GLOBAL FUEL ECONOMY INITIATIVE

UC DAVIS INSTITUTE OF TRANSPORTATION STUDIES

CAN WE ACHIEVE 100 MILLION PLUG-IN CARS BY 2030?

Working Paper 13

FIA FOUNDATION | UNEP | UC DAVIS INSTITUTE OF TRANSPORTATION STUDIES | iea International Energy Agency | icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION | International Transport Forum

Acknowledgements

This publication was co-authored by Lew Fulton (Co-Director, STEPS Program), Gil Tal (Senior Researcher, PH&EV Center) and Tom Turrentine (Director, PH&EV Center), of the University of California, Davis, Institute of Transportation Studies.

The authors would like to acknowledge very helpful comments from the IEA (Pierpaolo Cazzola and Marine Gorner), ICCT (Zifei Yang), ITF (Wei-Shiuen Ng) and Alex Korner. However the authors are responsible for any errors in the analysis or data. The authors would also like to thank the FIA Foundation for their support of the UC Davis STEPS program and Sheila Watson, Richard Clarke and the FIA Foundation for their direct efforts to help produce this paper.

Table of Contents

Executive Summary

This paper explores recent trends in the market penetration of plug-in electric vehicles (PEVs) in selected countries around the world, and the implications of this for a potential transition to a fairly dominant PEV market presence within the next 15 years. A useful context is provided by the Paris Declaration on Electro-mobility (UNFCCC, 2015), which calls for 400 million PEVs on the world's roads by 2030, of which at least 100 million are expected to be passenger light-duty vehicles (automobiles, sport utility vehicles/SUVs, vans and passenger light trucks). Today there are about one and a quarter million PEVs (IEA, 2016), comprised of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), on the world's roads with the vast majority in the United States, Europe, Japan and China. Thus the Paris Declaration represents a call for nearly a 100 fold increase in these numbers over the coming 15 year period.

This paper investigates the feasibility and extent of the challenge in achieving such a target in a number of ways:

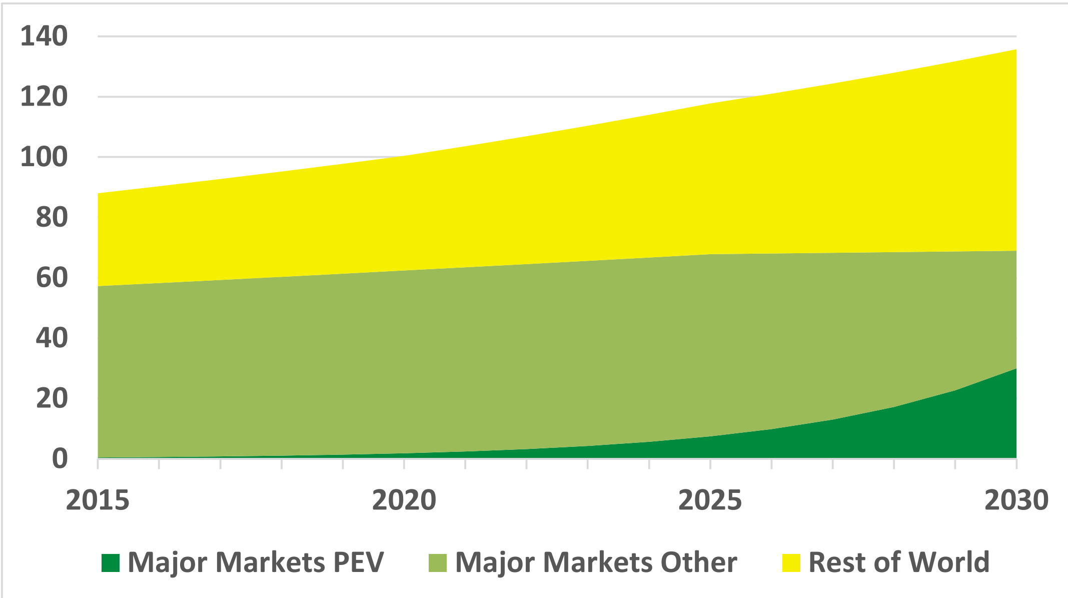
- It reviews the status and recent trends in development and sales of PEVs across the 8 largest world markets (China, Japan, France, Germany, Netherlands, Norway, UK and US), representing the vast majority of global PEV sales to date.
- It explores the expected growth in all light-duty vehicle sales and stocks around the world, and what a 100 million target may mean in terms of a necessaryinternational sales growth trajectory for PEVs.
- It undertakes a PEV market analysis for a few specific countries.
- It creates one plausible scenario for growth in PEV sales to meet the target, and how growth in sales per model sold can help drive the much needed growth in the number of models offered.
- It considers some of the challenges in achieving this scenario, and some initial considerations around policies needed to achieve the 100 million target.

Regarding achieving 100 million PEVs worldwide by 2030, our analysis finds:

- To reach a global stock of 100 million PEVs by 2030, sales growth will need to be very rapid and reach somewhere between 20 and 40 million per year by 2030, depending on the shape of the sales growth curve. Here we use a 30 million target which represents a slightly declining growth rate over time, consistent with a growing market, and an average growth rate of about 35% per year for 15 years.
- This target can be thought of in terms of numbers of PEV models multiplied by the average sales per model. For example, 30 million sales could be achieved with 100 models of PEV selling 300,000 units each around the world in that year, or 300 models selling 100,000 units each; either way a daunting challenge. We look at the case of 200 models with 150,000 unit sales.
- Figure ES-1 shows one potential sales trajectory to get to 30 million per year in 2030. If it occurred completely in the current "Major Markets", it would represent nearly half of the projected 4-wheel passenger light-duty vehicles (PLDV) sales in those countries in that year. Clearly it will be easier to meet this challenge if a significant number are also sold in non-OECD countries, where nearly all overall PLDV sales growth is expected to occur.

- Although the 30 million sales target is not that large compared to the projected global PLDV sales in 2030 (about 22%), it becomes a more daunting task when considered from the point of view of the required growth rates in PEV markets around the world.

Figure ES-1: Achieving 30 million PEV sales in 2030



Source: PLDV sales projections from IEA 4 degree scenario (4DS)

Other key findings of this paper include:

- Though 2015 is still "early days", it is encouraging that between 2011 and 2015, PEV sales across the top 8 world markets (US, Japan, China, and 5 European countries) showed an overall steady increase with average growth rates over 50% in all years (though this is not true of all countries individually). The number of PEV models available across most of these countries also increased steadily, with by 2015 a reasonable overall balance of PHEV vs. BEV models, and across different light-duty vehicle market classes (i.e. small, medium and large/luxury cars as well as SUV models). By far the weakest PLDV segments for models and sales were vans and pickup trucks.
- However, these trends were quite uneven across the 8 countries and in 2015 there was still a lack of wide PEV model selection in key market segments in most countries. Although in our database we track close to 100 PEV models worldwide, very few were sold in more than a few countries.
- A deeper look at the US, France and Japan shows that, across all passenger light-duty vehicle sales, there are very different distributions by market class, and that the models of PEVs were not well aligned with the various dominance of vehicle types in these countries. It also showed that average sales per model for PEVs were quite low relative to non-PEVs. On the other hand, BEVs tend to dominate smaller vehicle classes and more PHEVs are now appearing in larger car segments (such as SUVs), which may be appropriate given the characteristics of these two types of PEVs.
- An examination of PEV prices across compact and mid-size car market segments in the U.S. shows that the PEVs sold tend to be quite expensive for these market classes, even with national

price incentives. Given the tendency for high price sensitivity of consumers in these market classes, it is not surprising to see that some of the more successful PEV models are in premium market classes.

- We estimate that the benefit of price incentives, in terms of making PEVs more price competitive, rises rapidly for PEVs that are competing in these lower price categories, especially once it puts their sales price into a zone where large numbers of conventional vehicles are sold. Current US national incentives do not appear to help current compact and mid-size PEV models reach these price points.

In the next phase of the study, a deeper policy analysis will be undertaken, including a competitiveness analysis taking into account the impact on likely market trends of a full range of vehicle attributes such as vehicle range and recharge time, and the effects of various public policies on PEV competitiveness by country and market segment. We will also develop more detailed scenarios of vehicle sales to 2030 and how 100 million cars on the world's roads by 2030 could be reached.

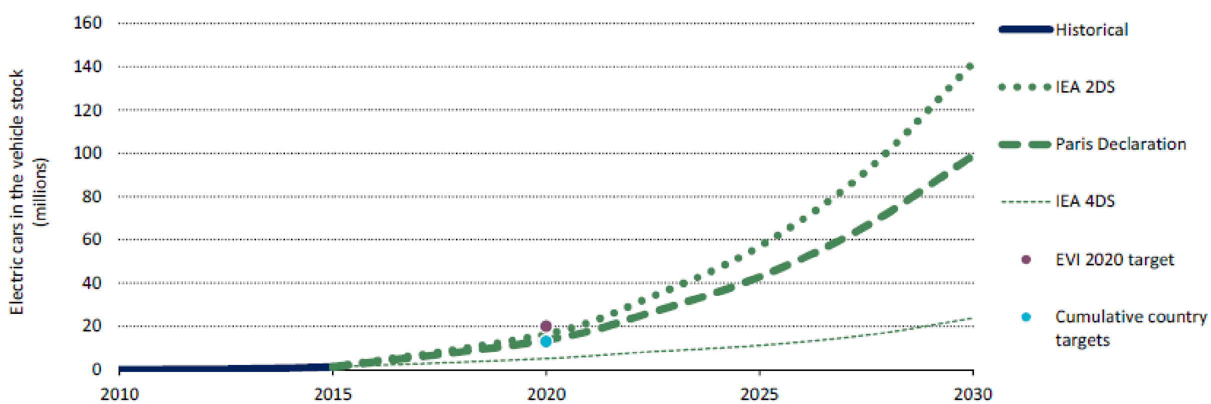
1. Introduction

Plug-in electric vehicles (PEVs), including battery electrics and plug-in hybrid electric vehicles, will need to play a major role in the future in order to achievedeep decarbonization of transportation systems around the world. This is especially true post-2030, when efficient conventional cars alone will not be sufficient to reach a 2 degree emission trajectory (IEA 2016). The recently adopted Sustainable Development Goals (UN, 2015) call for a doubling of the energy efficiency improvement rate, as well as major reductions of air pollution. PEVs can contribute to both goals.

To play a major role post-2030, PEVs will need to reach full commercialization and large sales levels by 2030. The Paris declaration on electro-mobility (UNFCCC, 2015), launched at the 21st session of the Conference of the Parties (COP21) in Paris in December 2015, calls for at least 20% of all road vehicles around the world to be electrically driven by 2030. Even if a very high share of 2-wheelers were electrified by then, achieving this20% target would also require a large number of 4-wheel passenger light-duty vehicles (PLDVs) to be electrified; the declaration explicitly mentions 100 million or more, out of the expected 1.5 to 2 billion PLDVs on the world's roads by 2030. While still a small share of the global totals, achieving 100 million by 2030 compared to today's number of around 1 million plug-in electric vehicles will require a very rapid rate of growth in sales – effectively a revolution with some markets at very high sales shares to help lead the way.

It should be noted that there are other targets in play – notably the IEA ETP 2 degree scenario, which targets 140 million PEV light-duty vehicles by 2030 (shown Figure 1, taken from GEVO 2016). This will clearly be even more challenging to reach than the Paris Declaration 100 million target. There are also targets for 2020 shown in the figure. All of these will be challenging to achieve. This paper focuses on the Paris Declaration 100 million target for 2030.

Figure 1. Different PEV targets for 2020 and 2030



Source: GEVO 2016, Figure 9.

Can the world reach 100 million electric passenger cars by 2030? What will be required to do this? This paper explores this future by drilling into some of the details and projecting how different aspects of the market, in multiple countries, would need to develop, and highlighting the challenges that are likely to be involved. These challenges include technical ones, economic ones, policy ones, consumer preferences and simple market dynamics – rates of change in sales and rates of technology diffusion that, at least for automotive markets, are faster than what we typically have seen in the past for major new automotive and new fuel technologies, although there are some encouraging recent examples of rapid tech market penetration[1]. Recent studies suggest this is possible (and is in fact consistent with summing the targets set by a range of national governments, GEVO (2016), Lutsey (2015a)), but will be very challenging to meet.

If the 100 million target can be achieved it will lead the way into a new world from which there is likely to be no going back. It seems reasonable to assume that it will put the world on a path whereby perhaps all new cars and other light-duty vehicles operate on electric drive by 2040, and a high share of all cars on the road do so by 2050. Coupled with a transition to low-carbon electricity generation around the world, this transition to electric vehicles could lead to very low operational CO_2 emissions from passenger cars in this time frame – though that assumption (of clean power) is critical to realize this outcome. In any case, a world with plug-in electric drive vehicles operating on low-carbon electricity is the vision behind the Paris declaration, and has fairly broad support as a strategy for decarbonizing automobiles by 2050.

This paper considers the 100 million PEVs in 2030 scenario from several perspectives. First, we develop a scenario with sufficient detail to have a rough idea what level of sales might be needed in different parts of the world, and how fast PEV sales growth may need to occur. Next we look at where things stand in 2016, both in terms of sales and in terms of other market and policy characteristics. Third, we roll out new PEV models and assume sales growth, and diffusion, on a global/regional basis to identify the growth rates that will be needed. Finally, we take an initial look at policies for achieving the 2030 target. A deeper policy analysis will be provided in a follow-on paper.

