the chart are three relatively new entrants specialising solely in EVs - these are **Tesla**, **Bluecar/Bolloré** and **BYD**. Of these, Tesla is by far the largest with around 9300 new cars sold in Europe in 2015, and with many more in the USA and around the world. In contrast, Bluecar sold only around 1200 new cars in Europe in 2015 (down from earlier years), but is particularly notable for its involvement in a range of high-profile integrated electric car sharing schemes across Europe's major cities. BYD sold only a handful of cars in Europe in 2015, but this number is practically guaranteed to rise rapidly in future years if it can establish itself in the European market (see below in the section on China).

In summary, this illustrates that the mainstream European carmakers have reacted very differently so far to the challenge of EVs, with some doing very little and others making more or less conspicuous efforts. Nonetheless, for even the most active amongst them EVs constituted only a very small percentage of their total sales in 2015, with the highest share going to Volvo at 3.2%. The one outlier was Mitsubishi, with total sales roughly equal to those of Renault/Nissan taken together. As explained in later sections, however, this picture may be about to change.

Electric Passenger Car Sales by Member State

Sales levels of EVs vary considerably from country to country across the EU in 2015, with most countries still having seen very few EV sales of any sort. This list includes several of the larger Member States such as Italy, Spain and Poland. Here sales are small not only in absolute terms, but also as a proportion of total car sales.

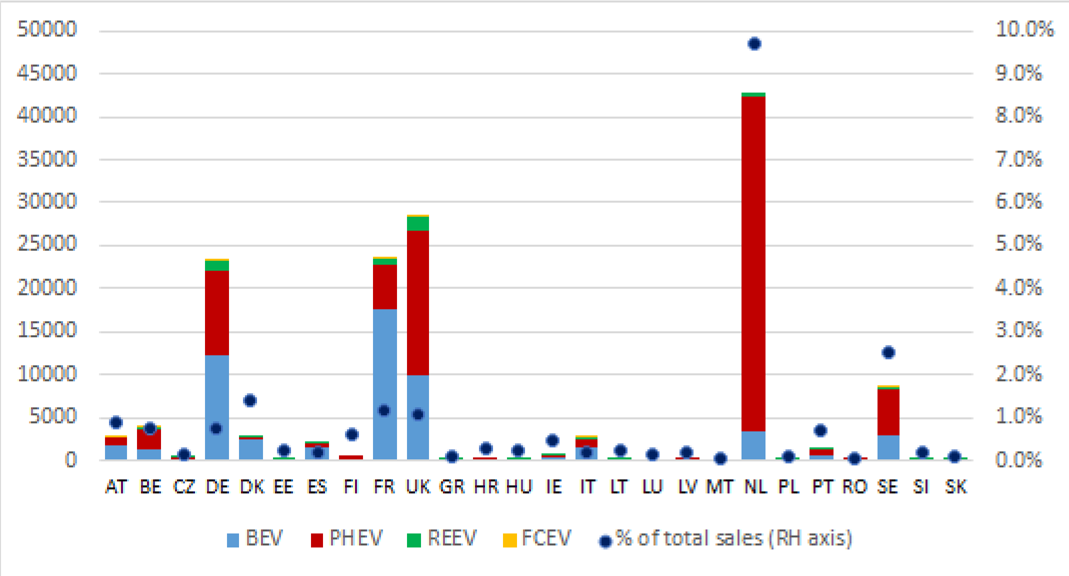

Figure 7: Total EV car sales and EVs as percentage of total sales in EU member states in 2015

The **Netherlands stands out as the frontrunner for the third year in a row**, and EV sales also represent by far the largest share of total new car sales at nearly 10%. This reflects its very generous subsidies, especially towards PHEVs. The UK sells the second highest level of EVs although it is notable that PHEVs predominate in sales even though the purchase incentive offered is now markedly less. Germany and France sell similar numbers of EVs with France having the highest share of BEVs, again reflecting the relatively generous bonus under its CO_2-based bonus-malus car purchasing scheme. Germany has a very ambitious electro-mobility scheme that aims for a million EVs on its streets by 2020. However, it has only recently introduced any incentives that should increase demand in 2016. Germany accounts for nearly all of the small number of FCEVs on the road to date. Sweden has the second highest share of EVs in terms of the proportion of car sales at 2.4% with a programme of subsidies and circulation tax exemptions, while all other countries remain below 2%.

Electric van sales

Historically, electric van sales have been rather slow to take off, growing by only around 1000 sales per year between 2012 and 2014, and with levels of sales far below those seen for electric cars. This is largely the result of minimal choice and supply to the market with early sales dominated by the Kangoo Z.E.

Overall trend in electric van sales

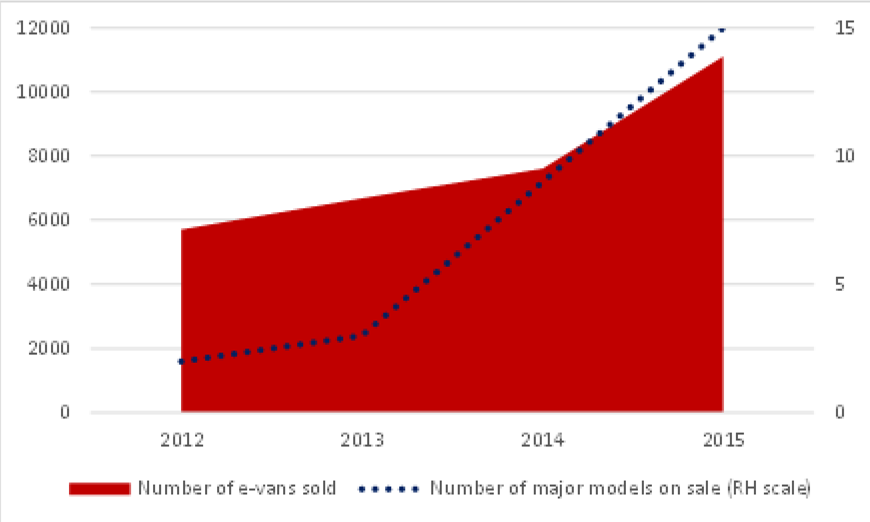

Figure 8: overall trend in electric van sales

In **2015 there has been a significant acceleration in sales** to more than 11,000 along with an increase in the number of electric models on the market. This highlights the need for a range of different van sizes and types to be supplied with electric powertrains to capture an appreciable share of the van market.

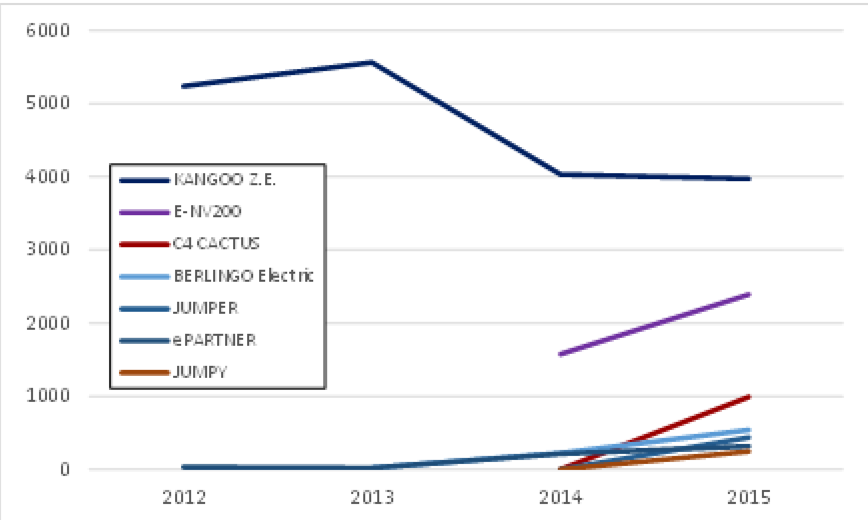

Figure 9: Development of main EV van model sales in the EU

The historical dominance of the Kango is now being challenged by the Nissan E-NV200. A number of other models also appear to be establishing a solid presence in the market, and should represent a growing diversity of the models on offer which in turn should stimulate further growth in sales. Several of these are electric versions of established conventional van models.

All the **major models originally on sale were battery electric,** but 2015 also saw the arrival of some mainstream hybrids in the market – most notably the Jumper, Jumpy and Cactus.

With increasingly choice, falling battery prices and improved performance there are growing reasons for optimism. However, the market in electric vans is far more immature than that of cars with the top two models manufactured by partner brands Renault and Nissan respectively The majority of the vans sold were also sold in France under a national purchase incentive scheme and it seems that the French companies were first to respond. Sales in Germany and by German vanmakers, for example, remained much more limited.

Electric van sales by country

For new electric van sales, the variation in sales between member states is even more marked than it is for cars.

In absolute numbers, **France is by far the largest market for electric vans** and makes up nearly half of the EU total, owing to national incentives discussed in greater detail below. Overall France has a very large market for vans, and EVs now account for about 1.5% of these. A striking second, however, is Denmark, with over 2,600 electric vans sold in 2015, accounting for 8.5% of all vans sold there. Also of note is that, unlike in any other country in Europe, the vast majority of these are plug-in hybrids and the latter account for almost all of the PHEV van sales across the EU.

As with electric cars, there are many member states where electric van sales remain close to zero.

