

Sales Forecast of Electric Vehicles

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Abstract

The present research presents the sales forecast of electric vehicles in Spain until the year 2040, all of these under the conditions of different technological generations and scenarios. Although the market structure isn't clear yet, governments and car makers recognize that is an important strategical factor to know the sales forecast to mid and long term; so both could design the most suitable strategy. The evolution of the transition between ICE and EV is conditioned by objective factors (Fuels prices, autonomy range and government grants) and subjective factors (Post-materialist values related with ecology and the interest in new technologies). The present research uses a developed versión of the Bass Model (1969), known as BB-04X (P. Bass & Frank, 2004), which allows to contemplate different generations of the product as well as the leap-frogging phenomenon. A **preference model** is used to calculate the number of potencialdrivers, this contemplates that the switch can be based in the drivers preferences only when the EV has a certain amount of features, independently of the entry barriers and the forced adoptions. All the data used has been obtained form the survey developed by IPSOS-TRT company in different countries of the European Union in 2012. The present research presents the sales forecast of electric vehicles in Spain until the year 2040, all of these under the conditions of different technological generations and scenarios. It uses a developed versión of the Bass Model (1969), known as BB-04X (P. Bass & Frank, 2004), which allows to contemplate different generations of the product as well as the leap-frogging phenomenon.

Keywords: Electric Vehicle (EV), Bass Model, InternalCombuston Engine (ICE), forecasting, sales

Background Related with the Methodology Design

Given the advantages associated with the Bass Model, in recent years different versions have been used to predict the EV diffusion of EV (Becker et al., 2009; Feeney & Adams, 2009; Jeon, 2010; Liu, Klampfl, Tamor, & Co, 2014; Wei, Wu, & Huang, 2009). Following these cases, this paper aims to use the potential of the Bass diffusion model to analyze the adoption of the EV in the Spanish market.

Becker, and Tenderich Sidhu (2009) used a single model of Bass (1969) to predict the adoption of new technology in the time interval between 2010 and 2030. The work of Becker et al. (2009) suggests that starting, all drivers are susceptible EV market potential, and then discards some of them based in their transportation behavior. This paper aims to make a more comprehensive approach to the calculation of the potential EV market, therefore, has developed a model taking into account individual preferences and circumstances (ie barriers and assumptions of forced adoption) models the possibility that the driver is part or not of the potencial EV market.

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Feeney and Adams in his work for AECOM (2009) about the spread of EV on the horizon 2050 used different scenarios derived from factors such as infrastructure development or expectations of changes in fuel prices

Jeon (2010) studied the expansion of HEV in the US, using a modification of the original Bass model (ie Norton & Bass-87), which allows taking into account the number of generations in which the expansion of the technological innovation is developed.

Contract & Lot (2012) shaped in a theoretical model the factors that may affect the adoption of the electric car clearly distinguishing between adoption in the commercial sector and private. Adoptions by private users would be influenced by the attitudes that ultimately have an effect on the behavior of the user-consumer. To that effect, this work is also based on a model of preferences for developing the M parameter, that is, to determine who is part of the potential EV market.

Shoemaker (2012) used the Bass model to predict the spread of vehicles using alternative energies as fuel.

Yimin Liu et al. (2014) also they used a modified Bass model to predict the spread of PHEV. In their model, apart from including the price of the vehicle, they had other factors such as GDP and driving costs (fuel price derivatives).

Methodology

The used methodology follows the next steps, in first place the Bass model is presented and all the items related with it must be specified according to the present research (i.e. potencial market, p and q parameters for innovators and followers, time or number of generations and their lifespan). To determinate the potencial market size, firstly a **preference model** is developed using the survey data. After this, we can differentiate segments based in their characteristics (i.e. Transportation habits or socio-economic characteristics) and exclude them from the potencial market - this is known as **entry barriers**. Later the **forced adoptions** are included – this means that in many cases the individual could be included in the potencial market independently of his preferences. Now, we can present the **three scenarios** used in the proposed model under different conditions of three parameters: fuel prices, charge infrastructure development and government grants. Finally, for each scenario two cases have been studied: **renting and selling batteries**.