This paper specifically addresses:

- The numbers and types of PEVs in specific markets and the trajectory of sales to 2030 that would likely be needed to meet the 100 million target;
- How this breaks down into the required number of PEV models and sales per model by markets and market segments;
- Some initial considerations of the need for models to be competitive within their segments, and where policies could most effectively help achieve this.

This paper is intended as a "think piece" on this topic but also as guide for countries; and also for the GFEI, for whom an active involvement in advancing PEVs will help carry forward the idea of sustainable, individual motorized transport – based mainly on maximizing the efficiency of conventional combustion engine vehicles in the near- to mid-term (GFEI 2014) – to a long-term, truly low carbon future.

2. Electric vehicle market status worldwide

Vehicle type

Battery electric and plug-in hybrid electric vehicles are currently sold in significant numbers in just a few countries around the world. These include the large car markets of the EU (particularly northern EU), Japan, the U.S. and China.

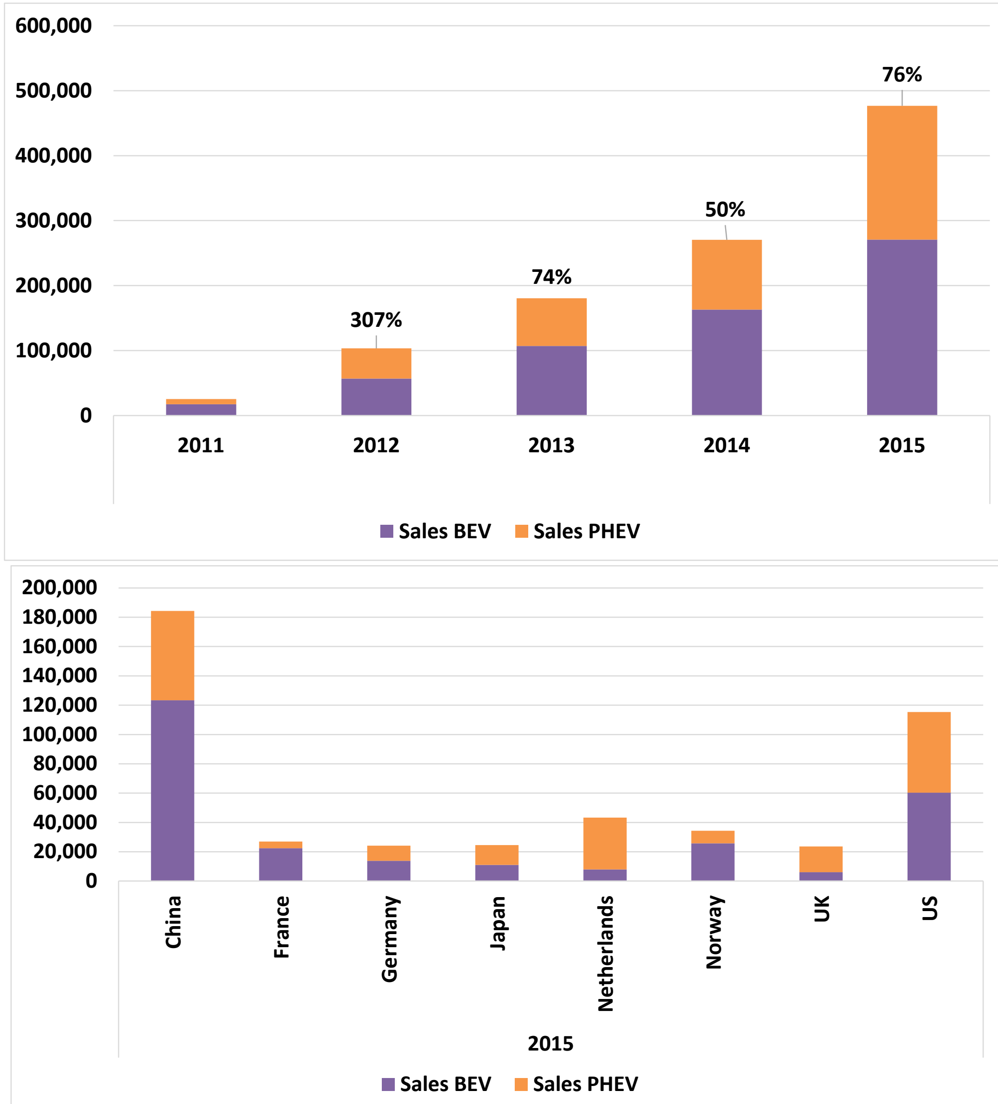
[1] Though there are some cases where such fast increases have been observed, such as diesel uptake in Europe (GEVO 2016)

In 2015, about 550,000 PEVs were sold worldwide, with the vast majority in the 8 countries included in Figures 2a and 2b, including both battery electric and plug-in hybrid cars[2]. The sales growth rate has been impressive, with 50% or more increase in sales across the 8 markets each of the past 4 years, and 71% in 2015. In 2015, China became the largest PEV market, followed by the US, after four years where the US was largest. In the same year, European nations together reached the sales level of the U.S.

Since 2011, the international market has shown impressive growth, yet PEVs still account for less than 1% of the 90 million-per year global PLDV market. As a percentage of sales the dominant leaders at this time are Norway where PEVs have over 20% market share, and the Netherlands with around 10%. No other country has more than about a 2% market share (Sweden and Demark were slightly over 2% in 2015, all others were below 2% (GEVO 2016). Figure 2b also shows that countries are experiencing a large variance of relative shares of BEV and PHEVs, with the Netherlands and UK leading on PHEV share and Norway and France on BEV share. The United States, Japan and Germany had close to equal shares of the two.

[2] The data used in this paper is based on a range of data sources and was compiled by UC Davis. These data do not precisely match other compiled data sources such as EIA (as shown, for example, in GEVO 2016). In the future, better alignment of international PEV data and data sources is a goal of GFEI.

Figure 2a and 2b: PEV sales in eight largest vehicle markets (annual sales growth rate above bars)

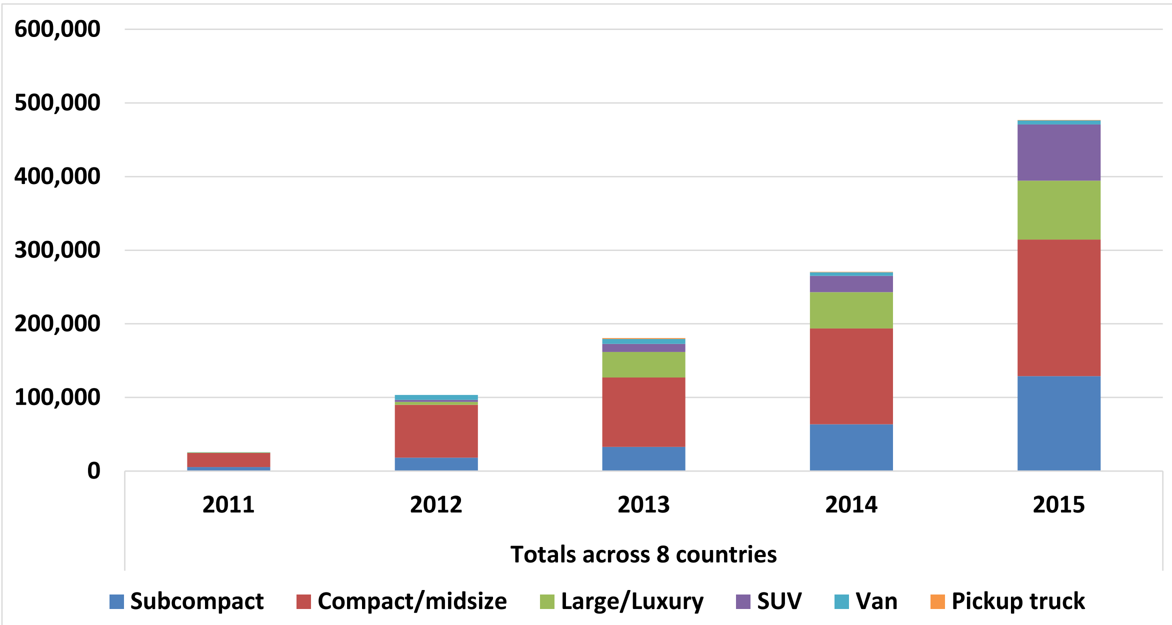


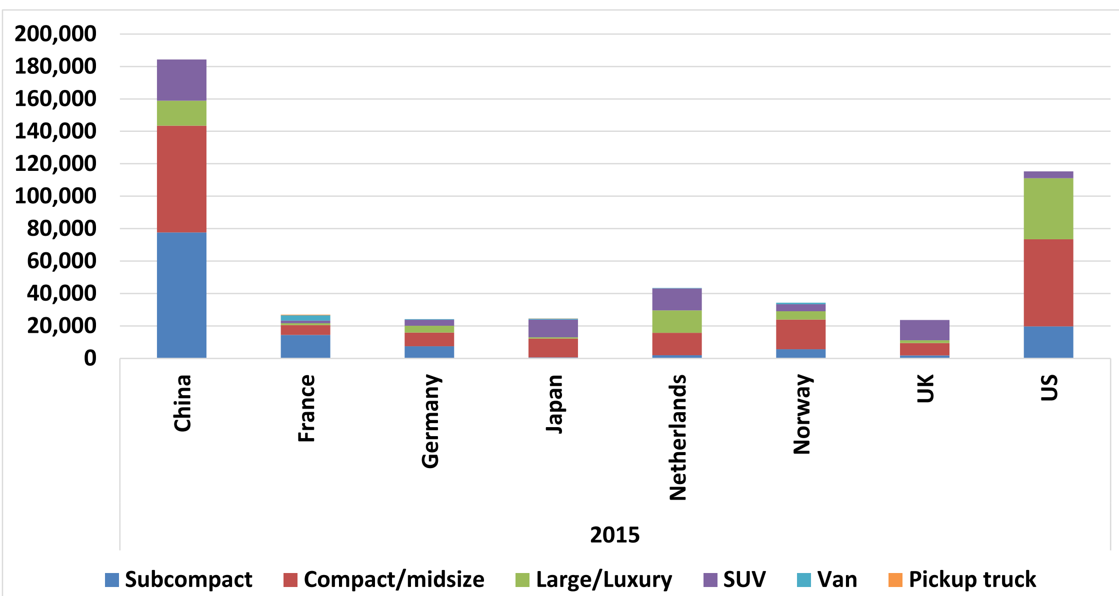
Source: UC Davis compiled data based on a range of internet sources (see references).

Vehicle size

Another view on PEV sales is by market class. Figure 3a shows the evolution of sales 2011-2015 on this basis, while Figure 3b shows it by country for 2015. These show that PEV sales are concentrated in cars rather than "light trucks" (SUVs, vans and pickups), with the latter categories accounting for about 15% of PEV sales in 2015 (nearly all of which was SUVs), and well less than 10% in most of the 8 countries. On the other hand, SUVs were the fastest growing group in 2015.

Figure 3a and 3b: PEV sales by market class



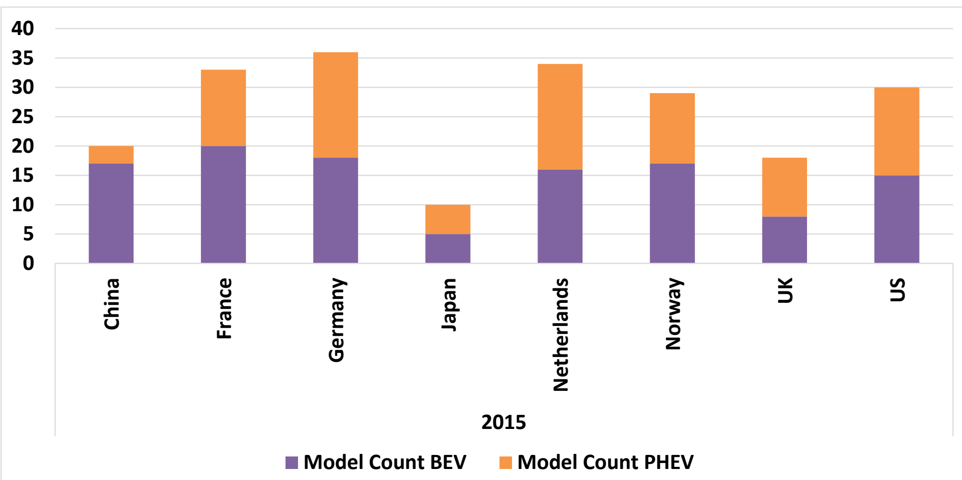


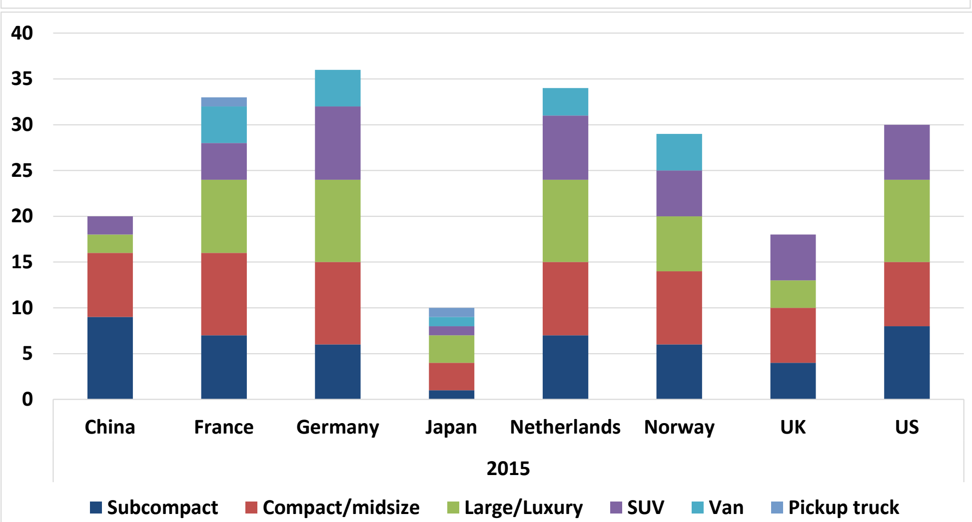
Number of models

The market development of PEVs is uneven across countries, and across PEV types (both in terms of BEV vs. PHEV and in terms of market class shares). One reason for these sales differences is the relative availability of specific models of PEV. There are fairly divergent offerings of PEVs in these 8 countries – including within the different countries that are part of the EU.