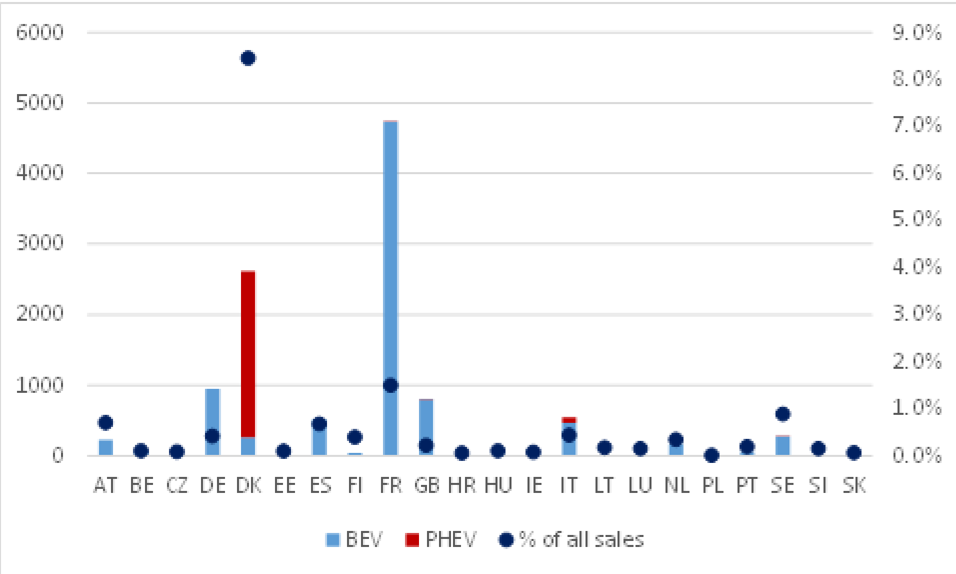

Figure 10: Total EV van sales and EVs as percentage of total van sales in EU member states in 2015

Europe in the Global Context

In a global context Europe is an important but not leading player in terms of EV sales as illustrated by the graph that shows only battery electric cars sales). Global PHEV sales remain at about a third of the level of BEV sales in 2015.

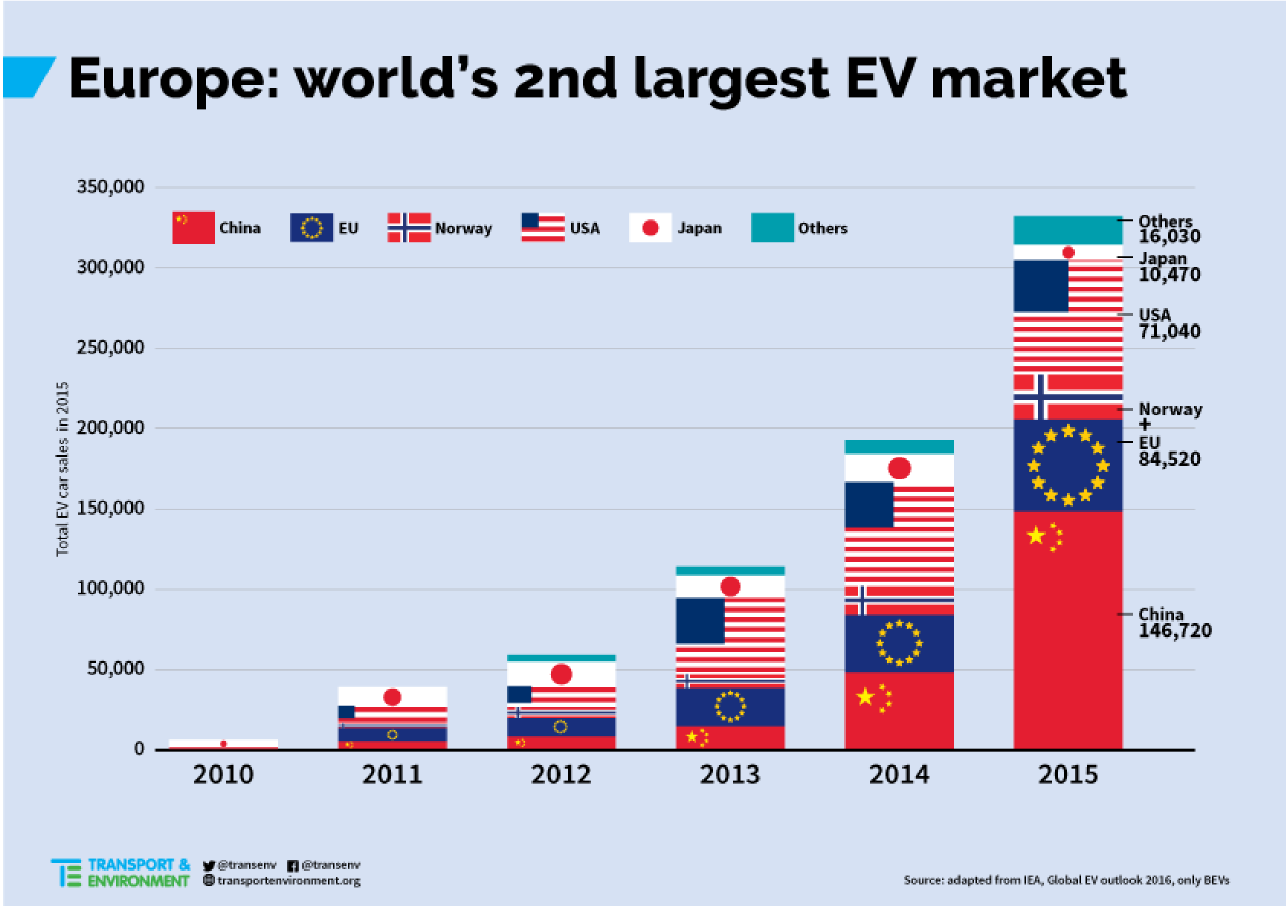

Figure 11: Total EV car sales globally, by year

The early market in Japan has failed to develop and in 2015 China became the biggest world market exceeding sales in the USA for the first time. European sales have grown steadily from 2011, with Europe (including Norway) now the second biggest market. This belies the idea Europe is lagging other major regions and indicates that were sales to be spread across more countries it could become a dominant market.

The rapid growth in the Chinese market results from a range of incentives and other government interventions. This growth has been achieved largely through domestic vehicle manufacturers.

Given its ongoing investments in further production capacity for both electric vehicles and their batteries and the growing domestic demand, China is expected to remain the biggest global market in coming years.

The importance of the Chinese market is further emphasised by BYD topping the ranking of the global sales of plug-in hybrid and battery electric vehicles. With Tesla and Nissan competing strongly for second place. BMW, VW and Renault complete the top 6 global manufacturers.

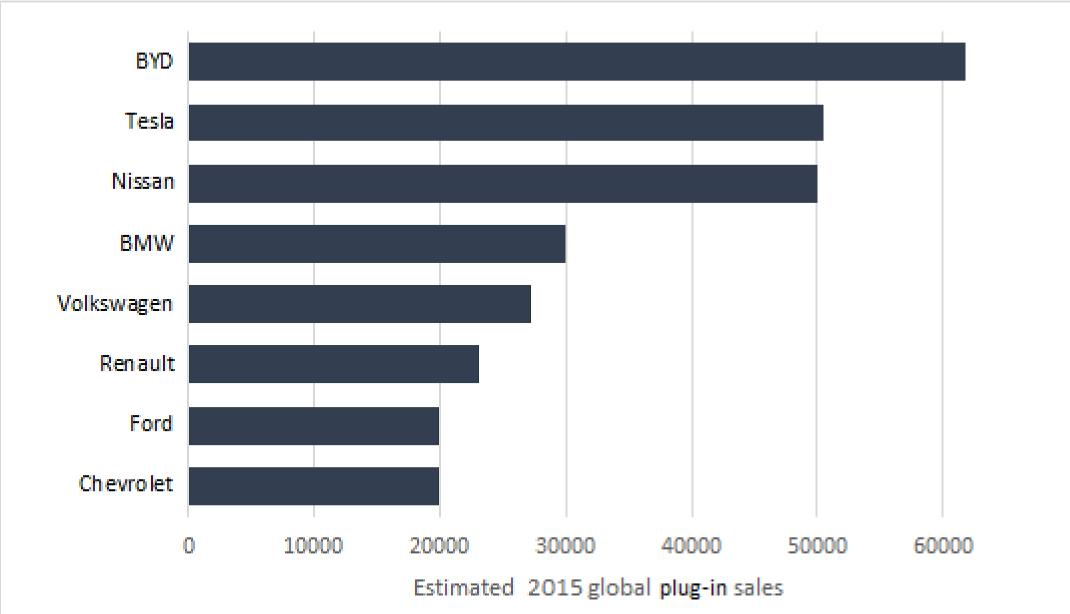

Figure 12: Estimated 2015 global Plug-in sales, Source: T&E based on industry sources

The figure includes both PHEV and BEV.

Taken together sales of plug-in vehicles by the Nissan Renault alliance exceed those of BYD with other European brands currently somewhat distant. The overall picture is that Europe is competitive in supplying plug-in vehicles and an important global market. But it needs to raise its game in a highly competitive global market.