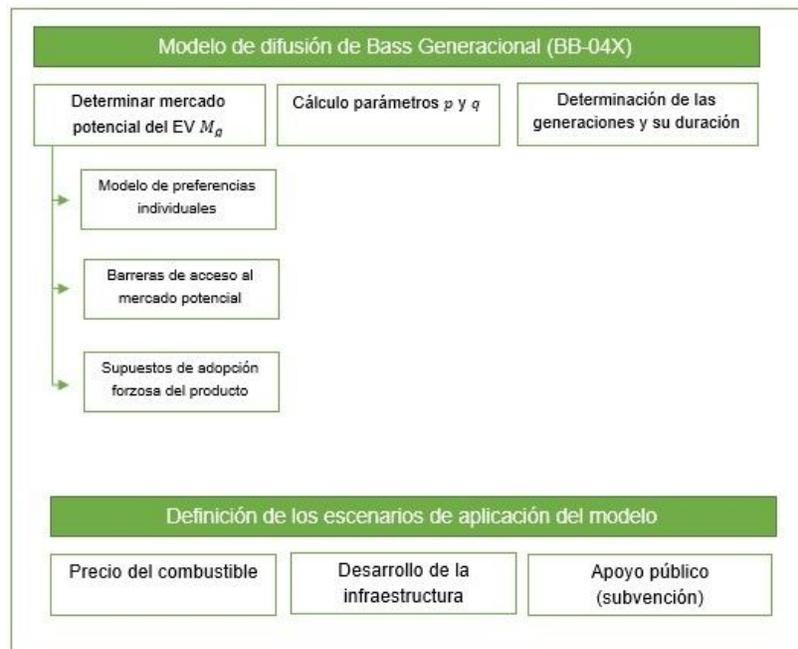


Figure 1: Methodology Scheme

Explanation of the Model Applied

Individual Preferences Model

The preference model assesses how technological changes in the EV, along with other demographic characteristics, affect the propensity to purchase an EV as the next vehicle compared to ICE, based on a priori probability. Given the characteristics of Bass model, **Mg parameter**, which represents the potential growth of a technological innovation market by generation, setting the limits of the expansion, the maximum number of adopters of the product in each generation. Following other studies that have analyzed the process of adoption of the EV (Becker et al, 2009; Feeney & Adams, 2009), this research involves identifying the factors that can influence a driver to be part or not of the potential market (iedrivers preferences, entry barriers and cases of forced adoption), to adapt this parameter to the characteristics of the Spanish market. **As for forced adoptions**, there are individuals who will be forced to become EV users, since the decision on the adoption of the technological innovation is taken by someone else. For example, in the workplace, the company can provide workers with an EV for their daily work. Similarly, there are some user segments, due to its characteristics, which are preferring an EV versus an ICE as next vehicle but they can't be users due to the segment where they belong. In this group we can distinguish the **technical barriers**, related to issues such as autonomy and **sociological barriers** established by socio-economic criteria. In this case, they are excluded because of their low probability to be part of potential adopters.

Number of Generations and their Lifespan

The number of generations are related with the evolution of the technical characteristics of the EV. Advances in research and development of new batteries will set the maximum autonomy of electric vehicles, which is the most influential variable in buying an electric car. Moreover, another variable to be considered is the time required for the development of a generation of EV. The possibility of a reduce in the lifespan of the generation as effect of the passage of time, generations tend to be shorter when the product it's been on the market for a longer time. Generations and their duration have been established based on industry reports such as: Boston Consulting Group - "Focus Batteries for Electric Cars" (2011). (See Table 1).

GEN1	GEN2	GEN3
From 2010 to 2020	From 2020 to 2028	From 2028 to 2040

Table 1: Differentgenerations

One of the previous decisions the analysis was to establish the cutoffs for each generation to classify individuals as likely to acquire the EV against ICE, and partially correct biases arising in models declared intentions. (Juster, 1960, 1966; Morwitz & Schmittlein, 1992; Theil & Kosobud, 1968).

Mg Parameter

This first part of the development of Mg aims to determine the proportion of drivers who would purchase an EV versus an ICE to different EV settings.