Figures 4a and 4b show the number of PEV models offered for sale in the 8 countries in 2015, broken out by BEV/PHEV and by market class. While there appears to be surprisingly good availability of different types of PEVs across most of the countries, some interesting differences emerge. The two countries with the lowest PEV sales (Japan and UK) also have quite low numbers of models on offer. This may reflect a number of factors, such as manufacturers choosing not to sell models in those countries, but in any case it suggests that the number of models on offer matters in terms of total PEV sales. There does appear to be a reasonable selection of models in most countries across market classes – though the absolute numbers are quite small compared to the numbers of conventional vehicle models on offer (over 500 in larger markets like the US and China, as well as around the EU).

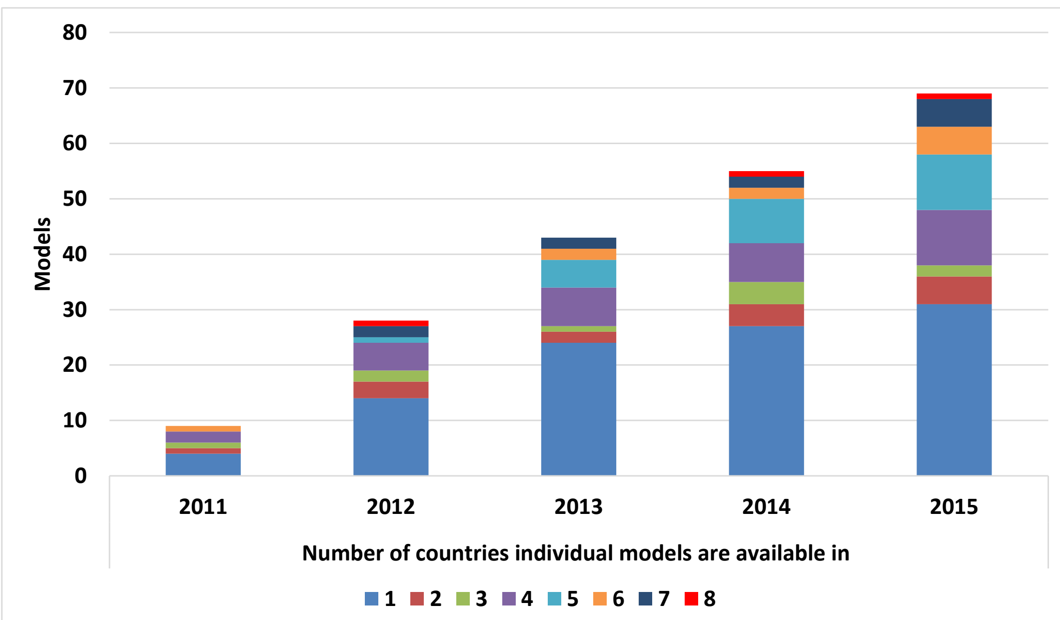
Figure 4a and 4b: PEV model counts by vehicle type and country, 2015





Another question is whether individual models are sold across markets, or whether they are concentrated in just a few markets (and thus with a more splintered global PEV market). Figure 5 traces the growth in the number models available for sale from 2011 to 2015, from the point of view of how many countries they were sold in. One evident trend is an increase in the number of PEV models offered – reaching at least 70 worldwide by 2015. However, no clear trend has emerged so far – there has been steady growth in the number of models available in only one country (typically US or China) along with those available in many countries. Almost no models were available in 2015 or earlier years in all 8 countries, though there has been growth in the number of models available in 5 to 7 countries. Overall, many models may be restricted in global sales because of the limited number of markets they are sold in. Availability in only a few countries could reflect technical obstacles, such as incompatible charging infrastructure across countries. Type approval may be a challenge in some countries, for some models. And some may just be targeted to a single market or sold by small manufacturers that are not in a position to sell internationally.

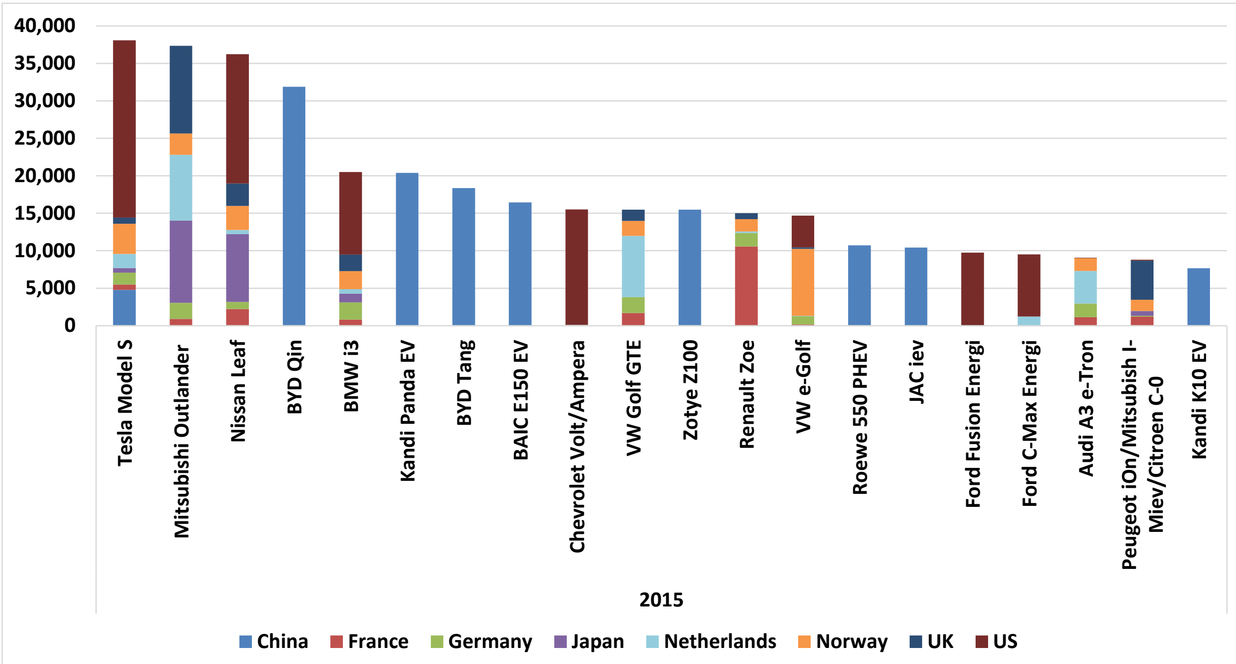
Figure 5: Number of countries in which individual PEV models were sold



Model sales in different markets

Figure 6 looks at the sales situation from the point of view of specific models. It shows the 2015 sales of the top 20 selling PEV models worldwide, and where they sold. There are arange of experiences, but the top three selling models, the Tesla S, Mitsubishi Outlander and the Nissan Leaf, sold in a range of different countries. The Tesla S and Nissan Leaf had the U.S. as something of an “anchor” country, while the Mitsubishi Outlander was notable for being sold mainly in European countries. Some models did reasonably well selling in only one country, but in almost all cases this country was either the U.S. or China. Clearly, models that were only sold in one or two small markets were not likely to be high sellers. One notable exception was the Volkswagen e-Golf, which was one of the top selling models in the robust PEV market in Norway.

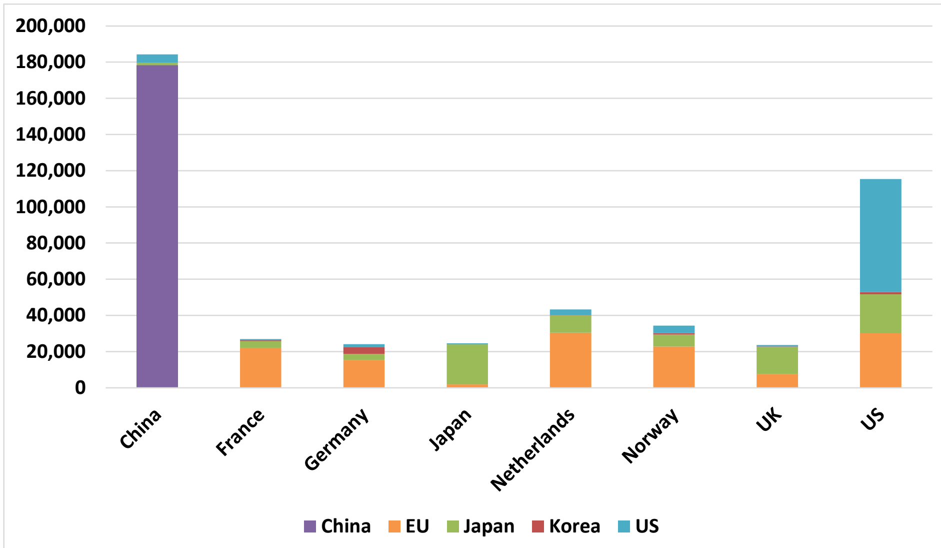
Figure 6: Sales of top 20 countries in 2015, broken out by country of sale

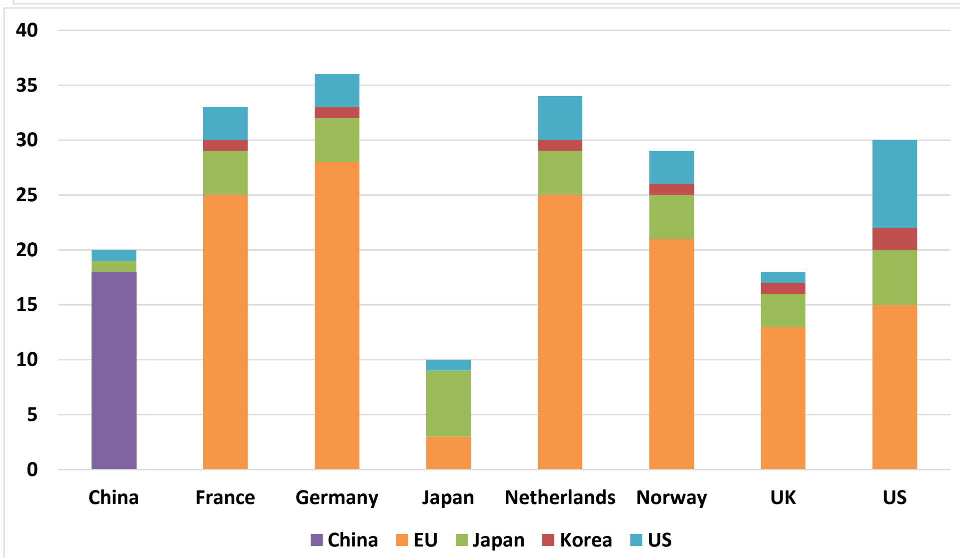


Finally, Figures 7a and 7b show the 2015 sales and numbers of PEV models in the top 8 markets, broken down by vehicles produced by domestic manufacturers versus those by foreign manufacturers (based only on the nationality or region of the manufacturer, not the specific location of production). There was a range of experience, but typically national producers have done well within their own country (if there are any). China and Japan sold almost exclusively PEVs produced by Chinese manufacturers (some in collaboration with foreign manufacturers, but with the Chinese manufacturer nameplate), while the US and European countries sold a mix of domestic and international models. Japanese models (such as the Nissan Leaf) did well in most international markets while the only other regional “crossover” was that models from EU manufacturers did well in the US. This is mostly consistent with the availability of models across the 8 markets – the one clear difference being the widespread availability of U.S. manufacturer models in Europe, but with modest sales.

All of this shows that there is as yet relatively little “cross fertilization” of models from different regions selling in other regions. A greater spread of “internationalism” may help to increase the overall rate and level of PEV sales over time.