Overall, **ICCT estimates that there are now about 1.2 million electric light duty vehicles in use globally.** The US currently has the largest EV fleet of about 400,000, with California accounting for nearly half of the total resulting from the early and proactive policies that were adopted. Europe has the second biggest fleet with around one-third of a million. Norway has more EVs on its roads than any EU member country reflecting the strong fiscal incentives, and coordinated campaign to develop a national recharging infrastructure, and strongly supportive local measures in key urban areas. As a result, while most parts of the EU and US still have EVs as only a fraction of one percent of their total light duty fleet, this figure has already reached 2.5% in Norway – one in every 40 vehicles. China now has the third biggest fleet of EVs and is advancing rapidly.

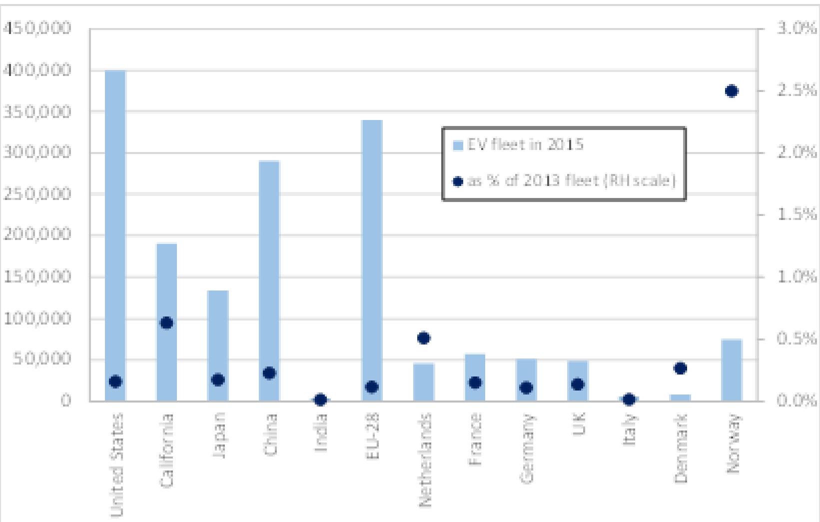

Figure 13: Estimated size of main global EV fleets on the road in 2015

EVs in China – a case study

In 2009, China overtook the USA as the world's largest car market, with a record 13.9 million vehicles sold. This reflected a rapidly-industrialising country in which more and more people were sufficiently wealthy to buy their own cars, and national and local authorities were turning their backs on the 'old' bicycle-based society in favour of 'modern' personal motor transport.

However, this spike in car traffic was accompanied by an even bigger upsurge in motorcycle and moped use, and together these contributed a huge part of the choking air pollution and traffic congestion for which Chinese cities have become infamous. This in turn caused many city authorities to restrict or ban two-wheelers with conventional engines, but electric bikes, mopeds and motorcycles were exempt. This further fuelled the enormous growth in sales of two-wheeled electric vehicles, with annual sales of bicycles and scooters increasing from 56,000 in 1998 to over 21 million in 2008. This was more than twice the level of car sales in the same year.

Car use remained a problem, however, not only for air quality and traffic congestion, but also because it stimulated huge demand for oil which had to be imported at very high cost. In terms of industrial policy, too, it was clear that the Chinese auto industry would struggle to compete on the world stage with either the hybrid technologies of the Japanese and Koreans or the sophisticated ICE technology of Europe and North America. Conversely, Chinese industry was already well geared up to EV technology thanks to its burgeoning two-wheeler production, while western car companies were in most cases showing little interest in this area. In response, therefore, the government established a policy framework to accelerate EV car and bus technology development, encourage market transformation by supporting research and development, regulate the industry to drive up standards, and incentivise the uptake of EVs both by private individuals and by transport businesses, for example through free licence plates for EVs in major cities. In 2009 in particular, the State Council approved the Auto Industry Restructuring and Revitalization Plan to invest RMB10 billion ($1.5 billion) in new electric vehicle industrial capacity, and RMB20 billion ($3 billion) in technology and process development. The government also announced a two-year pilot program of EV purchase incentives in five major cities covering both BEVs and PHEVs, with rebates of up to RMB60,000 (around $9,000). Some of these investment funds would also help to build up the country's battery production capacity, with the aim of supplying at least 150,000 electric vehicle batteries a year by the end of 2011.

The overall aim was to have five million plug-in electric cars on the roads of China by 2020, and to manufacture a million EVs annually by the same year. Initially progress was slow, as there was little recharging infrastructure and few Chinese city dwellers had access to a garage or front yard. This problem was addressed through a **huge programme of installing public recharging points, at which point sales began to accelerate rapidly as illustrated in the charts above**. Owing to the slow start, the aim of 5 million electric vehicles on the road by 2020 looks out of reach, but the target of a million EV sales in that year now looks more than possible. China's EV market grew by 162% in the first half of 2016 to 170.000 sales, divided into 134000 EVs and 36000 PHEVs. Owing to its interventionist industrial policy spanning both public and private sector developments, China now has a range of major electric vehicle and battery manufacturers, of which BYD is as yet the best known outside China. However, it is likely that a number of Chinese brand names will become increasingly familiar in Europe's EV markets over the next few years.

Developments in battery production

The electric car was invented in the 1830s – long before the internal combustion engine came upon the scene. However the heavy weight and relatively poor performance of batteries meant the internal combustion engine became the dominant car technology in the 20th century. This remained the case until relatively recently, when demand for consumer electronics drove a rapid advance in high-powered battery technology that could also be scaled up for heavy duty uses in vehicles. This is now reflected in the rapid growth in production figures for new heavy duty batteries, as illustrated in the figure below.

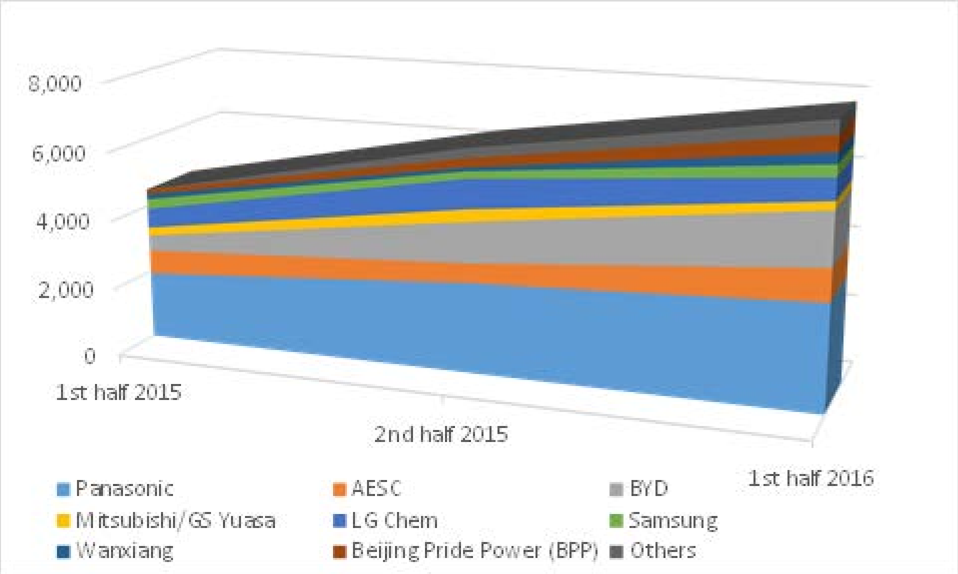

Figure 14: the growth in vehicle propulsion battery production for electric vehicles (in MWh), source: T&E data adapted from industry sources

Global battery production for EVs is currently dominated by Panasonic, which has a strategic partnership with Tesla to whom it sells most of its battery output. Reflecting this, output has been growing steadily and is expected to increase dramatically in the near future, reflecting the opening of Tesla and Panasonic's new joint venture 'Gigafactory' in the Nevada Desert, with its planned output of 35GWh per year adding nearly a quarter to current global production. However, other major manufacturers taken together also outstrip Panasonic's production in the past months and years, reflecting the growing demand for EVs across the board.

Aside from the new Tesla/Panasonic factory in the US, most manufacturing is currently based in China and Japan, with BYD in China as the largest battery producer after Panasonic. BYD has invested billions into its own battery cell technology and is expected to rival Tesla/Panasonic's battery production capacity by 2020. LG Chem of Korea, which supplies battery packs for the Volt, expects to exceed even this level with annual output of 50GWh of cells by 2020. These projects alone will double world output by 2020, although this alone will still probably not be enough to keep up with demand.

The battery is the key component that will determine the development and uptake of electric vehicles. Future costs, availability and technical performance are all key aspects of the growth in e-mobility.

Concerns that the continuing dependence on battery packs manufactured in the Far East is limiting the value added from EVs in Europe now appear to be receding with a number of striking announcements for new battery plant in Europe:

- As part of its Strategy 2025, **Volkswagen** has outlined plans for a €10 billion battery factory in Salzgitter (Germany), where it currently has an engine plant. It is not yet clear whether VW would rely on its own proprietary battery design, but it clearly wants to avoid relying on the existing battery giants BYD, Panasonic, LG Chem or Samsung for supply. The exact capacity of the plant is presently unclear but the size of the proposed price tag suggests that output may be of global scale.
- **Samsung SDI** plans to invest about €320 million to build an electric-vehicle battery plant in Hungary, joining the race to build capacity and exploit growing European demand. Samsung, whose customers include BMW, have announced that the factory near Budapest should start production in the second half of 2018 and will produce batteries for 50,000 EVs annually.
- Industry sources report that South Korea's **LG Chem** plans to build an EV battery factory in Wroclaw in Poland to meet rising demand from European automakers. The plant is expected to be completed in 2017-18. It is estimated that the plant will ultimately have a production capacity of 229,000 EV batteries a year, making it LG Chem's second-biggest EV battery factory outside China. LG Chem supplies around 25 automakers globally, including Renault, Volkswagen, Audi and Volvo in Europe.
- It is rumoured that **JLR** is also holding talks with **Ford** and **BMW** about building a battery factory for future electric vehicles in Europe. It believed that Jaguar is keen to get the project started and build its first all-electric car soon, according to a report published by *The Times*[10]. If this is correct, all three companies will have plans for their own electric vehicles, and are keen to be able to manufacture independently of the big fat eastern battery makers.
- **Tesla** CEO Elon Musk has also indicated that he aspires to a major battery plant in Europe as part of his global ambitions, but plans are not yet far advanced.