Statistical Model and Data Used

Used a binary logistic regressionprobit model, which allows to predict the likelihood of a driver to be part of the EV potential market in a given generation by the variation of the technical factors (ie autonomy, charged or to recharge the EV at home without having garage) and the expected price of EV in that timeframe. We used data from the survey carried out by IPSOS-TRT company during 2012 in different countries of the European Union (ie Spain, France, UK, Italy, Germany and Poland) and from the study commissioned by the European Commission (Institute transport and Energy) to the Joint Research Centre (Fiorello, Scarcella, Zani, & Alemanno, 2012; Thiel, Alemanno, & Scarcella, 2012). To take part in the study, the interviewee must have a valid driving license, have driven a passenger car in the last four weeks, and drive a passenger car at least one once a week. Only participants who met these three requirements were selected for the survey. In the second phase, participants had to fill out a diary about their driving habits for a week, specifying the day driving routes and other relevant details relating to them. Finally, the respondent was presented with basic information related to a generic conventional vehicle (purchase price range recharging time, cost of use and emissions) versus a generic electric vehicle, before asking them asked to assess on a scale of 0 to 100 the chance to buy that electric vehicle.

In this last phase of the survey, the respondent could make three improvements to any of the following characteristics: purchase price, range, recharge time, recharge ability in house without a garage. The respondent could choose reduce the price in 3000 euros or improve autonomy in 50 km or reduce recharge in half an hour, or be able to recharge at home without a private garage. After implementing the three selected changes by the respondent, the final characteristics of the vehicle were presented again, and drove him to ask about the probability (a posteriori) that the next vehicle acquired outside the EV modified by the user against the ICE (Fiorello et al., 2012). The sample size for Spain was 617 cases.

Scenarios

This research presents three scenarios, one of **maximum diffusion** characterized by high oil prices, significant aid for the purchase and a great development of the charging infrastructure. At the other extreme a scenario of **slow development** characterized by low oil prices, less aid to the purchase and poor recharging infrastructure. The third scenario is an intermediate situation, called "**late development**".

Binary Logistic Regressionprobit Model

The model includes three independent variables, the probability of purchase a priori, the technical characteristics of the vehicle (purchase price, autonomy, recharge time and the ability to recharge the car) and sociodemographic variables (age, prior knowledge of the product, the tenure of housing, sex and garagedisponibility). As for the a priori probability, this is defined as the probability that under the conditions of that time (2011), the interviewee prefer to buy an EV versus an ICE as their next vehicle. Works such as Rogers (1962) show that all individuals have the same predisposition to acquire technological innovations, the prior probability is to set the baseline scenario that faces the entry of the EV in the Spanish market.

Individual Preferences Model Explained

In order to set the scenarios which this research work and recommendations to the agents involved in the value chain in order to encourage the adoption of electric mobility, this study summarizes the main results of most recognized surveys (IBM-2011, EurotaxGlass 2010, Cetelem 2011, BCG-2011, 2010 Accenture, Deloitte, 2010, Deloitte-2011, va-2010, 2010 Harvard, UCLA, 2011, Airbiquity-2010, Fiorello et al., 2012) about the drivers preferences, the variables considered critical and entry barriers. Between 50% and 75% of all respondents at the cited studies say:

- The reasons why they would take the electric car are saving and environment.
- The entry barriers are ignorance, price, range and recharging.
- A development of recharging infrastructure favor the adoption of EVs