Figure 7a and 7b: sales and models available within top 8 markets by country of vehicle manufacturer





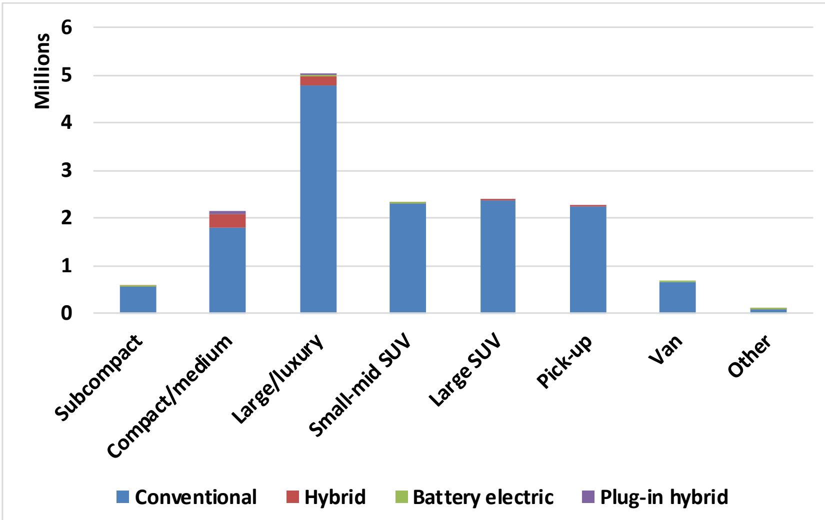
3. Three PEV markets in more detail

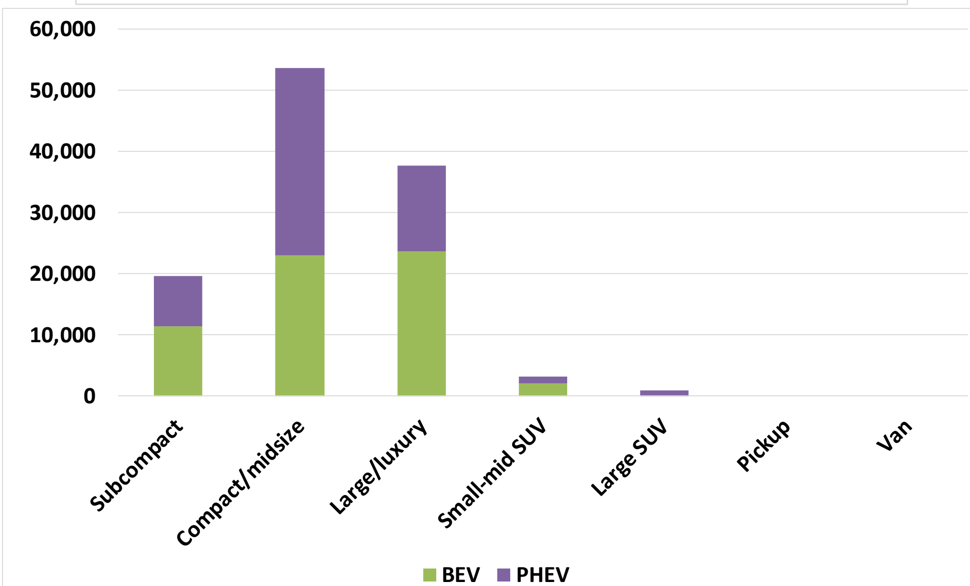
To further explore questions around the sales of PEVs across countries and market classes, we now consider three PEV markets in somewhat greater detail andin the context of the broader light-duty vehicle markets the US, France, and Japan.

United States

In the United States, sales of light-duty vehicles (LDVs) tend to be dominated by relatively large cars, SUVs and pick-up trucks. This is fairly unusual world wide – the U.S. has by far the highest market share of these types of vehicles (relative to small cars) of any major world market, and lowest share of subcompact (European market class A and B) vehicles. Figures 8a and 8b show the U.S. sales distribution of all passenger light-duty vehicles (PLDVs) for the most recent year available (2013) and just for PEVs (updated tor 2015). This reveals that while medium and large cars, SUVs and pickups are the dominant market classes in the US, sales of PEVs are to date occurring mainly on the medium to smaller car side. Even hybrids (shown in the left hand graph) sell mainly in the compact and medium/large car segments, rather than SUVs or pickups. There are very few sales of hybrids, BEVs and PHEVs in light truck (SUV or pickup) market classes.

Figure 8a and 8b: U.S. PLDV sales in 2013 by Market Segment and technology/fuel type, and just PEV sales (updated to 2015)

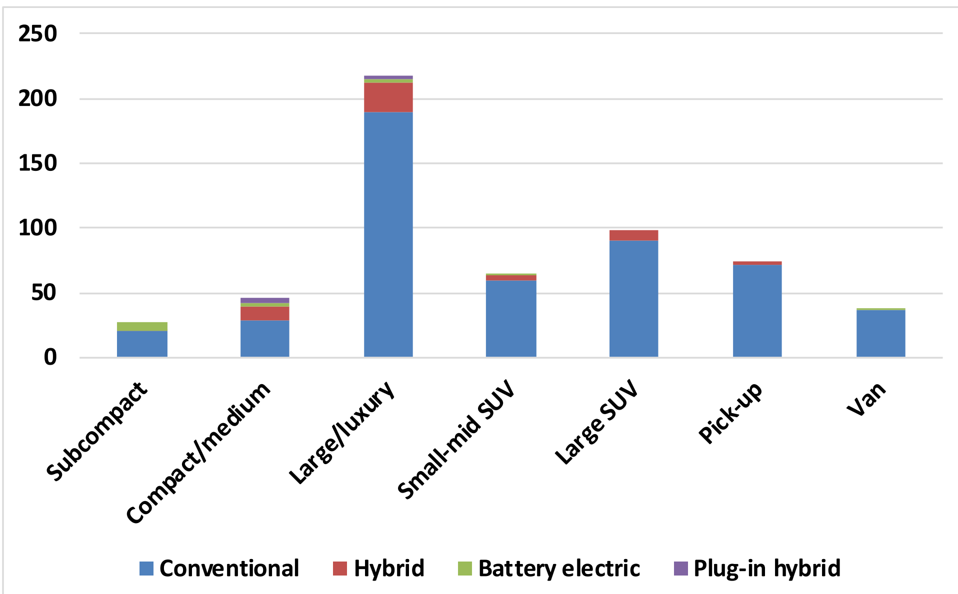


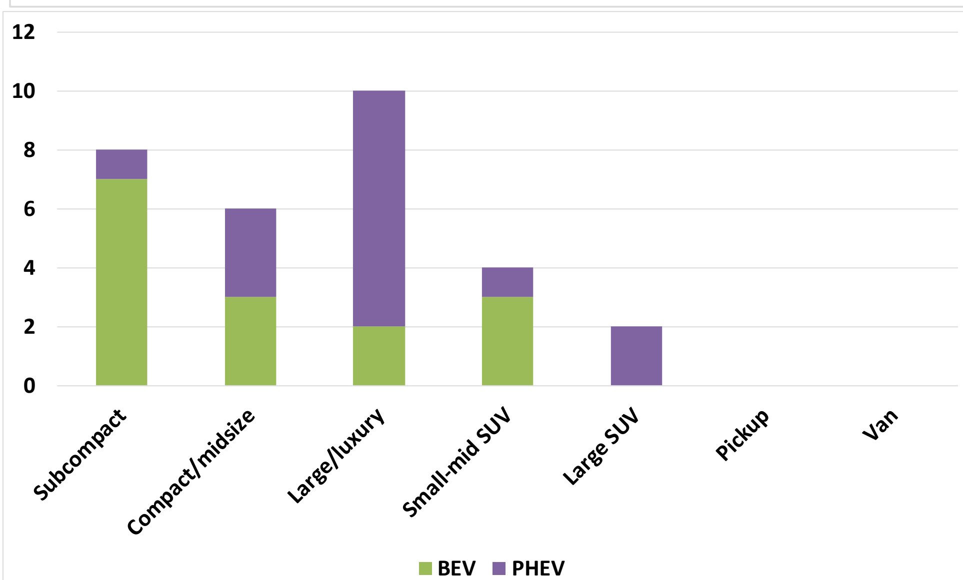


Looking at the number of PEV models on offer, Figures 9a and 9b show that one reason for the preponderance of PEVs in just a couple of car classes is that the number of models offered in most car classes is roughly proportional to the sales of that car class. To some degree, this is true for BEVs and PHEVs as for other types of cars; clearly the reason that BEVs had no sales in the pickup and van classes is because there were no models on offer. Similarly there were only two models on offer in the large SUV class. On the other hand, there were many models offered in the subcompact class, more than in the compact/midsize class, but sales for subcompacts were far lower (as per previous figure).

The focus on producing PEV models for car rather than light-truck market segments may reflect the fact that smaller (and lighter) vehicles need smaller battery packs and are thus cheaper to produce; they are also more oriented toward shorter range driving (such as mainly urban driving), than longer cars. But it does mean a lack of PEV availability in market segments that account for a large share of U.S. LDV sales.

Figure 9a and 9b: U.S. vehicle models offered in 2013, by market class and technology/fuel type, and updated to 2015 for PEV models



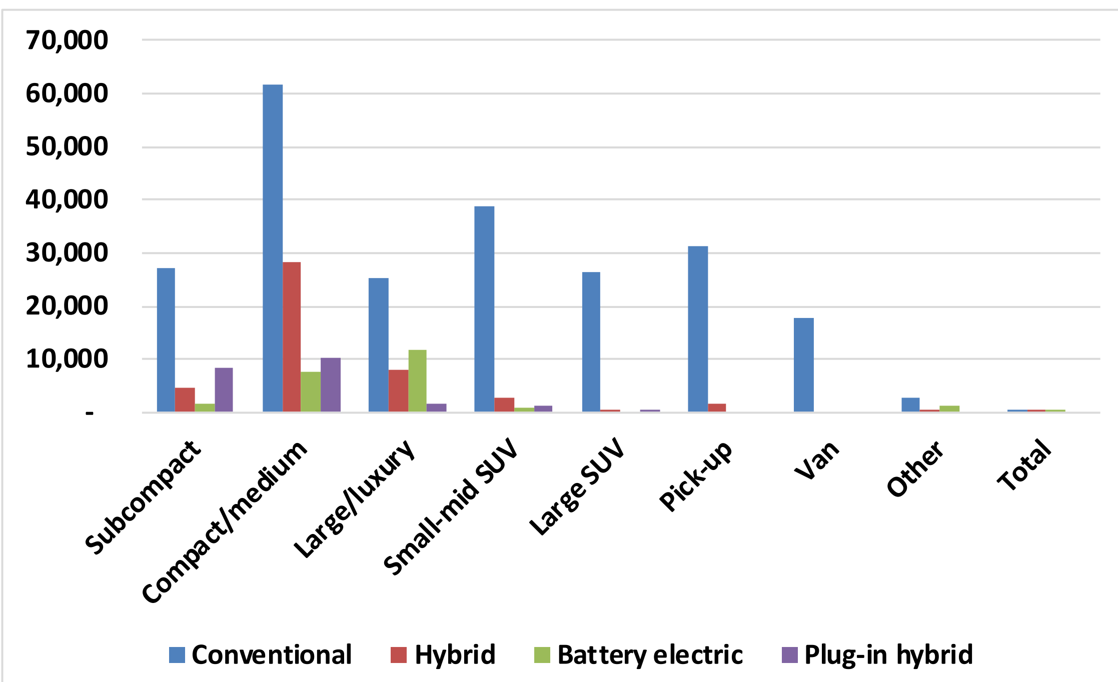


Another metric, average sales per model by market segment and vehicle technology, is shown in Figure 10. This is obtained by dividing the total sales within each segment by the number of models sold in that segment. In the U.S., compact cars have by far the highest sales per model, with an average around 60,000, while most other classes average in the 20,000-40,000 range. This reflects a fairly high variance – top selling models such as the Honda Civic and Toyota Corolla are well over 100,000, with some models far below 50,000. Similarly a few pickup trucks such as the Ford F-150 sell hundreds of thousands of units, but these are offset by many low-sales models, resulting in the average around 30,000 per model. Thanks mainly to the Prius, hybrids sold an average of 30,000 in the C class.

At such an early stage of market introduction of PEVs, the relationship between the number of models offered and the sales in those market classes (and thus average sales per model) is similarly idiosyncratic – much can be explained by the success or failure of individual models. The Nissan Leaf (compact class), Chevy Volt (compact class) and the Tesla (sport class), account for more than half of all PEV sales. On the other hand, there does appear to be a pattern that PEVs have tended to be offered in very small car classes, while most LDV sales are in larger car and light-truck classes.

One reason for the low average sales of PEVs, especially in the subcompact class, is that there are really two types of models on offer: limited production models, sometimes titled “compliance cars” that are built by the OEMs to explore the technology and meet the Californian Zero Emission Vehicle (ZEV) program requirements, and larger production vehicles that though limited in production are still designed to be sold well above the ZEV requirement needs.

Figure 10: United States 2013 average sales per model (updated to 2015 for BEV/PHEV) by market segment



These figures indicate that it is “early days” for battery electric and plug-in hybrid vehicles, with relatively few models offered (and no models in some important market classes), and with quite low average sales per model in every segment.

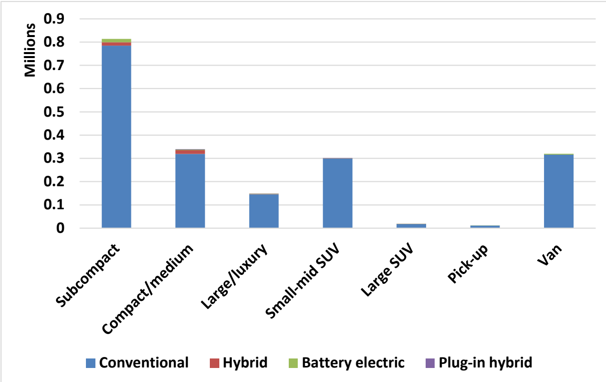
In some respects, the French and Japanese car markets provide a striking contrast to the U.S. situation: for example both are dominated by small car sales, and neither has a significant number of large SUVs or pick-up trucks.

France

As shown in Figures 11a-11e (in particular 11b), the French market in 2015 had around 25,000 electric-drive vehicles registered, and more than half were in the sub-compact class (such as the Renault Zoe), the rest being mainly compact cars (e.g. Nissan Leaf). Several hundred plug-in hybrids were sold, all of them in the medium/large car class. In terms of numbers of models, there were actually more medium/large car models on offer than any other segment, but average sales were fairly low as many of these are low volume luxury models. Electric drive vehicles were available in a fairly wide array of classes but there were far more subcompacts than any other type, and these were clearly the most successful (keeping in mind that total sales were very small for all electric drive vehicles).