Taken together**, these will represent a substantial increase in capacity to manufacture light duty electric vehicles, including their battery packs, in Europe**.

Battery costs worldwide

This growing capacity is also reflected in a steady and quite steep fall in the price of each megawatt-hour of battery power. This arises from economies of scale, evolving production techniques including vertically-integrated production, and from the development of new and more sophisticated battery technologies and control systems. This **fall in battery prices is also an essential component of the growing popularisation of EVs**, since the battery has always been a major component of the total capital cost of a new electric car, resulting in high prices and limited range, and hence a substantial barrier to their uptake.

A recent literature review by ICCT[11] summarises recent trends and future prospects in lithium-ion battery prices per KWh of capacity as follows:

[10] http://www.thetimes.co.uk/article/jaguar-revs-up-electric-car-alliance-llh2xsnd6

[11] ICCT, July 2016, *Electric vehicles: Literature review of technology costs and carbon emissions*, Working Paper 2016-14

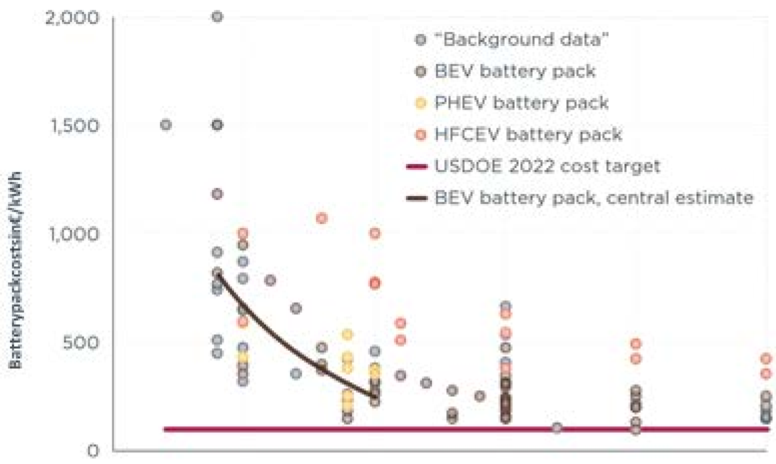

Figure 15: Synthesis of estimated battery cost trends in €/kWh historical and projected, Source: ICCT (2016)

There has been a very steep drop in prices to around **€250 per kWh in 2015**, **from more than three times that figure only six years earlier**. The average lithium-ion battery pack has recently plunged to $150 per KWh from $1,200 per kilowatt hour in 2010, according to some experts. Musk recently predicted that the Gigafactory could reach $100 per KWh by 2020, beating industry projections by about five years. Although manufacturers' battery prices are closely guarded secrets, Musk has said in the past that Tesla is ahead of curve, "We don't think anyone is on a path to be even close to us"; however GM has suggested only a slightly higher figure for the batteries for its new Bolt. If this proves correct, both companies are ahead of the cost trajectory set out in the ICCT study illustrated above, and of the US Department of Energy (DOE) target for 2022. This is significant as it represents the point at which EVs are expected to be competitive in performance and cost with equivalent ICE cars.

Future Models

In 2016, there are 34 EV models on the European market across the main car segments (Element Energy 2016). This is an improvement but a fraction of the 417 ICEV models available (and multiple variants). However, recent developments in battery prices and performance have generated a flood of new company plans and announcements over the past year. Some of the most notable developments are outlined below.

- **Volkswagen,** rocked by the Dieselgate scandal, has been forced to reconsider its long-term strategic reliance on diesel vehicle sales as a path to lower-carbon cars in Europe. In June 2016 VW group unveiled details of its Strategy 2025 business plan for the Audi, Porsche, SEAT, Skoda and Volkswagen brands, claiming this to be the "biggest change process in the Company's history". The plan includes announcements of over 30 new electric models expected to launch by 2025, with these new 'e-vehicles' using more efficient battery technology to allow greater all-electric range than in the brand's current offerings. The new vehicles will clearly include electrified versions of popular conventional models across the VW brands: **Porsche** for example will continue to offer PHEV versions of its most popular models, to include the 4-wheel drive Panamera 4 in 2018, expected to be followed by the production version of the all-electric Porsche Mission E electric luxury sedan, planned for production in 2019 or 2020. **Audi** has also announced ambitious plans to have three electric car models on sale by 2020 and for electric vehicles to account for 25 to 30% of all its car sales by 2025, according to Reuters. It is also expected that new developments will include the launch of a dedicated platform for compact electric cars along the lines it unveiled last year. Ahead of the 2016 Paris Motor Show the company unveiled the VW I.D. concept car, a Golfsized five-door all-electric hatchback expected to go into production from 2020, pointing the way to the brand's new low-emissions identity[12]. It is reported to offer a range of up to 600km on the European NEDC test cycle and is expected to go on sale at a price comparable to the company's mainstream conventional models.

- **Tesla** a relative newcomer to the car market, and tiny in global terms (50,000 cars sold in 2015, perhaps 80,000 in 2016 against a global market of over 60 million cars per year). However, it is the number two EV manufacturer. In 2006 it launched its "Secret Master Plan": step 1 was the Tesla Roadster, an expensive low-volume car to show the world that electric cars could be compelling and exciting; step 2 was the Model S, a mid-range and slightly less expensive car that was nonetheless a highly desirable high-performance electric sports car. Along the way it added the Model X SUV, and now is set to launch step 3 in 2017-18 — the Tesla Model 3 as an affordable mass-market electric car. This will be a direct competitor to the established best-sellers in the compact executive car class such as BMW's 3 Series, the Audi A4, the Jaguar XE and Mercedes C-Class, and is expected to be competitive in price (around €38,000 without subsidies) and performance (about 350km range). Ambitious plans are already in hand to boost production into the hundreds of thousands per year, and Tesla already has a waiting list of around 400,000 advance orders. This is pushing the other global players to rethink their plans for competitive EV offerings.
- **BMW** is expected to build on its start in the EV market with the i3 and i8 by launching a new electric SUV concept, the first of up to four new all-electric models planned, and announced at the 2016 Paris Motor Show. An all-electric version of the i8 is also expected.
- **Mercedes** revealed its new 'Generation EQ' all-electric luxurious SUV coupe concept with a range of 310 miles at Paris. There were also three models of Smart cars that debuted with their new Electric Drive powertrain option: the ForTwo coupe, ForTwo cabrio and the ForFour four-seat model.
- To date **Ford** has made only negligible efforts in the EV market, with a few battery-electric versions of the Focus sold in Europe. However, early in 2016 it announced plans to develop an all-electric model with at least a 200 mile (320km) range to compete directly with the Tesla Model 3. This plan has since been extended through the announcement in September 2016 of a $4.5 billion investment programme for electric cars to result in 3 new electric models covering 40% of its current model range by 2020. A new electric version of the Focus is also expected from 2019.
- Unlike other parts of the GM group, **Chevrolet** was an early entrant to the EV market with the Chevy Volt - also sold as the Ampera in Europe. From 2017, however, it will be launching the Bolt as an all-electric five-door hatchback. With a range rated at 238 miles by the EPA (equivalent to at least 400km in EU tests), the Bolt EV is expected to enter production later in 2016 and go on sale in early markets including California. It will probably appear in Europe in 2017 as the German **Opel** Ampera-e, with a competitive range up to 500km in NEDC, and will likely be priced-competitive with the new Tesla. Some have claimed that the Bolt epitomizes (or at least prefigures) GM's metamorphosis from an old-style car maker behemoth to a Silicon Valley-like developer of highly connected products and new mobility services, such as EVs, car-sharing, ride-hailing etc.
- **Nissan** has announced a 200-mile (up to 400km) option for the second-generation of its flagship Leaf BEV. Production is expected in 2018, featuring a larger battery pack than the current one to increase power and range.
- Meanwhile its partner **Renault** is expected to place a new battery-electric small car on the market, possibly as early as 2017, and may even have a sporty Gordini version available at the same time.

[12] http://www.autocar.co.uk/car-news/motor-shows-paris-motor-show/crucial-volkswagen-id-electric-concept-revealed

This will be a BEV hatchback primarily for city use. The price is estimated to be as low as €14,000, in which case it is likely to be very popular. It will be the first of a family of new electric vehicles planned by Renault, which intends that 30% of its car sales should be EVs by around 2025. This year's Paris motor show saw a surprise redesign of the Renault Zoe, Europe's best-selling electric car, which doubled its range to more than 150 miles (241 km) in real-world use.