Entry Barriers Operationalization

To find out which sectors of society are likely to be excluded we used as reference two studies conducted in the US, that use barriers in predicting the spread of EV. In the case of **Becker et al. (2009)**, the barriers are applied in considering the oil price scenario, so in the baseline, it is considered that households where vehicles make a monthly trip of over 80 miles should be excluded; to this, in the scenario of high oil prices, the vehicles in which 20% or more of the trips are made with 5 or more occupants and owners of large homes and high-income vehicles are excluded too. In the high oil prices scenario, the excluded vehicles reaches 30% of the US fleet Similarly, **Rosenfeld & Nyquist (2009)** added another type of barriers when they estimate the potential size of the EV market. In this case, eliminate market households with low and high incomes from the market for different reasons, the first ones because they can't afford the higher cost of an EV, and the second ones because they have enough income to follow other criteria than price when purchasing a new vehicle. This research considers **two barriers have been created related to the technical limitations of EV**, those who have more than five passengers by 20% or more of their trips, and those who make two or more trips of 120 km or more in a week. Subsequently it included as a barrier **to reside in a low-income household**, for this we have used socio-demographic profiles. In the section of barriers resulting from the **social characteristics of the groups** they are included **retirees and unemployed**, because they generally belong to households with the lowest incomes; and the acquisition of an EV which means involve increased outlay than in the case of buying an ICE would not be acceptable (FOESSA, 2012). Subsequently, in the case of students with a similar criterion applies, regardless of the formula this group tends to not acquire the vehicle itself, assuming they are full-time students, although they are users thereof.

Finally, the housewives have been included in this group since its role is identified by a traditional home in which there are often innovative in adopting durable goods (Tezanos & Field, 2008). **Finally, the barriers have also included two types of area, small towns and rural areas.** According to several studies on the expansion of EV (Becker et al, 2009; Feeney & Adams, 2009; Rosenfeld & Nyquist, 2009; Thiel et al, 2012), the development and form of the development of infrastructure on the recharge and change (if possible) of the batteries will be critical to the expansion of EV. In this case, rural areas and small towns are the places where infrastructure expansion could be delayed, in part because the proportion of innovators is often below average in these segments. The operationalization of the barriers and the percentage of population that affects each, is set out in Table 2.

BARRIERS (1=Barrier applied).		%	Maximum Difussion			Late Development			Minimum Development		
			GEN1	GEN2	GEN3	GEN1	GEN2	GEN3	GEN1	GEN2	GEN3
Technic Constractions	5 passanger or more by 20% or more of their trips.	10%	1	0	0	1	0	0	1	0	0
	Two or more trips of 120 km or more in a week.	10%	1	0	0	1	1	0	1	1	0
Low Socio-economicLeve	Retirees	15%	1	0	0	1	1	0	1	1	1
	Unemployed	10%	1	1	0	1	1	0	1	1	0
	Manual workers	4%	1	0	0	1	1	0	1	1	1
	Students	6%	1	0	0	1	1	0	1	1	1
TraditionalH ouse	Housewives	11%	1	0	0	1	1	0	1	1	1
Area:	Small Towns	20%	1	0	0	1	1	0	1	1	0
	Rural Areas	15%	1	1	0	1	1	0	1	1	1

Table 2: Entrybarriers

Forcedadoptionsoperationalization

The operationalization is contained in

Table 3. Note, as with barriers, the application or not in the model changes depending of the scenario.

FORCED ADOPTIONS (1=Applied).		%	Maximum Difussion			Late Development			Minimum Developme nt		
			GEN1	GEN2	GEN3	GEN1	GEN2	GEN3	GEN1	GEN2	GEN3
CEO–Managers/gestión media (Business Vehicle)		1	1	1	1	1	1	1	1	1	1
Manual workers (Business Vehicle)		4	0	1	1	0	1	1	0	0	1

Table 3: Forced Adoptions

Fuel Prices: Scenarios operationalization

In most work done about the expansion of EV, the price of fuel and its possible evolution is taken into account (Becker et al., 2009; Feeney & Adams, 2009; Liu et al., 2014.) Under the EV concept and possible adoption, lies a rational element related to potential savings in the medium and long term, since generally, due to the special features of these vehicles and reduced range of models available the purchase cost, on average, is usually higher in the case of EV (Boston Consulting Group, 2011, Cetelem Observatory, 2013). This paper aims to articulate the possibilities opened by the barriers and forced adoptions, including the effect that could have fuel prices on the rate of adoption of EV. Another key aspect in the expansion of EV that this analysis aims to take into account concerns the infrastructure development. This development enables the expansive use of the EV and therefore a number of studies that have been concerned about this aspect (Becker et al., 2009; Feeney & Adams, 2009; Thiel, 2013). In the case of technical barriers, it has been assumed that the limitations imposed by the autonomy of the EV can be mitigated in the case that the charging infrastructure is developed. When the ability to recharge the EV away from home has been developed, however limited autonomy EV compared to the ICE this won constitute a technical barrier, since drivers could cover long distances regardless of the number of times they had to refuel.