In general, sales per model in France are very low compared to the U.S., not surprisingly since it is a much smaller market. However there are nearly as many different PEV models available in France as in the U.S., probably due mainly to its position within the EU, sharing the much larger market, and serving as one of the current leaders in adopting PEVs. But sales of plug-in vehicles in 2015 averaged less than 1000 per model in all market segments except for subcompacts, indicating some combination of low production volumes, low competitiveness of these models and/or a very immature market (e.g. low awareness of available models).

Figure 11a-b: France new registrations, 2013 (updated to 2015 for PEV models)



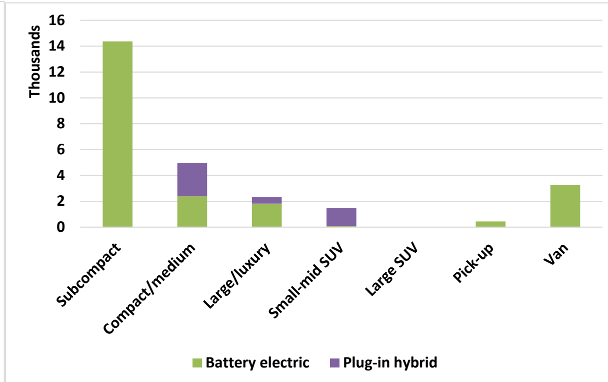
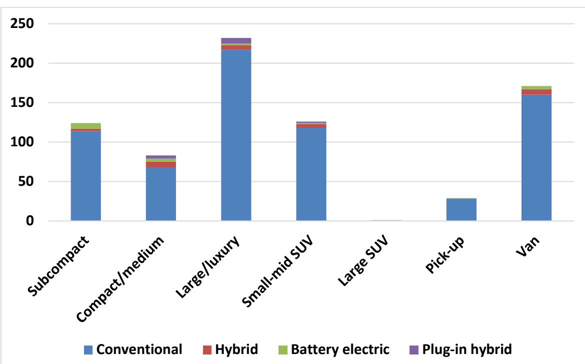


Figure 11c-d: France number of models offered for sale, 2013 (updated to 2015 for PEV models)



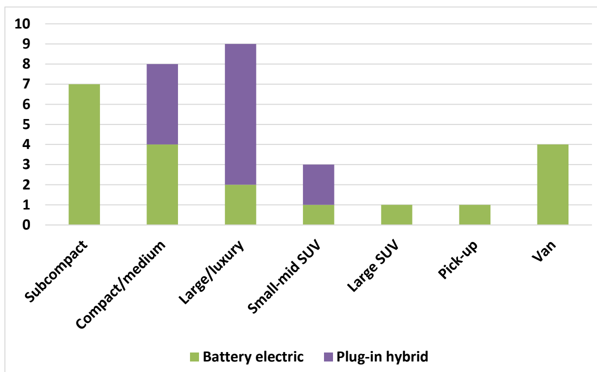
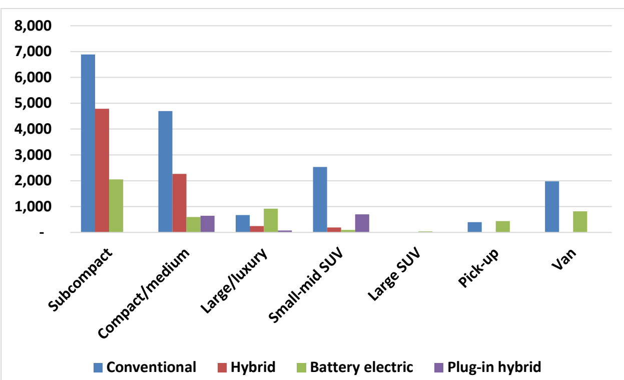


Figure e: France sales per model by market segment and technology



Japan

Japan is not that different fromFrance in terms of the dominance of small cars there, but two notable differences emerge (Figures 12a-12e). One is that compact cars in Japan in 2013 were dominated by sales of hybrid vehicles. This is probably the most successful market segment for hybrids in any country in the world (with the possible exception of Sri Lanka). The other difference is that electric drive vehicles in Japan were dominated by compact cars (namely the Nissan Leaf) rather than the subcompacts in France. Of the four subcompact electric vehicles available in Japan none sold more than a few hundred units. This may be related to the dominance of “kei” cars in this market segment, which are very low cost and create an environment that PEVs may have a difficult time competing with.

Figure 12a-12b: Japan new registrations, 2013 (updated to 2015 for PEV models)

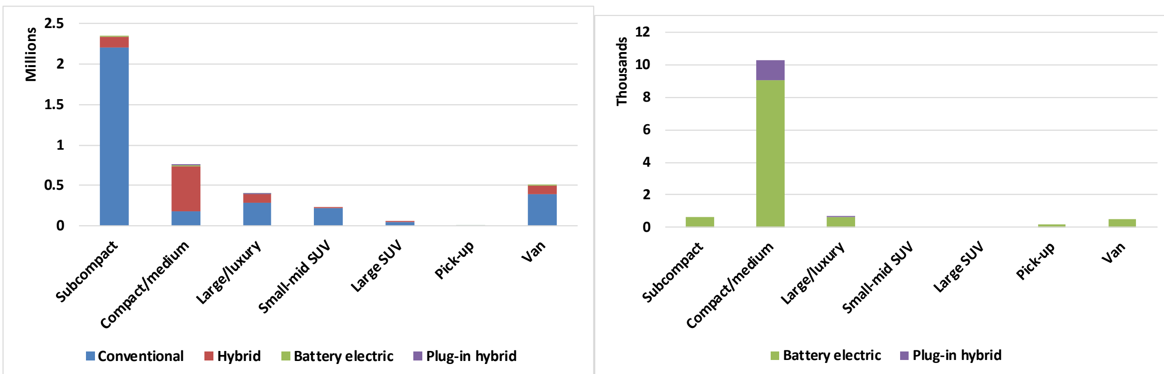


Figure 12c-d: Japan number of models offered for sale, 2013 (updated to 2015 for PEV models)

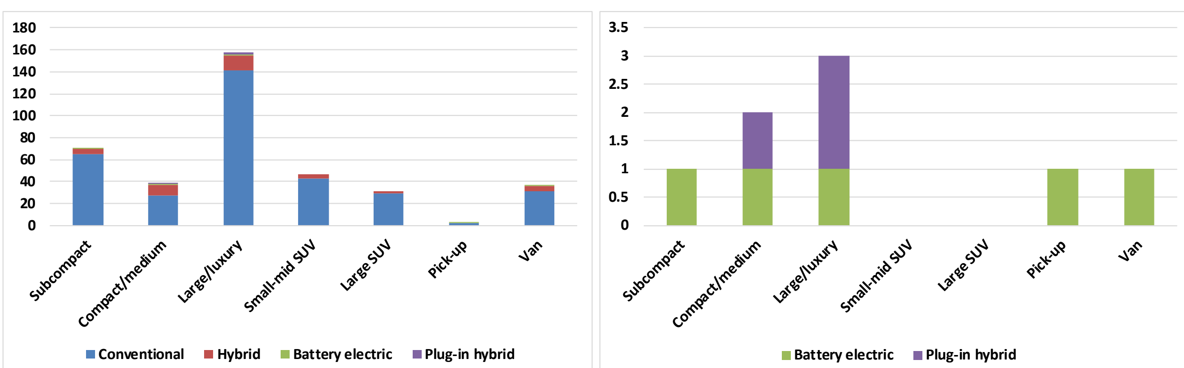
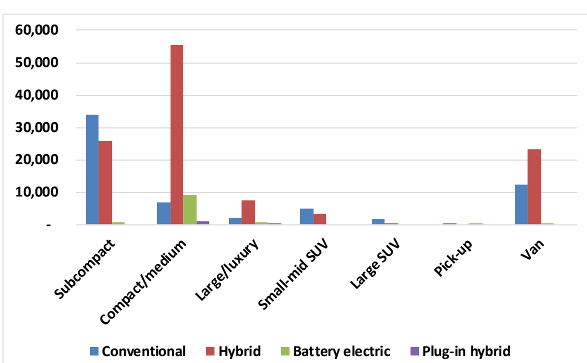


Figure 12e: sales per model by market segment and technology, 2013 (updated to 2015 for PEV models)



Conclusions from this comparison of sales and model offerings across the three countries are:

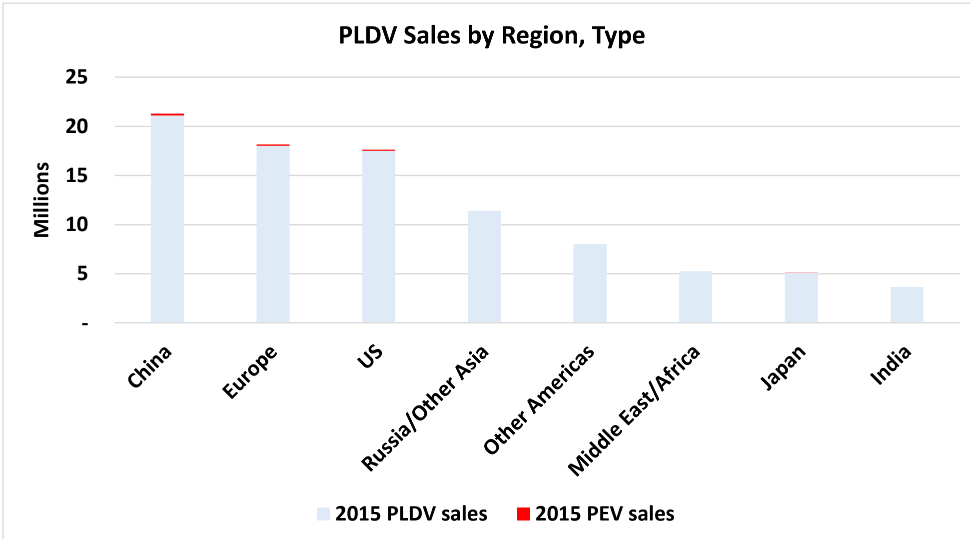
- Each country has its own market characteristics, and different market segments dominate. The U.S. is a particular outlier in the large size of its cars compared to France and Japan (and almost any other country worldwide, GFEI 2016).
- As of 2015, an increasing number of electric and plug-in hybrid models were available in the three countries, but the numbers were still very small relative to non-plug-ins, and tended to be dominated by certain market segments, whilst others had few or no offerings.
- Even where models were offered, sales per model tended to be quite low – not surprising for new technologies.
- As a result, thecentral question that companies and policy makers in all of these markets areasking ishow can sales of PEV models be increased?

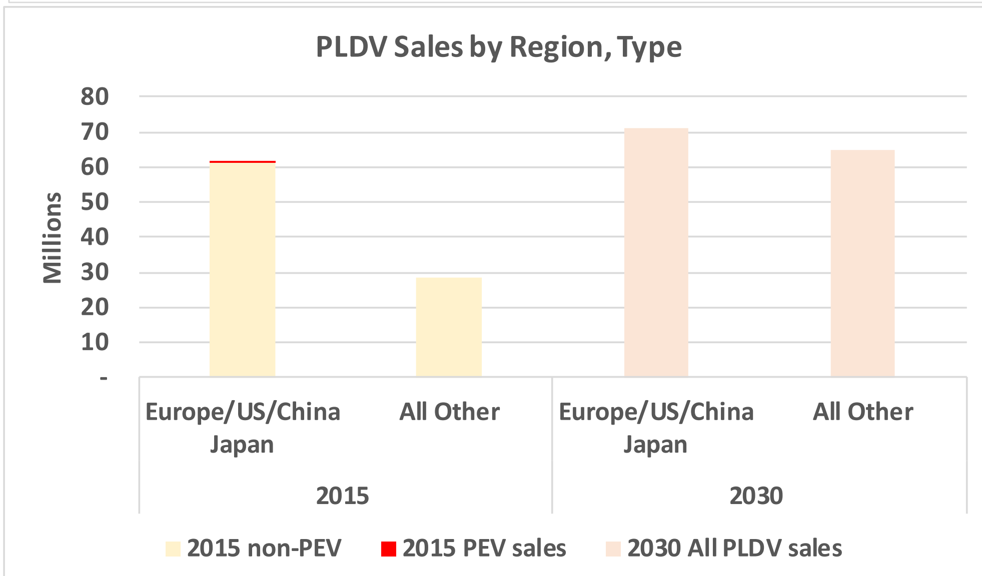
4. Achieving the 100 million target

The preceding discussion suggests that PEVs are making important progress across the world's four biggest car markets: the U.S., EU, Japan and China. A fairly large number of models are on offer, though sales per model are generally quite low and the coverage of different market segments can be spotty in many cases.

When put into perspective with global light-duty vehicle sales (Figures 13a and 13b), it becomes clear that PEVs have a very long way to go to become an important part of the entire world market. To achieve a target of 100 million PEVs on the road by 2030, significant sales will need to occur in many more countries and world regions. This is even more apparent when one considers the likely growth of PLDV sales outside of the "big 4" markets – the rest-of-world sales nearly matches these markets by 2030 (figure 13b). Total world sales of PLDVs are projected by the IEA (in their 4DS, IEA 2016) to increase from a little over 80 million per year today to over 130 million per year by 2030, with most of the growth outside the current "big 4" markets.