In all, as result of this flurry of new activity, at least two dozen electric cars were exhibited at the 2016 Paris Motor Show. Plans do not necessarily translate into production models in all cases. However, there are strong reasons to believe that this upsurge in interest is not merely greenwashing but represents a step-change in the scale and sophistication of the European EV market.

Decarbonising electricity supply

EVs and power plant emissions

A common criticism of electric vehicles is that, although they emit no greenhouse gases at the point of use, they are still responsible for their share of emissions from power stations. This is true, but the criticism on its own overlooks two very important points about EVs: first, that they are inherently much more energy efficient than conventional petrol or diesel cars and that this reduces their average emissions per kilometre; and second, that the average European energy mix has already strongly decarbonised from the days of coal-fired generation, first through the switch to gas, and second through the rapid installation of new renewable power sources. Already CO_2 intensity has fallen by more than a quarter since 1990, and more ambitious plans are expected to follow under national commitments on climate change.

As a result, an electric car in use in Europe today already produces much lower greenhouse gas emissions per kilometre than any conventional car on the road. This advantage will improve further as ambitious plans for renewable energy and greenhouse gas reductions are implemented.

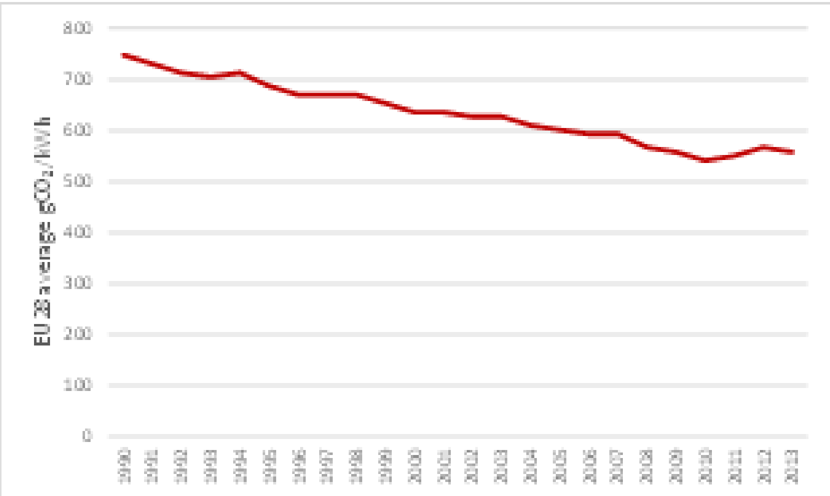

Figure 16: Average CO_2 intensity of EU electricity generation, source: EEA national emissions database

The growth in European renewable electricity

The EU's Renewable Energy Directive sets an overall binding target of meeting 20% of all final energy consumption from renewable sources by 2020. To achieve this, EU countries have committed to reaching their own national renewables targets, ranging from 10% in Malta to an ambitious 49% in Sweden. All EU countries have also adopted national renewable energy action plans showing what actions they intend to take to meet their renewables targets. Going beyond 2020, EU countries have already agreed on a new renewable energy target of at least 27% of final energy consumption in the EU as a whole by 2030. This target is part of the EU's energy and climate goals for 2030, and underpins the EU’s ratification of the 2016 Paris Climate Change Agreement.

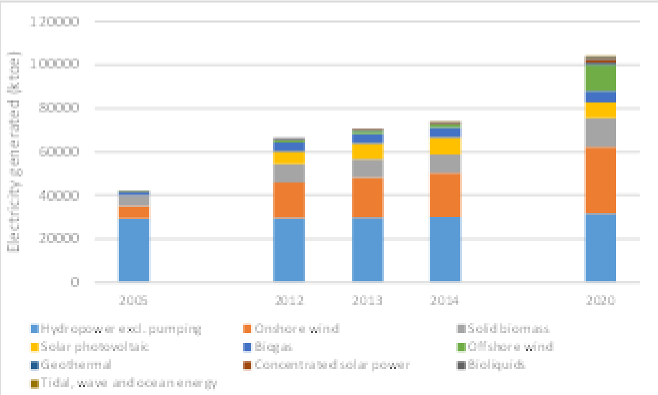

Figure 17: Growth in renewable electricity generation, recent and projected, source: EEA Renewable Energy in 2016

This figure illustrates the enormous growth in renewable electricity generation in Europe over the past decade. In 2005 large scale hydroelectric was the dominant source, but has since been joined by substantial tranches of onshore wind, biomass and solar photovoltaic power. As a result renewable electricity supply has doubled over a decade, and a further major increase is projected for 2020, largely thanks to further expansion of capacity onshore plus the very rapid growth of offshore wind farms in the North Sea and elsewhere. Wind and solar technologies are already becoming competitive with conventional generation plant, and costs are expected to fall further in the coming years. Hence the rapid uptake of renewables is set to continue.

The longer term, Europe’s electricity supply is expected to be almost completely decarbonised by 2040-2050 as a part of the EU’s contribution to tackling climate change. By this time, EVs will be essentially carbon free.

Renewable electricity and EVs

EV’s introduced to the European car stock now can expect their average CO_2 emissions per kilometre to decrease year on year — a characteristic with which no conventional vehicle can compete. Conventional engines, which are already less good than electric motors in total carbon terms, will soon approach the theoretical limits of how much further their efficiency can be improved, and so the relative environmental advantage of EVs will continue to grow over time.

Further, electric vehicles are most commonly charged overnight and can be expected in future to offer smart recharging characteristics that will allow recharging demand to follow the availability of electricity supply. In this case, the widespread introduction of EVs is likely to contribute positively to managing the variability of the level of electricity supply from renewable sources.

Developing recharging infrastructure

For conventional ICE vehicles, a network of refilling stations has developed and matured over many decades, to the point where motorists can drive in almost any part of Europe without any concern that they will run out of fuel, and usually without even prior knowledge of the location of the nearest filling station. For EVs, an analogous network is essential but as yet is far sparser and patchier. Concerted efforts are needed to develop such a network if EVs are to be used as widely as conventional vehicles on a European level, allowing EV drivers to charge across borders.

Recharging points for EVs will differ in type and location according to their primary function. For example:

- Many EV owners will have a low-power domestic recharger for overnight charging, and this may be sufficient for most or all of their driving needs
- Workplace recharging points can effectively double the available range for EV commuters
- Public recharging points at shopping centres, park-and-ride stations and other destinations can improve their accessibility and attractiveness for EV drivers, but will need to recharge at moderate power to be useful
- Fast and reliable recharging points at motorway service stations, for example along the European TEN-T corridors, will be essential to facilitate long journeys in BEVs.

The network of recharging points has been developing steadily in recent years, rising from only a few thousand recharging points in 2010 to nearly 100,000 today,[13]and with growing, but by no means sufficient, levels of interoperability. To create a truly European market for EVs, access and payment to EV charging needs to be open to all EV drivers and managed transparently, for example through a European consumer data base as exists already in some countries such as Netherlands or Norway.

EU member states need to accelerate roll-out of EV charging infrastructure by implanting the EU Alternative Infrastructure Directive 2014 in a coherent manner, allowing multiple standards to be used on public infrastructure without impeding innovation on private charging points by mandating specific standards in this area as well.

Investments in infrastructure need to be linked to the growing share of renewable energy, and a more flexible electricity grid allowing better demand-response, smart charging and storage solutions for optimal integration of EVs into the grid. These reforms need to be done as part of the 'Reform of the European Energy Market', beginning in late 2016.

The prospects for fuel cells

For the time being it is clear that battery-based EVs are establishing a strong foothold in the car market and dominate ultra-low carbon and zero -carbon vehicle sales. However the likely future trajectory of EVs is complicated by global automakers drawing different conclusions on whether battery electric technology or the hydrogen fuel cell provides the best long term option. In Japan, both Toyota and Honda have large FCEV development programmes, whereas Nissan has historically had a much smaller fuel cell programme and is focused on battery electric technology. Active engagement by US carmakers is similarly mixed, with General Motors showing the biggest long-term commitment to FCEVs, while Ford appears to have shifted its stance and alliances several times.

[13] See for example http://www.eafo.eu/

When or if they become widely available, it is clear that fuel cells offer certain key advantages over battery-electric — most obviously better range at perhaps twice that of a typical battery EV, and much faster refuelling in just a few minutes. As against this the technology is still under development and some aspects such as on-board fuel storage remain problematic. The necessary infrastructure for hydrogen refuelling also presents even greater challenges than those of installing EV recharging points, while the most sustainable means of mass-producing the hydrogen needed remains unclear. Mass-market hydrogen also looks likely to remain very expensive to make, transport and store by comparison to electricity.

Furthermore fuel cells, even when fully developed, will use energy only half as efficiently as BEVs, so it is far from clear that they represent the most sustainable option for general use in the long term. FCEVs will occupy at least some market niches. They will however have to compete in a market where a growing range of BEV models are already established, and whose range and cost limitations may be fast diminishing. Whether FCEVs can catch up with BEVs therefore remains to be seen. In Europe where range limitations are arguably less of an obstacle than in the US, and where an already-growing electric recharging infrastructure looks much less problematic than a hydrogen one will be, battery looks at present to be the most promising option.

Policies and measures to encourage uptake of EVs

A recent analysis from the ICCT,[14]shows there is a clear relationship between supportive national incentive schemes and the level of uptake of EVs. For cars, purchase incentives are the most conspicuous measures, but in most of the more proactive countries reduced annual circulation taxes and concessions on company car taxes are also important. Examples of measures taken in some of the leading member states are outlined below.