Mg Parameter Operationalization

The application of the three factors which include Mg is performed in a hierarchical manner. First we have calculated the probability of preferring an EV compared to ICE for all individuals. Subsequently, irrespective of the individual preferences, those affected by any of the barriers are excluded from the potential market. Finally, individuals who have corporative vehicle and belong to any of the professional areas mentioned in the previous section are automatically included in the potential audience.

Calculating Base

According to DGT, at December 31, 2012, in Spain were 26.309.230 valid driving licenses, excluding licenses for heavy agricultural vehicles and vehicles for the disabled. (<http://www.dgt.es/Galerias/seguridad-vial/estadisticas-e-indicadores/censo-conductores/series-historicas/2012.pdf>). Of those driving licenses, 24.272.202 are driving cars (ieB License). (<http://www.ine.es/jaxi/menu.do?type=pcaxis&path=%2Ft20%2Fp321&file=inebase&L=0>) Once established this base, the CIS barometer at September 2013 gives us an approximate ratio of those who have driving license and those who, even occasionally, drive a car. (http://datos.cis.es/pdf/Es2997mar_A.pdf). From this basis, and taking the final calculation of percentages for Mg, it is presented in

Table 4. In this table you can find the value of Mg for each scenario, for more information about setting up different scenarios reading the section of the report devoted to this aspect is advised.

Scenario	Detail	%			M _g (Generational Increment)		
		GEN 1	GEN 2	GEN 3	GEN 1	GEN 2	GEN 3
	B Licenses.	24.272.202					
	Car drivers.	22.815.870					
BUY	Maximum Diffusion	1.4%	4.7%	13.7%	319.422	752.924	2.053.428
	Late Development		4.1%	10.4%	319.422	616.028	1.437.400
	Minimum Development		1.4%	4.1%	319.422	0	616.028
REN T	Maximum Diffusion		21.1%	43.0%	319.422	4.494.726	4.996.676
	Late Development		10.6%	28.6%	319.422	2.099.060	4.106.857
	Minimum Development		2.9%	12.2%	319.422	342.238	2.121.876

Table 4: Mg Calculation by Scenario and Generation

As for the final results in

Table 4 it should be noted that **it was decided to maintain a constant population base over time**, because do not exist evidences that make us consider large population movements.

http://www.ine.es/inebaseDYN/propob30278/propob_resultados.htm. Operationalization in BB-04X Model: p and q Parameters Given the historical data for EV registrations in Spain, p and q parameters were calculated for the first generation (current). The results are presented in the following table:

<i>M</i>	<i>p</i>	<i>q</i>	<i>R</i> ²	SSE
319,422	.00047*	.4919*	.91	26521.6

* $p < .05$

Table 5: p y q Parameters

The comparison of data based on other studies and parameters derived from historical data of registrations in Spain, we suggest that the expected evolution of EV is in line with other studies.

Study	Objective	Parameters
Liu <i>et al.</i> (2014)	Determine EV expansion rhythm in US.	$p=0.00303$; $q=0.6631$
McManus & Senter (2009)	Determine PHEV expansion in US. Uses Bass and <i>Generalized Bass</i> .	$0.0012 < p < 0.0026$; $0.709 < q < 0.779$
Jeon (2009)	Determine Hybrid and electric expansion in US. Norton-Bass '87 – with constant parameters across different generations.	$0.01 < p < 0.03$; $q=0.3$
Shoemaker (2012)	Bass model to study the diffusion of vehicle using alternative fuels.	$p=0.007$; $q=0.39$

Table 6: Different Studies and Their Parameters

We will use our own parameters calculated for Spanish case for the first generation and applied to the two subsequent generations. About this Norton & Bass (1987) spoke, stating that there is usually minimal differences in the parameters of different generations for most products do not imply a difference in the development of the model.