Figure 13a and 13b: PLDV sales by all major world regions, 2015 and projected to 2030

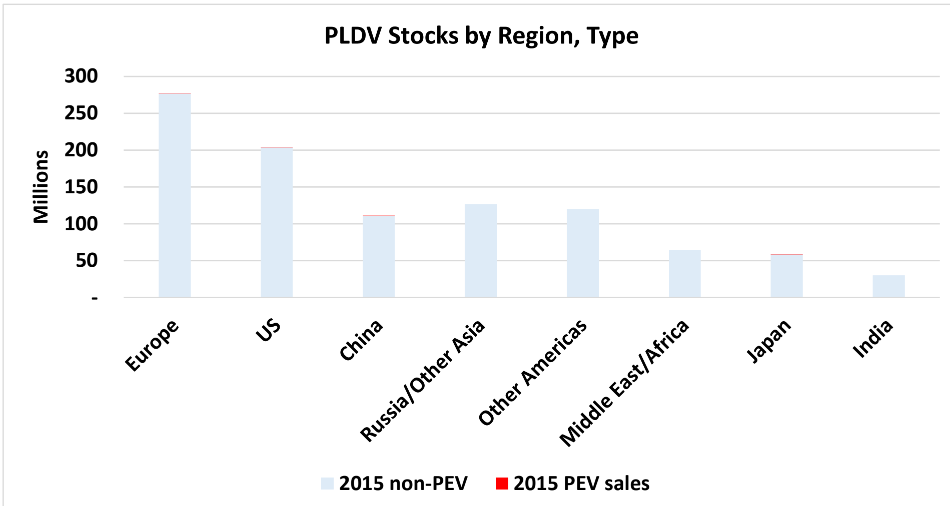


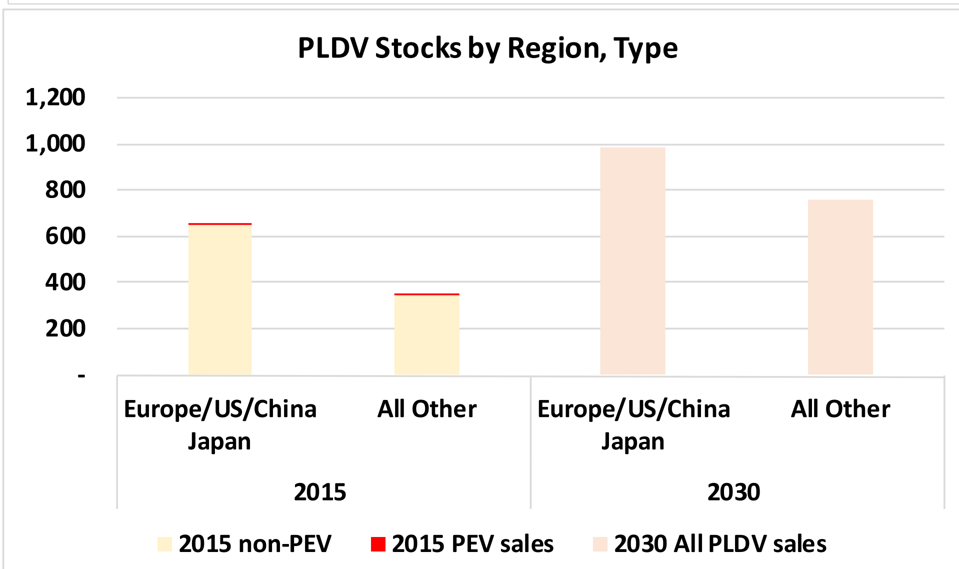


Sources for total PLDV and PEV data and projections: IEA Mobility Model (IEA ETP 2016), with updates for US and China 2015 sales data

Figures 14a and 14b relate these sales projections to the stock of vehicles. Given an average vehicle life-time of 15-20 years in different parts of the world, the IEA projects the stocks of vehicles as a function of sales and retirements. Global stocks by 2030 are projected to rise from about 1 billion today to nearly 1.8 billion light-duty vehicles. These figures do not break out PEV stocks in 2030, which is discussed next.

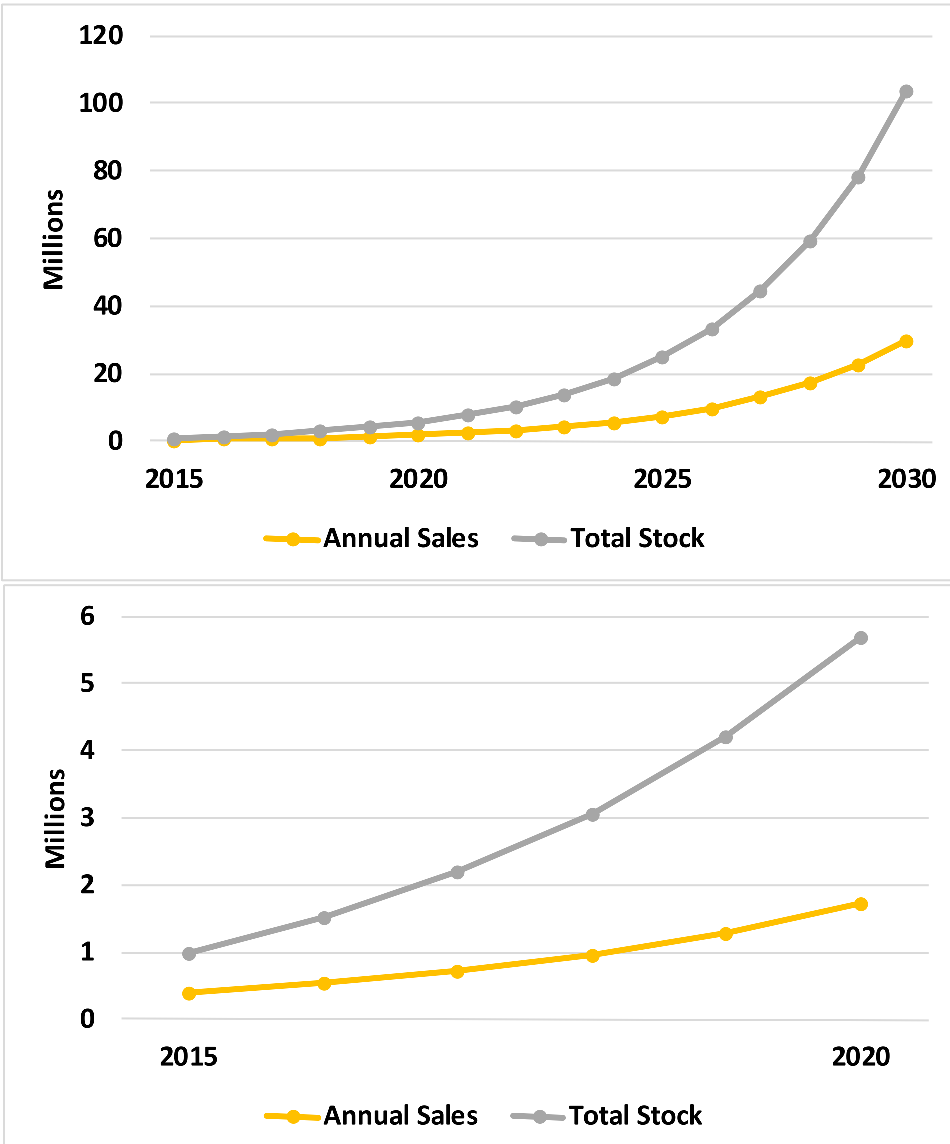
Figure 14a and 14b: PLDV stocks by all major world regions, 2015 and projected to 2030





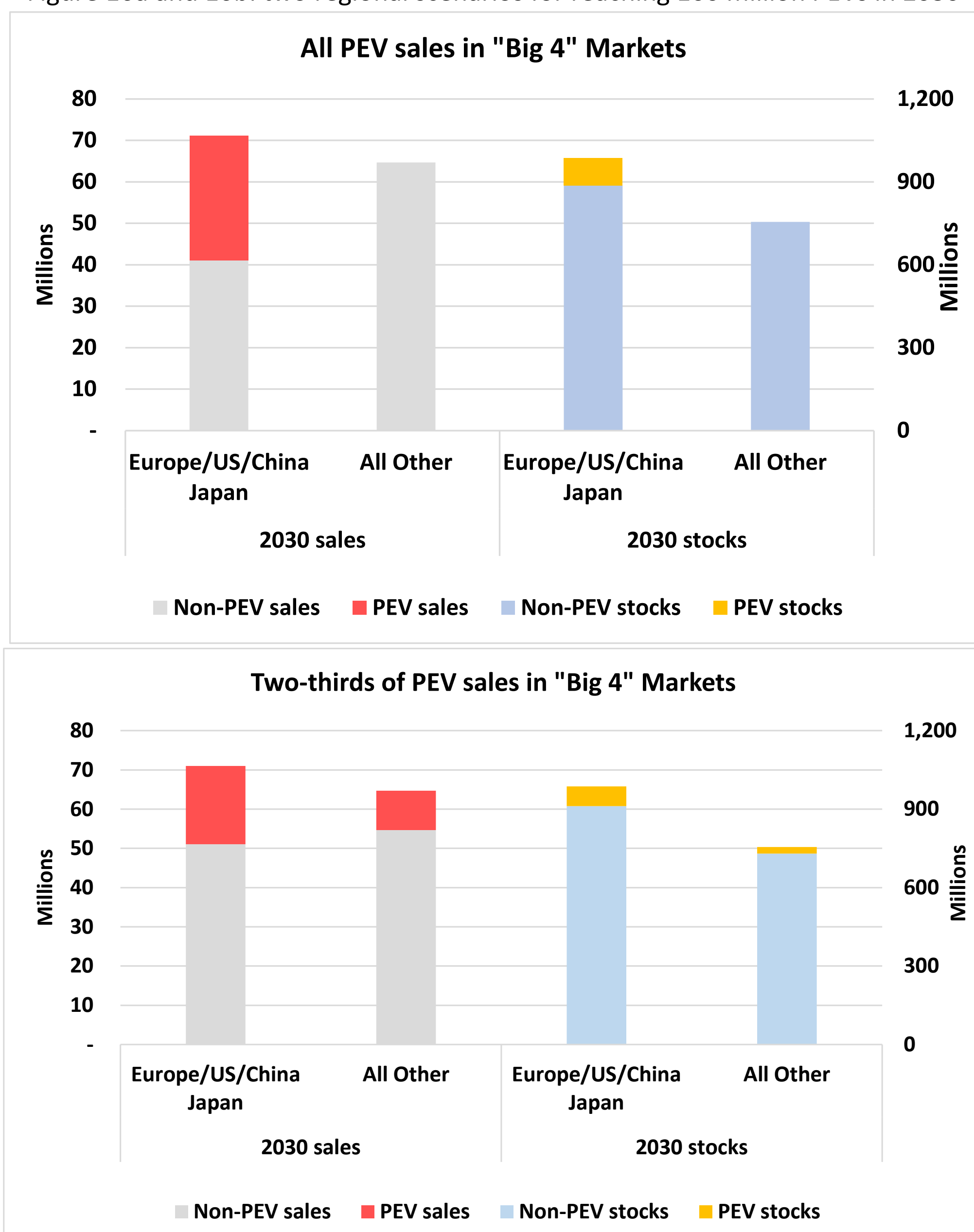
The next question is how sales and stock relate to each other for PEVs, i.e. what sales trajectory can produce stocks of 100 million PEVs in 2030? A range of sales curves could, but one fairly logical way to view this is to establish a steady sales growth rate that achieves the stock target. Such a sales rate is shown in Figure 15a to 2030 (and with a zoom into just 2015-2020 in Figure 15b). From their current levels of about 550,000 units per year worldwide, sales would need to grow by about 28% per year, every year from 2015 to 2030. Along the way they must reach nearly 2 million in 2020, nearly 10 million in 2025, and about 30 million in 2030 – with a combined effect (including some retirements over that time frame) that hits the stock target of 100 million in that year.

Figure 15a and 15b: One possible scenario for growth in number of models and sales per model to 2030, to reach 100 million PEVs on the world's roads by that date. (Figure 15b zooms in on next 5 years)



This leads to the next question: in terms of setting targets, how might such a sales and stock trajectory be logically "allocated" across the world's countries and regions? As shown in Figure 16a and 16b, the 100 million PEVs, if sold entirely in the "Big 4" markets of the U.S., EU, Japan and China, would account for about 10% of stocks in those countries in 2030. However, the sales required to reach this stock level would need to account for about 42% of sales in that year. Clearly this will be challenging, and this target would be easier to reach (for the big 4 markets, at least) if a significant number of PEV sales occur in other parts of the world. For example, if we assume that by 2030, the PEV sales in the "rest-of-world" grows to be about half that in the "Big 4" markets (i.e. about 10 million out of 30 million total, with 20 million sold in the "Big 4" markets). This reduces the market share requirement of PEVs in the "Big 4" markets in 2030 from 42% to about 28%, with about a 15% sales share in the rest-of-world. This latter distribution will serve as an indicative basis for the analysis in this paper.