- **The Netherlands** remains by far the frontrunner for the third year in a row in terms of percentage uptake of EVs amongst new car sales at nearly 8%. In early 2015, the Dutch parliament voted to make 100 per cent of new car sales emissions-free by 2025, and called on the government to push for an EV sales quota for carmakers as part of the next round of EU car CO_2 standards. Its success to date reflects its very generous subsidies, especially towards PHEVs, which the Dutch government has preferred on account of their flexibility and the relatively small size and dense population of the Netherlands. Electric vehicles are exempt from the national initial registration tax, and vehicles emitting up to 50g CO_2/km are also exempt from annual circulation tax.
- The **United Kingdom** has a relatively large grant (up to €6000 approximately) towards the price of new EVs. For BEVs and PHEVs, annual circulation taxes are set at zero and a much reduced rate respectively, and there are also company car tax benefits. In most cases the UK distinguishes the rate of benefit for PHEVs according to the average CO_2 emissions and the electric-only range available.
- **France** announced its 14-point national plan to develop electric and hybrid vehicles in October 2009. This has been effective in that it now has the highest share of BEVs and the largest EV market in the EU. This reflects the relatively generous bonus available for EVs under its CO_2-based bonus-malus car purchasing scheme — previously up to €10,000 on BEVs, and currently set at €6300. In addition, a “super bonus” is available for motorists scrapping old diesel cars, which can raise the maximum total subsidy to €10,000 for the cleanest EVs. A concerted infrastructure development plan and widespread local incentives have also been important in stimulating the uptake of EVs.

[14] http://www.theicct.org/sites/default/files/publications/ICCT_EVpolicies-Europe-201605.pdf

- **Germany** has a very ambitious electro-mobility programme that aims for about a million EVs on its streets by 2020. It is currently running somewhat behind this demanding target, but offers substantial incentives for BEVs, some PHEVs and also FCEVs. For example, EVs are exempt from annual circulation taxes for their first ten years of operation. On account of its particular incentives, Germany accounts for nearly all of the small number of FCEVs on Europe's roads to date.
- **Sweden** has also strongly encouraged the uptake of EVs, with a very large number relative to its population, and the second-largest share of new sales at 2.4%. Sweden has a purchase subsidy programme for new EVs (SEK40,000 or approximately €4300) and the best PHEVs (SEK20,000 or approximately €2100 for those emitting up to 50g CO_2/km), and a five-year exemption from annual circulation taxes.

Most recently, the **Polish** government has announced a target of 1 million registered EVs in Poland by 2025 – a dramatic turnaround from its lack of action to date, and an indication that further national incentives may follow.

Incentives for electric vans have been less widespread, and in most cases less effective to date. In the UK, for example, the purchase subsidy for new cars extends also to vans at a higher maximum rate (up to approximately €9500), but has so far had only limited impact on the level of purchases.

- **France** achieved by far the largest electric van sales in 2015 at 4500 and accounted for more than half of the EU total sales — as in previous years. In addition to the fiscal incentives outlined above, Renault's offering of a battery rental scheme on the Kangoo ZE van has proved attractive to a range of fleet operators. First amongst these was La Poste, the national postal service, which has ordered 10,000 of the new vans in what amounts to a major and very effective national public procurement exercise.
- **Denmark** achieved the EU's second highest level of electric van sales in 2015 after France, and by far the highest electric share of all van sales at over 8%. It has also become the principal market for plug-in vans to date. As in France, this sales uptake is not explained by private sales but fleet programs: Over 100 Mercedes models were first leased and then bought by postal services, and several thousand Nissan NV200 leased cheaply through a government funding program. In addition, all EVs in Denmark are exempt from the very substantial national registration taxes. The overall sale in 2015 was mostly due to the beginning of taxation of EVs in 2016, mainly driving up the sale of Teslas.

The figure illustrates the relative progress of European countries based upon their progress in selling EVs and providing an encouraging fiscal environment; and developing recharging infrastructure. It shows the Netherlands and Norway as the clear leaders; most countries in Western Europe chasing to catch up but almost nothing in the East and South.

Figure 18: Progress in E-mobility market creation across Europe

EU-level policies towards EVs

On the European level, Co2 standards for cars and vans have been the main driver for car makers to invest in electrification. Recent analysis (Element Energy 2016) shows that in order to achieve a -30% emission reduction by 2030 (from 2005), car makers will not be able to rely on complying Co2 emission standards with optimised combustion engines only. They will need to sell ultra-low emission vehicles. This "Zero Emission Vehicle gap" will open up for passenger cars from 2022, for vans from 2020. To provide investment security for car makers and enable companies to accelerate electrification of their fleets, ambitious new CO2 targets would need to be set in 2025 and 2030.

In addition, a new form of incentives for ultra-low carbon vehicles (ULCV) are needed. Current EV sales incentives (so-called supercredits) have proven to be inefficient. The multiplier of EV sales allows car makers to effectively undermine their CO2 targets while artificially rising EV sales. As the EV market growth will be significant post 2020, supercredit multipliers run the risk to increase the gap between paper and real CO2 emission reductions. Supercredits planned for 2020-2022 will therefore have the adverse effect: instead of stimulating EV sales, keeping supercredits in new vehicle emission regulation will weaken stock emissions reduction by 1.3 %, this means cause 31 Mt. of additional Co2 from 2020 until 2030 (Element Energy 2016).

The example of California shows that ULCV targets for carmakers are the most reliable solution to ensure EV uptake, strengthening domestic industry and meeting climate needs. The Chinese government is in advanced discussions on introducing a similar instrument. The EU has also started to discuss the idea, stating that it will "*analyse the impact of different ways to incentivise low- and zero-emission vehicles [...] such as setting specific targets for them".*[15] T&E analysis has shown that in order to meet 30% GHG reductions in transport by 2030 though CO2 regulations, these targets need to be at 10% in 2025 and 32% in 2030 (Element Energy 2016). These targets can be set independently or combined with the next CO2 targets. Incentives for car makers are provided through a credit system in which BEVs and PHEVs are credited according to their emission values to ensure compliance with emission targets. Further, Light Electric vehicles could be included to stimulate the growth of this dynamic market segment in Europe.

Interoperable Charging Infrastructure to build an EU-wide e-mobility market is also needed as well as a more flexible electricity grid, allowing demand-response, smart charging and storage solutions for optimal integration of EVs into the grid.

Local measures to support the use of EVs

As the previous sections have illustrated, national and EU-level policies and measures have been important in accelerating the entry of EVs into national LDV markets, and will continue to be for some years to come. These have been driven primarily by global considerations, in the form of the need to reduce CO_2 emissions from transport.

In addition, however, EVs offer important local benefits, particularly in the form of dramatically reduced noise levels and the absence of local pollutant emissions by comparison to equivalent ICE vehicles. These are particularly important considerations in urban centres, and especially the many which suffer from persistent air quality problems. This has led a range of municipal authorities across Europe to apply local measures to incentivise EVs and/or discourage use of polluting conventional vehicles in urban centres.

Such measures have been usefully categorised and evaluated in two recent publications. The first of these is *Local measures to encourage the uptake of low emission vehicles*, published by the UK Low Carbon Vehicle Partnership in June 2015[16]. This is primarily a good practice guide aimed at UK local authorities, but contains many good practice examples from around Europe. The second is the recent ICCT report cited above, which includes detailed and well-structured case studies from a range of countries. The summary which follows highlights some of the key points from these studies.

- Through their role in **city planning and infrastructure provision**, local authorities can play a key part in facilitating and accelerating the installation of recharging infrastructure, reserved parking spaces, etc. Designation of low emission zones can also be a hugely important indirect driver for the uptake of EVs.

[15] Commission's Low Emission mobility strategy (2016)

[16] http://www.lowcvp.org.uk/news,lowcvp-new-publications-to-support-low-carbon-and-low-emission-road-transport_3335.htm

- Local authorities also typically operate large vehicle fleets for a wide variety of municipal functions, many of which are ideally suited to electric vehicle operation. In these areas, **public procurement** programmes can be an important driver of demand for EVs. The city of Stockholm, for example, has a wide-ranging EV procurement programme.
- Local authorities may also be in a position to give **preferential access to road infrastructure** for EVs, or to restrict access for conventional vehicles. Germany's Electric Mobility Law of 2014, for example, allows municipalities to operate a wide range of preferential access measures for EVs. Norway, controversially, designated electric vehicles are allowed to travel in bus lanes.
- Similarly, **local road charging schemes and toll points** can offer free access or reduced rates as an incentive for the use of designated electric vehicles. The London road charging scheme is a good example of a scheme that has effectively incentivised low emission vehicles for some years.
- **Interventions influencing dedicated urban fleets** such as distribution and maintenance vehicles and taxis can also be particularly effective in improving air quality in central areas. Utrecht, for example, has banned heavy duty diesel vehicles in the city centre and has helped establish a light electric vehicle distribution network for 'last mile' deliveries. In London, the Mayor proposes that from 2018 all new taxis and private hire vehicles must be capable of zero emissions operation for up to 30 miles (just under 50km).
- **Parking policy** is an important area of local authority powers that can directly influence decisions on EV ownership. Measures available might include preferential parking rates or free parking in both residential and on street parking bays, reserved bays for EVs, etc. Dedicated parking bays for electric car sharing schemes are also an effective enabling measure. Barcelona, for example, offers exclusive access to certain central parking areas for electric vehicles only. Amsterdam offers preferential access to residents' parking permits for electric cars, while conventional vehicles are subject to a five-year waiting list.
- Support for electric **car sharing schemes** is also becoming more widespread. Of these, the Paris Autolib' scheme is one of the most ambitious and best-known.