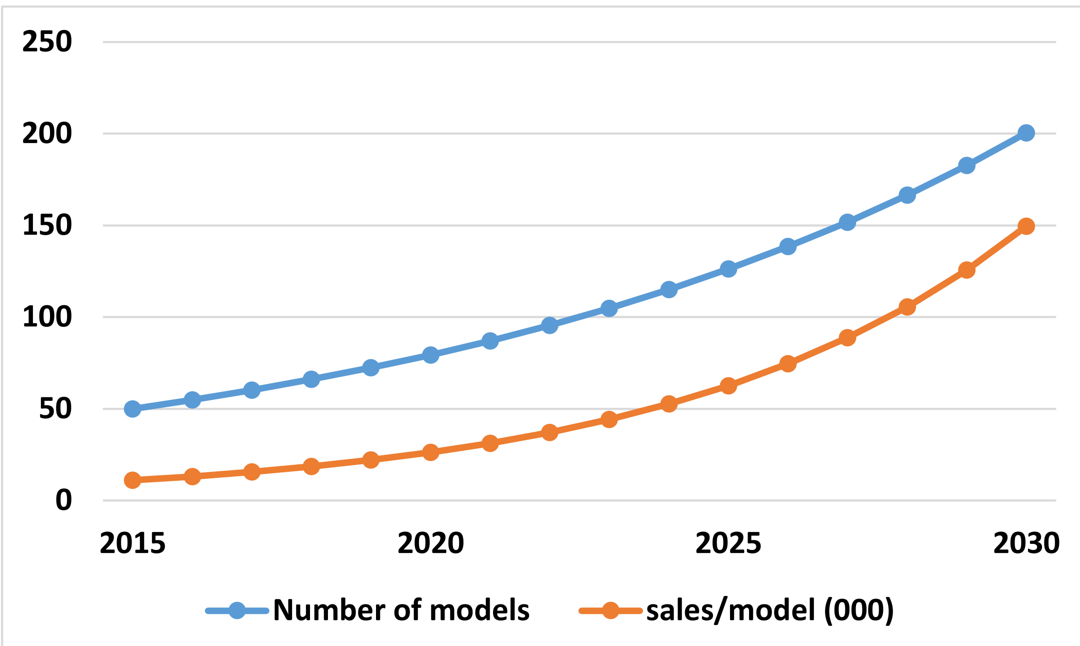
Figure 16a and 16b: two regional scenarios for reaching 100 million PEVs in 2030



PEV market growth dynamics

The central point of the foregoing discussion is that PEV markets around the world are still evolving, and as of 2015 are becoming more international, with rising numbers of models, and models that sell reasonably well (e.g. over 5000 units per year). Though in comparison to the overall size of the PLDV market and the typical sales of PLDV models, PEVs are still in their infancy. In order to increase overall sales of plug-in vehicles, many more makes/models will need to be offered, in more market classes, more countries, etc. However, in order to encourage manufacturers to introduce more models, current models will need to sell increasingly well. Figure 17 shows one combination of growth in the number of models and sales per model that can achieve 30 million sales in 2030 (and thus, as shown above, the 100 million stock target). This is to achieve 200 models selling 150,000 units each in 2030. That compares to the current situation of roughly 50 models selling 10,000 units each (taking into account all models that currently sell 1,000 or more units worldwide). Of course this target could also be achieved with fewer models and higher sales per model, or more models with lower sales per model; in any case the combined targets will be very challenging to achieve.

Figure 17: PEV models and sales per model that could achieve 30 million sales by 2030



As a "thought experiment", one can hypothesize a level of average model sales that is great enough to encourage new models to be introduced. Though highly uncertain, perhaps as average PEV sales move upwards from 10,000, past 20,000, 30,000 etc., this will encourage manufacturers to introduce more models (with some lag time in terms of planning – though also affected by market analytics that suggest that such sales increases are coming). In turn, sales per model are basically a function of the state of competition within the market segment, and PEVs will need to become much more competitive within their market segments in each country to increase their sales counts.

The following is a simplified scenario taking the United States market as an example[3]. It uses Polk data on US PEV registrations and the number of models by market segment. The scenario is based on the following logic:

1) Via a range of policies to make PEVs competitive, and improvements/cost reductions in PEV technologies, sales per PEV model are assumed to increase from the 2013 averages by steady amounts per year until total PEV sales reach 28% of the market (the same percentage as represented by 30 million sales in 2030 for the global UN target). They must reach this market share by 2030. The exact nature of the needed policies to achieve this is not considered here (and not critical for this example, but is a key question to be addressed in the follow-on study).
2) A new PEV model is assumed to be introduced when the average sales per existing PEV model reaches a target level. This target is related to the average sales level of all models in the same market segment, with the threshold set low in early years – 50% of average sales (in other words, manufacturers will add models if the current ones are selling at least half as well as non-PEV models). This rises over time to 100% in later years as the market matures and manufacturers expect equal market performance from PEVs as non-PEVs.
3) Both the number of models and the sales per model in each segment are capped to avoid reaching particularly unrealistic levels by 2030; the number of models may not exceed 50% of the total models in a segment, and the sales per model may not exceed 120% of the average for non-PEVs in the segment. This forces the 28% market share target to be reached by more than just a few models (or a few market segments) doing incredibly well – it requires a broad success of PEVs across a range of market segments.

With these "rules" or assumptions, one key degree of freedom remains and the question: what annual growth rate in the sales per model will drive the market so that a) new models are introduced at a rapid rate and b) the combination of additional models and sales per model reaches the target of 28%?

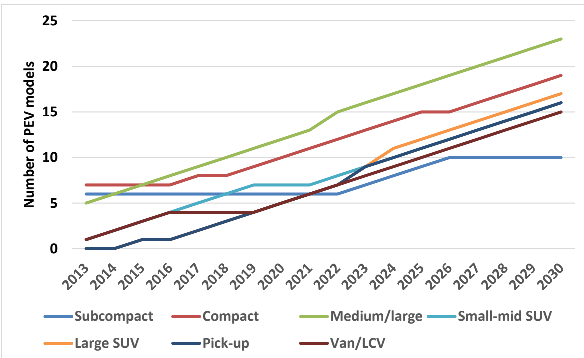
The results are shown in the following figures (18a-18d). The first shows the number of models in the U.S. and how this grows for each market segment; the second shows this as a percentage of all models in the segment; the third shows the average sales per PEV model by market segment, and the last shows the combined effect of these on total sales of PEVs, as a percentage of total light-duty vehicle sales. The weighted average of these percentages in 2030 is about 28%.

The third figure contains the answer to the question of necessary sales growth rate per model – 30% per year. Average sales per model in all market segments grows by 30% a year until it reaches its capped level, which triggers enough increase in the number of models to hit the overall sales target in 2030. Figure 18a and 18b indicate that the growth in models is "lumpy", as it only increases when sales per model hit a target level. Figures 18c and 18d show the growth rates per model and overall, as a share of total PLDV sales within the market segment. The overall growth rates are variable but in some cases very rapid.

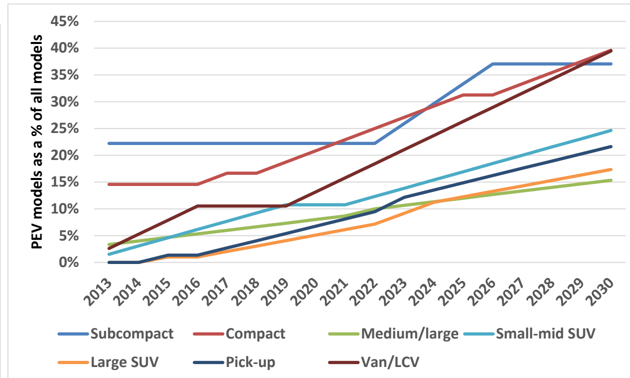
[3] For this example, using the entire world market instead of the US might be preferable, but key data is not available worldwide, such as total vehicle sales by market class, or sales per model.

Figures 18a-18d: A PEV models/sales growth scenario:

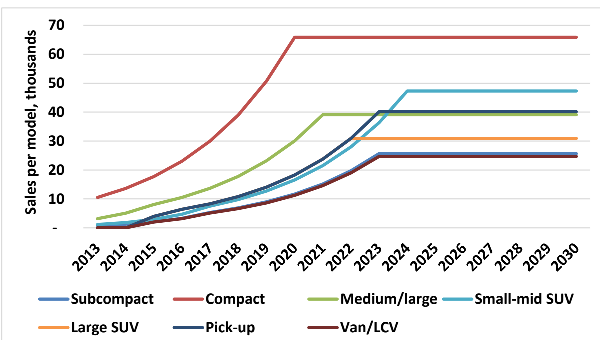
18a: PEV models per market segment



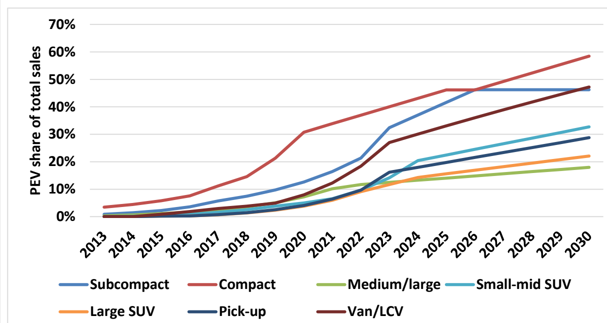
18b: PEV model share of all PLDV models in segment



18c: PEV average sales per model



18d: PEV share of total sales by market segment



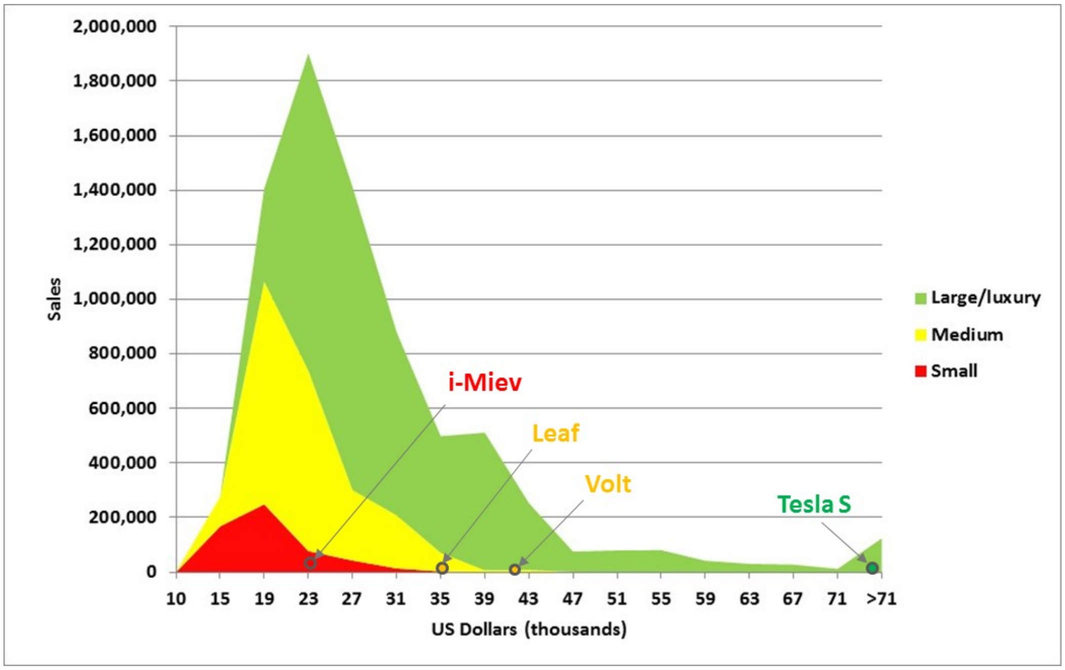
This is simply one example, meant to illustrate the challenge of reaching a 28% market share target in 15 years. One important takeaway is that, when broken down into component problems of sales growth per model and number of models, it will require rapid growth in both the sales of existing models and the number of models offered, in all market segments, to have a reasonable chance of hitting a 28% sales target in the U.S. If any of these market segments failed to achieve at least a 20% market share, others would need to pick up the slack.

5. An Initial Exploration of Policy: Competitiveness of PEVs in their market segments

Given the need for rapid growth in the sales of individual PEV models, how can such rapid increases be achieved? It all comes down to the competitiveness of PEVs. This section examines some aspects of PEV sales and competitiveness in the U.S. to explore this question.

Earlier in the paper, it was noted that in the U.S. there is something of a "mismatch" between the market segments where PEVs are offered and the market classes with high potential sales. PEVs are mostly offered in the smaller car classes whereas in the U.S. large cars and light-duty trucks (SUVs, pickups, vans) account for a large share of sales. In addition, the PEVs offered in these small classes tend to be significantly more expensive than the vehicles they compete with. This is not surprising, given that PEVs use expensive technology. Figure 19 breaks out US car sales (small, medium, and large/luxury cars) and shows the sales of each at different MSRP price points. This shows, for example, that nearly all subcompact cars are sold for less than $27,000, and compact cars for less than $35,000. Large cars and luxury cars, on the other hand, go up to about $60k with a small additional "wedge" over $70k. Several recent models of PEV are also plotted (only with respect to the x axis; sales are not reflected in the y axis position). These plots are intended to that these (fairly representative) models tend to fall near the high end of their market classes.