Risks of Plug-in Hybrids

A key development highlighted in this report has been the recent upsurge in sales of plug-in hybrid EVs, and it is therefore important to assess the impact of these vehicles on the overall ambition of low carbon or zero emission vehicle use.

On the positive side, plug-in hybrids already offer an enormous increase in the range of models available, particularly in some segments which are not well or easily provided for by pure battery electric configurations at present. Furthermore, if used primarily in battery only mode, they can in principle give an emissions performance as good or nearly as good as a BEV.

However, it is equally clear that in some cases the choice of a PHEV may have been driven in part or in total by the attractive sales incentives or beneficial tax treatment as a company car benefit in kind, and in these cases, there may be little or no incentive for the driver to make full use, or possibly any use at all, of the electric drive capabilities of their car. In these circumstances, a PHEV may have an emissions performance which is no better than that of its conventional ICE equivalent. First real world data from the Netherlands suggest that this is the case: drivers use PHEVs only at 35% electrically (Element Energy 2016 and TNO 2015). The Dutch Government reacted to these findings by correcting down purchase incentives for PHEVs. Although a larger data sample is needed to confirm this trend, the increasing sales numbers of hybrids suggest that degree of environmental benefit being derived from these vehicles is reason for concern.

Member states may need to review the scale of the financial and other incentives that they offer to PHEVs on environmental grounds, and ensure that all preferential measures are suitably structured in order to maximise the incentive for electric hybrid operation, and to discourage use of the conventional ICE engine except when strictly necessary. Tougher criteria may also be needed to ensure that only the best-performing PHEVs qualify for the available incentives.

Equally, it will be important that future EU standards or EV sales targets incentivise the most environmentally-friendly PHEVs, ie those with the longest and most realistic all-electric range, and those with the lowest average real-world CO_2 emissions.

3. Conclusions and Policy recommendations

The 2015 sales of EVs in Europe reached an important milestone reaching a 1% market share - a small but important niche. EV sales doubling in a year to at least 131,000, the largest annual increase in total to date. The most recent data in 2016 suggests further growth albeit at a reduced rate with a forecast of more than 200,000 plug-in vehicles to be sold in Europe this year. This takes the total number of EVs on the road to approaching 600,000, slightly more than half of new sales are PHEV.

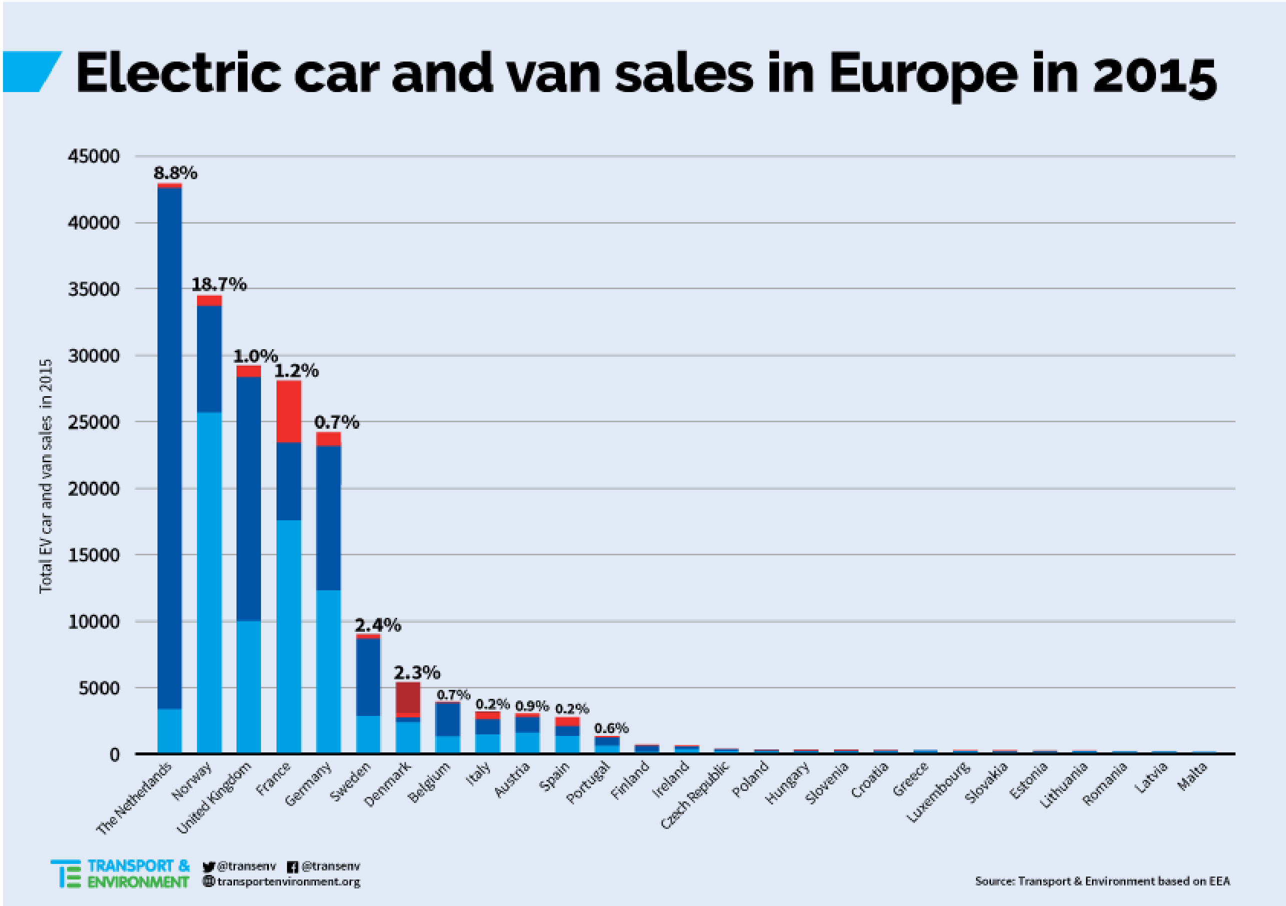

Figure 19: Electric car and van sales in Europe 2015

Contrary to common perception Europe is an important global market, albeit aided by strong sales in Norway. In the Nissan-Renault alliance Europe is also the headquarters of the world's largest manufacturer of EVs. Most European carmakers have, until recently been keen to talk-down the prospects for electric cars (largely because they have been slow to provide an offering into the market). That is now changing.

The raft of new announcements at the Paris Motor Show represents another milestone in the evolution of the electric vehicle in Europe. From their rebirth in the 1990's EVs are now adolescents and about to become highly disruptive. It is now clear that the demise of the "dirty diesel" and its replacement by clean, ultimately renewable electricity will be one of the revolutions in driving over the next 15 years along with the establishment of connected and progressively autonomous cars and growth of shared mobility services replacing traditional ownership models.

The rapid fall in price of batteries and further advancements in both performance and cost as a result of both technology developments and mass market production of large battery packs is the underpinning driver of the revolution. The cost of packs have reduced by more than 3 times to around 250 Euros per kWh in 2015 and further reductions to the critical 150 Euros per kWh level at which EVs compete with conventional technologies are anticipated by the mid 2020's enabling EVs to be competitive on a 4-year cost of ownership basis with conventional vehicles.[17] This is likely to result in comparable leasing prices with conventional vehicles making EVs a highly attractive offer for both businesses and private buyers that are increasingly making use of leasing arrangements.

Contrary to perceived wisdom, this the shift need not lead to the destruction of value in the European automotive industry. Fears that Europe will import batteries from the Far East or US appear to be increasingly unfounded with new production facilities planned by **Volkswagen** in Salzgitter (Germany); **Samsung SDI** in Hungary; and **LG Chem** in Wroclaw (Poland) and other plans in development. This will be additional the Nissan-Renault facility in Sunderland (UK). Furthermore, research by the European Climate Foundation shows that between 501,000 and 1.1 million net additional jobs could be generated by 2030 if cars shift from current engines to electric powertrains. By 2050, this rises to between 1.4 million and 2.3 million additional jobs.[18] These figures take full account of jobs lost in refining and distribution of fossil fuels. The benefits take time to achieve, because Europe's vehicle fleet takes 12 years to renew, but new jobs are created from day one. The shift to electric and connected cars can therefore provide new opportunities for the mature, largely replacement European automotive market.

But the progress Europe has made in shifting to EVs is based upon progress by a handful of countries and companies. Norway, Netherlands, Sweden and Denmark are the only countries achieving more than a 2% market share in plug-in vehicles. Sales in the UK, France and Germany are growing but the share still small.

[17] Element Energy (2016), to be published end of 2016.

[18] https://europeanclimate.org/wp-content/uploads/2014/03/FEF_Final.pdf

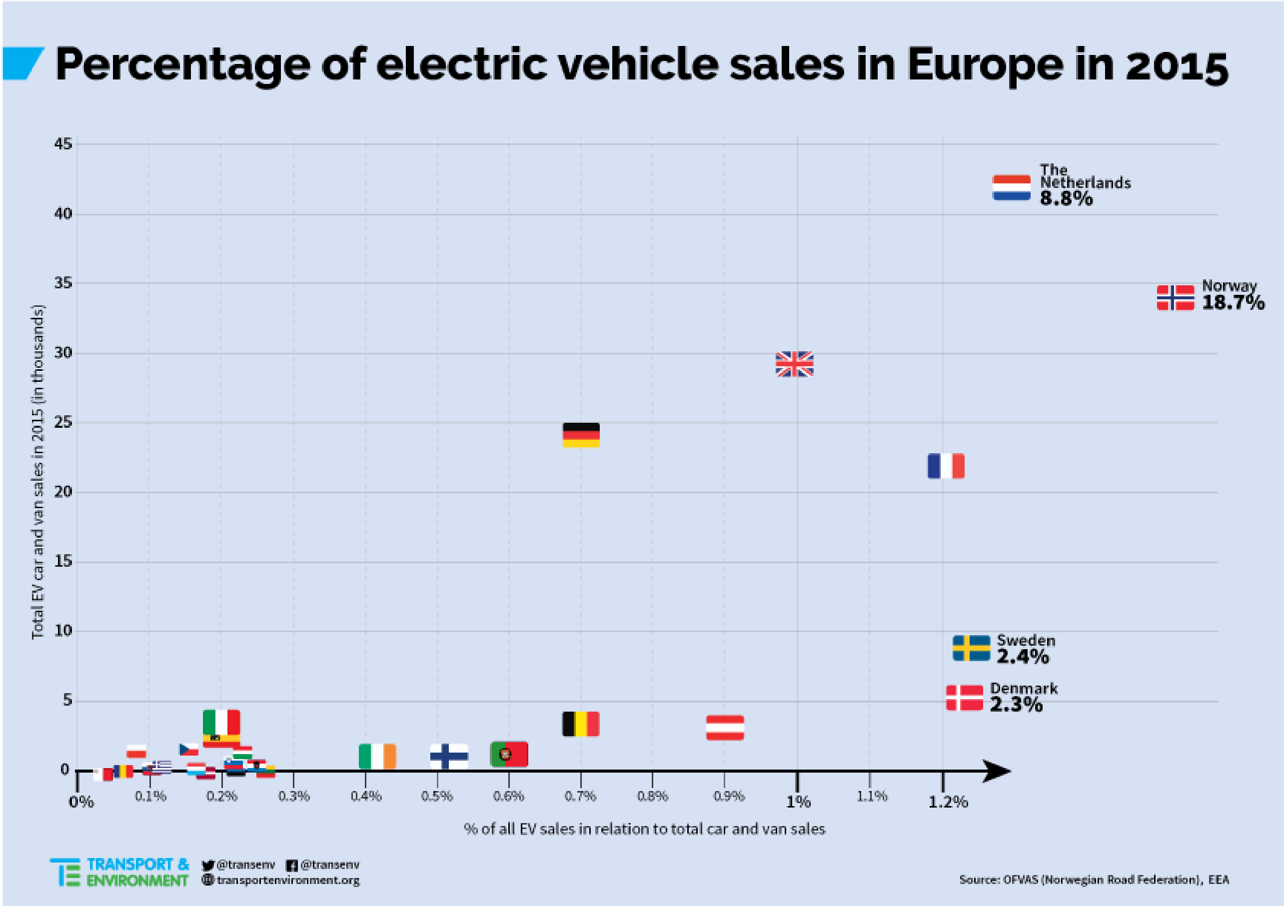

Figure 20: Countries by percentage of EV sales (cars and vans) in 2015

There is not a single market for electromobility in Europe as many countries continue to make minimal effort to support the transition either through incentives or establishing infrastructure and this must be the focus on action by the European Commission as part of its Energy Union. Member states have a key role to play in boosting the European market and 3 measures in particular are needed to increase demand for EVs:

1. A French-style bonus-malus form of taxation is needed in which the higher purchase costs of EVs are offset by lower taxes with higher charges on gas guzzlers and dirty diesels. This must include private and company car taxation systems.
2. There must be investment in quality infrastructure located where demand for charging is. This means ensuring access to appropriate recharging points for all EV drivers with low power chargers where cars are parked overnight; medium power where they are parked for short periods, such as for shopping or leisure activities; and high power on highways for rapid recharging. EU member states need to accelerate roll-out of EV charging infrastructure and implement the European Directive on Alternative Fuel Infrastructure (2014) allowing multiple plug standards and interoperable payment systems to be used on public infrastructure to ensure all EV users can charge seamlessly.
3. Governments and local authorities must exclude excessively dirty diesel cars from city centres (or require them to pay); and exempt or reduce charges for emission free plug-in vehicles. This measure can be complemented by other utility benefits for using an EV, such as discounting parking.

Just as few countries are making the difference so only a handful of companies are engaged in making the market. Mitsubishi, Porsche and Volvo are the only mainstream manufacturers to a sell more than 3% plug-in vehicles. In addition the Nissan-Renault alliance and increasingly VW sell a large numbers of vehicles. Other manufacturers have been "playing" at building an EV market. Some manufacturers continue to largely ignore the evolving market: Ford and Fiat being obvious examples. The recent announcements show a promising attitude change that is needed if these companies are to compete in the emerging global market.

With the notable exception of Nissan-Renault there is virtually no offering from either BEV or PHEV vans. This grossly neglected market is one rich in opportunities, particularly in the city delivery market where average daily distances are not long and vehicles return to depots overnight and can be recharged. The failure of the automotive industry to provide choice for their customers in this market is a largely ignored issue and the primary reason why sales of electric vans a fraction those of cars. The European Commission must act. The forthcoming car and van CO2 regulations provides the opportunity to encourage manufacturers to supply new models and build choice for customers. Co2 standards need to be issued in 2025 to reduce road transport emissions by 2030 and accelerate electrifying the vehicles fleet. T&E research has shown that from 2022 (2020 for vans), car makers will face a ZEV gap, i.e. will not be able to meet a -30% reduction by optimizing combustion technology. To help car makers close the 'EV gap', a sales target for ultra-low carbon vehicles in 2025 could be added or combined with the next CO2 standards.

Environmental risks emerge from a growing PHEV segment as these tend to be driven in electric mode only for one third of their mileage. Sales in this segment have been driven by attractive incentives that do not take into account the actual emission reduction delivered by these cars, especially if they are integrated into company fleets not giving drivers incentives to save fuel money. Only the best-performing PHEVs should qualify for the incentives in the future.

Europe also needs to ensure it is at the forefront of developments in battery technology. Recent announcements of new production is a welcome step but the EU needs to invest heavily in research to to develop better cells which the EU current battery industry is poorly placed to do. Since Europe has a technology gap concerning current lithium ion technology, investment should instead focus on breakthrough technologies such as new chemistries that may enable Europe to leapfrog competitors in South Korea and Japan and be at the forefront of the next revolution in battery chemistry, such as lithium air. This is unlikely to be in products for at least a decade and in the meantime by increasing demand in Europe for electric cars and vans we will create demand and expertise in manufacturing battery packs that will be assembled in Europe close to the growing market here. Recent examples of inward investment show by creating a market for batteries in EVs in Europe investment will follow and jobs will be created.

One of the primary criticisms of EVs from the oil industry, keen to maintain its virtual monopoly on the supply of energy to transport is that EVs do not reduce emissions but simply move them from the tailpipe to the chimney. Rapidly falling prices for renewable energy capacity installed in Europe, and reduction of carbon intensity of Europe's electricity show that this does not hold true. In addition, EVs on average are more energy efficient than ICEVs and reduce car transport's energy consumption overall. This is why a European EV policy needs to be part of the reformed EU Energy market. A market for EVs provides domestic demand for European renewable electricity, reducing Europe's dependence on oil and increasing energy security. Creating an EV market needs to be a priority for EU investments in a reformed electricity market beginning in late 2016, a more flexible electricity grid allowing better demand-response, smart charging and storage solutions for optimal integration of EVs into the grid.

When T&E produced its last examination of the EV market in 2014, the market was significantly less mature but equally promising. However, there were serious concerns that Europe's focus on diesel powertrains would make it a laggard in the global market and that electric powertrains represented a threat to this traditional strength. This report shows Europe is a serious EV market and has growing industrial strength.

Furthermore, the #dieselgate debacle has firmly closed the door to a global diesel market and the niche 1 in 20 new cars sold globally that is a now diesel will only decline. This realisation by Europe's carmakers has been the trigger for many exciting new announcements, most notably from VW and hopefully marks a paradigm shift. Finally, it is important to remember that electric cars and vans providing only part of the electromobility revolution that is underway. Light Electric vehicles are innovative and offer alternatives to short trips with conventional cars, but remain largely ignored. Electric quadricycles should be incentivised through the car CO2 regulation. Even more important are the growing numbers of electric bikes and scooters that make it easier for longer distance commuting than conventional pedal cycles. Electromobility including electric trains and trams provides the opportunity for a clean, green mobility future that assign dirty diesel cars and trains that choke cities and commuters to the dustbin of obsolescence. Through constructive policy interventions at an EU, national and local level the revolution can be accelerated and our cities become quieter, cleaner and the imminent threat of dangerous climate change abated. This is no longer o question of whether this happens - but how quickly.