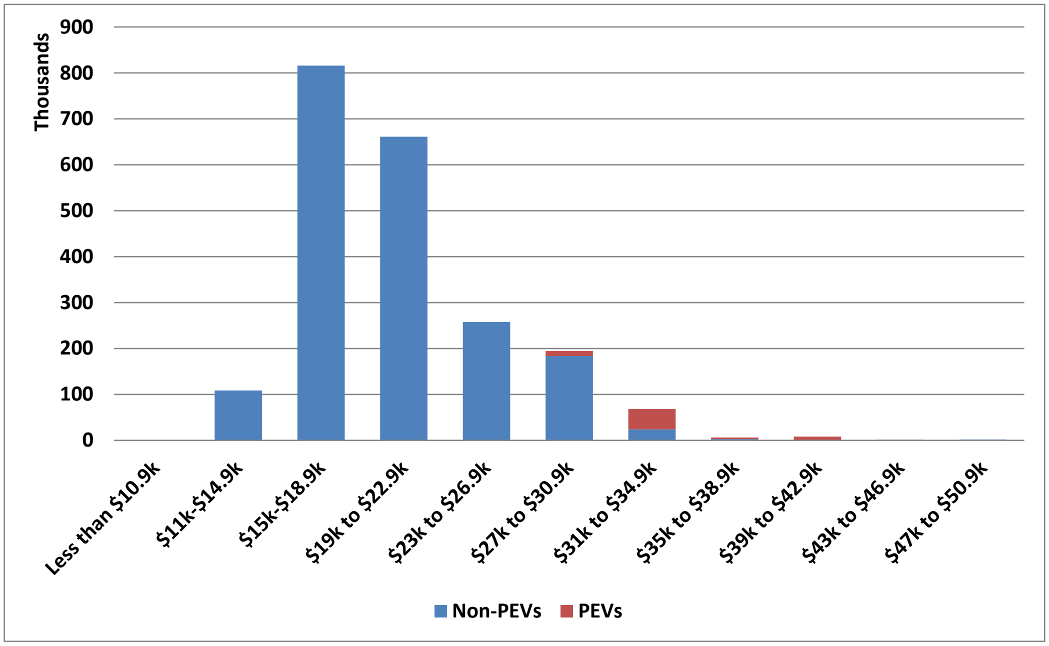
Figure 19: USA car sales by price point and market class, 2013

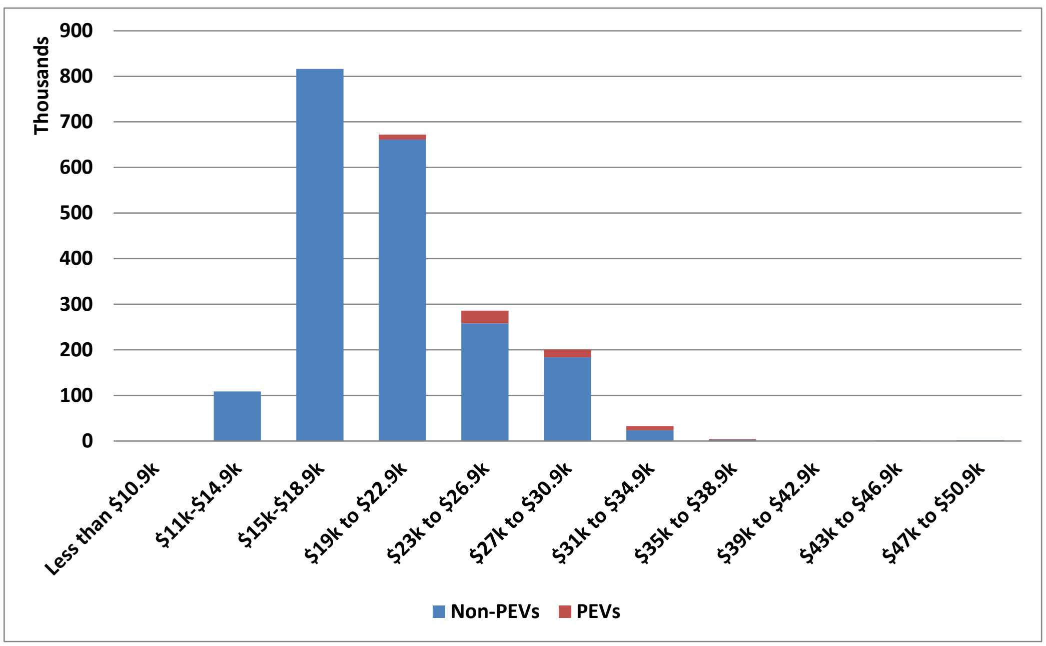


If PEVs are going to compete in compact and mid-size car classes, they need to be competitive on price in these categories, even given that theymay save significant fuel costs, and there are many other attributes that matter (such as driving range, recharge time, environmental performance, driving performance, etc.). Some consumers may be willing to pay a premium for PEVs, though others will not choose them even at a price parity point

Figures 20a and 20b break down themidsize car class by price point, and include all sales of PEVs along with other cars in 2013. In2013 PEVs were very expensive for vehicles within this class. While the "modal" price range for these cars was $15-19k, followed closely by vehicles priced at $19-23k, plug-in vehicles in this class were priced at $27k-35k. PEVs were actually very competitive with vehicles in the $31-34k price range, accounting for more than 1/3 of sales; but this is a tiny market segment with total sales of about 50,000 cars out of the 15 million sold in 2013.

Figure 20a and 20b: US mid-size car sales by price point, without (top) and with (bottom) national PEV incentives taken into account

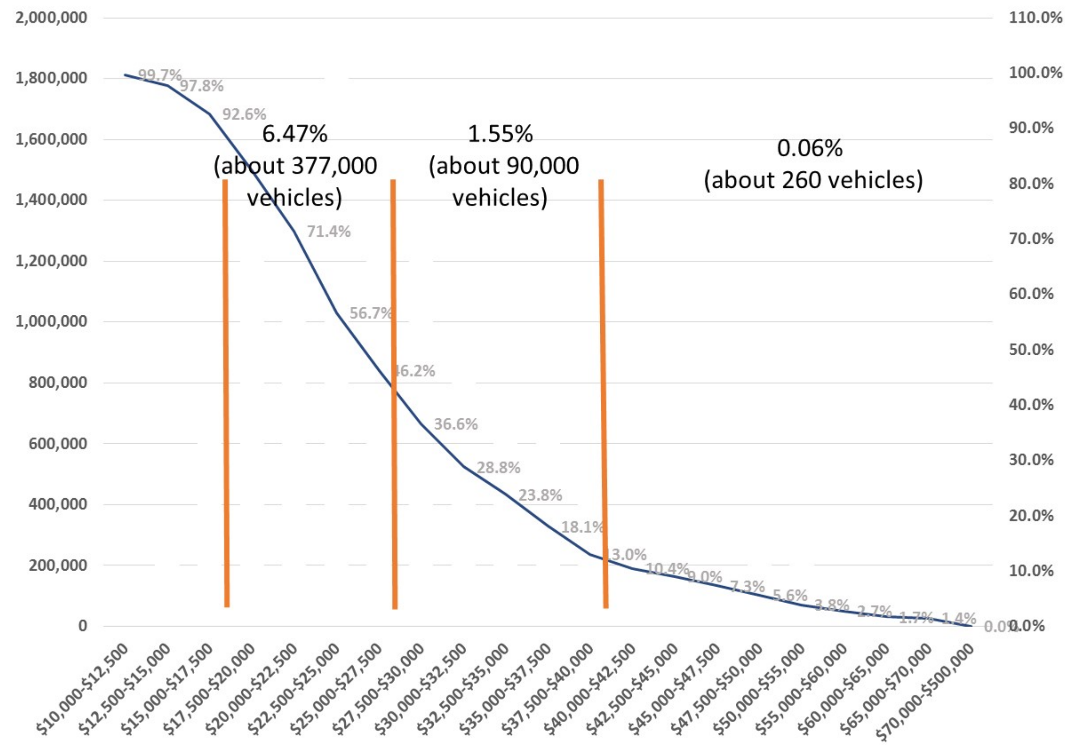




In the U.S., the preponderance of PEV models in the mid-size car segment is correlated with the potential demand for alternative fuel cars with low fuel consumption similar to the demand for hybrid cars, but it is also associated with U.S. policies and incentives. The U.S. government price incentives of $2500 to $7500 for PEVs (depending on specific vehicle characteristics) serves to effectively lower the retail price of PEVs by enough to move them into lower price brackets, as shown in the figure. However, even with these incentives the vast majority of PEVs were sold within the top three most expensive price brackets among mid-size cars. This suggests that even greater price breaks might be needed to get PEVs more solidly into competition with the cars that dominate the mid-size car market in the US.

The impact of cutting the retail price of PEVs across the U.S. mid-size market segment is shown for a more detailed range of cost brackets in Figure 21. Here the cumulative sales of all cars (and all car classes) is shown, and several "inflection points" become apparent. Getting PEV price below $40k is needed to begin to compete with market segments that have significant sales; getting it below $28k opens the door to much greater increases in the numbers of vehicles it may compete with (at least on price). Each $1000 drop in price increases the total number of vehicles that a PEV is price-competitive with by about 1.5% between $40k and $28k, and this percentage rises to 6.5% below $28k. Thus, for mid-size PEV car models that enter the market at $28k, each $1000 of price incentive high leverages the price competitiveness of the model. Providing incentives for vehicles with MSRP above $40k does comparatively very little.

Figure 21. The Impact of a $1000 vehicle price change on the potential market



The point of these figures is to demonstrate that a) for PEVs to have a chance to sell in large numbers, they probably need to be offered with a retail price (with incentives) that puts them into market price segments where a lot of cars are sold, and b) that once they are into such price segments, cutting their price further can make them price competitive with many more vehicles than if it is done when they are situated well above the high volume segments. In 2013 these conditions were generally not met for most PEVs in the U.S., even with significant government subsidies.

Next Study Phase: Scenario Development and Further Policy Considerations

The earlier discussion of PEV pricing policy is an important aspect of helping to make PEVs competitive, but of course there are many other relevant issues. Researchers at UC Davis and elsewhere are undertaking detailed studies of consumer behavior when buying (or not buying) PEVs as well as how they use these vehicles, how often and where they recharge, how much they drive plug-in hybrids on electricity (v. gasoline), etc. Policies that affect buying patterns (and vehicle production patterns) are clearlya critical element of future PEV success (Lutsey, 2015b). A fuller treatment of all of the consumer choice considerations, and how policies interact with these to increase the sales of PEVs, will be conducted during the next phase of this study. This will include consideration of key factors that are likely to drive demand for PEVs, with the following among the most important:

- Vehicle price
- Vehicle operating (e.g. fuel) cost
- Driving range
- Recharging time and availability/location of chargers
- Vehicle performance and reliability
- Other attributes of utility (e.g. vehicle interior volume, number of seats, trunk space)
- Environmental factors (e.g. CO_2 and pollutant emissions)
- Operational incentives or disincentives (e.g. access to “clean vehicle zones” or “high occupancy vehicle” lanes)

Understanding how all these factors are likely to interact, their relative importance to different vehicle buyers, how they may change over time, and how they are affected by specific policies, is highly complex. Further, all of these characteristics is likely to vary from country to country. Part II of this study, during 2016, will examine these issues in some detail and across several sample countries, and endeavour to glean some useful insights

References

GEVO 2013, *Global EV Outlook: Understanding the Electric Vehicle Landscape to 2020*, International Energy Agency, Clean Energy Ministerial and Electric Vehicles Initiative. http://www.iea.org/publications/freepublications/publication/GlobalEVOutlook_2013.pdf

GEVO 2016, *Global EV Outlook 2016: Beyond One Million Electric Cars*, International Energy agency, Clean Energy Ministerial and Electric Vehicles Initiative https://www.iea.org/publications/freepublications/publication/global-ev-outlook-2016.html

GFEI 2014, Working Paper 9, How vehicle fuel economy improvements can save $2 trillion and help fund a long-term transition to plug-in vehicles, authored by Lew Fulton, UC Davis, http://www.globalfueleconomy.org/data-and-research/publications/gfei-working-paper-9

GFEI 2015, Working Paper 11, IEA Report Update 2014: *International comparison of light-duty vehicle fuel economy: Evolution over 8 years from 2005 to 2013*, http://www.globalfueleconomy.org/data-and-research/publications/gfei-working-paper-11

IEA 2016, *Energy Technology Perspectives 2016: Towards Sustainable Urban Energy Systems,* International Energy Agency, OECD, Paris. http://www.iea.org/etp/etp2016/

Lutsey, Nic, 2015a, *Global Climate Change Mitigation Potential from a Transition to Electric Vehicles, ICCT*, http://www.theicct.org/sites/default/files/publications/ICCT_ghg-reduction-potential-evs_201512.pdf

Lutsey, Nic, 2015b, *Transition to a Global Zero-emission Vehicle Fleet: A Collaborative Agenda for Governments.* http://www.theicct.org/sites/default/files/publications/ICCT_GlobalZEVAlliance_201509.pdf

McKinsey/ARF, 2014*, Electric Vehicles in Europe: Gearing up for a New Phase?* McKinsery Corp and Amsterdam Roundtables Foundation http://www.mckinsey.com/~/media/McKinsey%20offices/netherlands/latest%20thinking/PDFs/electric-Vehicle-report-en_as%20Final.ashx

UN, 2015, Sustainable Development Goals, *Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all*, http://www.un.org/sustainabledevelopment/energy/

UNFCCC (2015), Paris Declaration on Electro-Mobility and Climate Change and Call to Action, released during COP 2015, Paris, http://newsroom.unfccc.int/lpaa/transport/the-paris-declaration-on-electro-mobility-and-climate-change-and-call-to-action/

Data sources for this study have included:

- IEA MoMo Database as used in the ETP 2016, International Energy Agency, Paris.(note that the PEV data used in this study does not match the latest IEA data used in, for example, the GEVO 2016 publication as this was not available to UC Davis.)
- Blogspot website, http://ev-sales.blogspot.com
- European Alternative Fuels Observatory, http://www.eafo.eu
- Inside EVs website, http://insideevs.com
- Various manufacturer websites

What is the Global Fuel Economy Initiative?

The Global Fuel Economy Initiative believes that large gains could be made in fuel economy which would help every country to address the pressing issues of climate change, energy security and sustainable mobility. We will continue to raise awareness, present evidence, and offer support to enable countries to adopt effective fuel economy standards and policies that work in their circumstances and with their vehicle fleet.

Secretariat

Global Fuel Economy Initiative
60 Trafalgar Square
London
WC2N 5DS
United Kingdom
+44 (0)207 930 3882 (t)
+44 (0)207 930 3883 (f)

Contact us

Email: **info@globalfueleconomy.org**
Web: **www.globalfueleconomy.org**

@GlobalFuelEcon | #GFEINetwork

www.youtube.com/GlobalFuelEcon

www.flickr.com/50by50campaign

With the support of