Time Factor: Generations and Lifespan

A generation should be interpreted as a perceptible change to the user (Bass & Bass, 2004b). In this work it has been established as the basic criterion of technological change, the change in the EV characteristics that is truly a leap to the user. Following this and based on the first and clearer criteria, the technical characteristics of EV, we can announce that in the next 30 years could talk about three generations. The first began in 2010 and is a first EV prototype that given its limited autonomy and low coverage in terms of infrastructure has a limited travel market for both businesses and individuals. With the substantial changes expected from 2020 (ie increased autonomy, reduced load time ...), we could talk of a second generation in which the technical features make it a viable alternative for a significant portion of the drivers that not make long journeys routinely (Boston Consulting Group, 2011). Likewise, it is expected that the time technological development will go shorter, examples of other products such as MP3 players or mobile phones show that with time and market opening, elapsed time between generations it is lower. (PI Bass & Bass, 2004; Norton, 1986).

Results

Scenario	Buy/Rent Battery	M total	Acumulated Adoptions		
			2020	2028	2040
Maximun Diffusion	Buy	3.125.774	57.145	350.115	1.801.027
	Renting	9.810.824	59.435	629.002	6.500.993
Late Development	Buy	2.372.850	57.061	339.601	1.442.617
	Renting	6.525.339	57.969	451.055	3.856.675
Minimum Development	Buy	935.451	56.684	293.480	545.301
	Renting	2.783.536	56.894	319.745	1.428.773

Table 7: Scenarios Summary

As summary:

	Maximun Diffusion		Late Development		Minimum Development	
	Buy	Renting	Buy	Renting	Buy	Renting
2010	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
2020	2.1%	2.3%	2.1%	2.2%	2.1%	2.1%
2028	3.6%	12.2%	3.3%	6.8%	1.8%	2.7%
2040	24.9%	79.6%	19.0%	52.2%	7.5%	21.9%

Table 8: Adoption

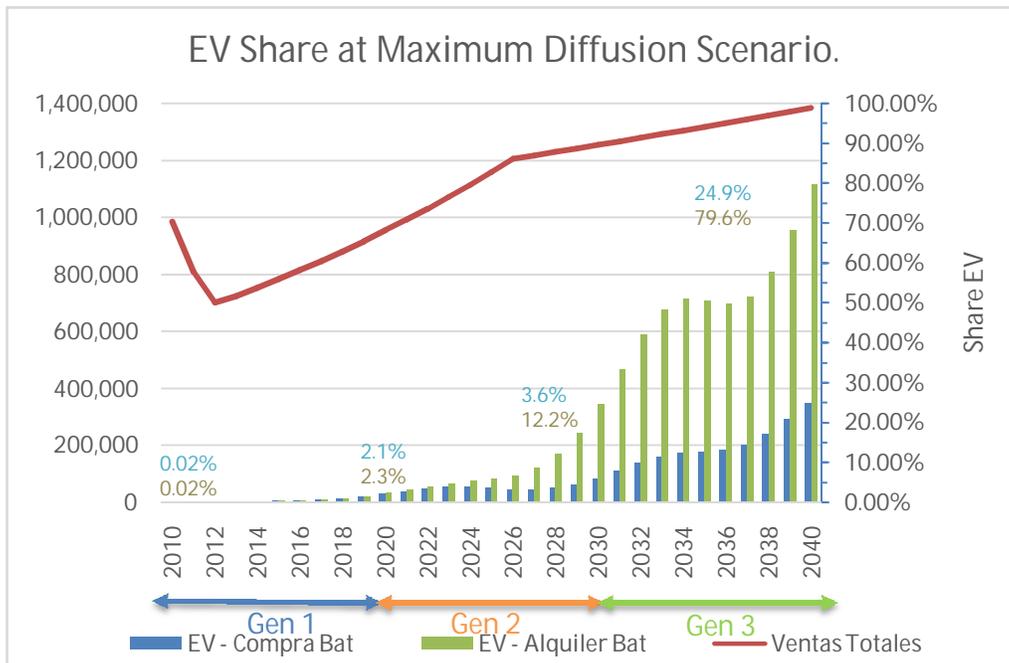


Figure 2: EV Share at Maximum Diffusion Scenario

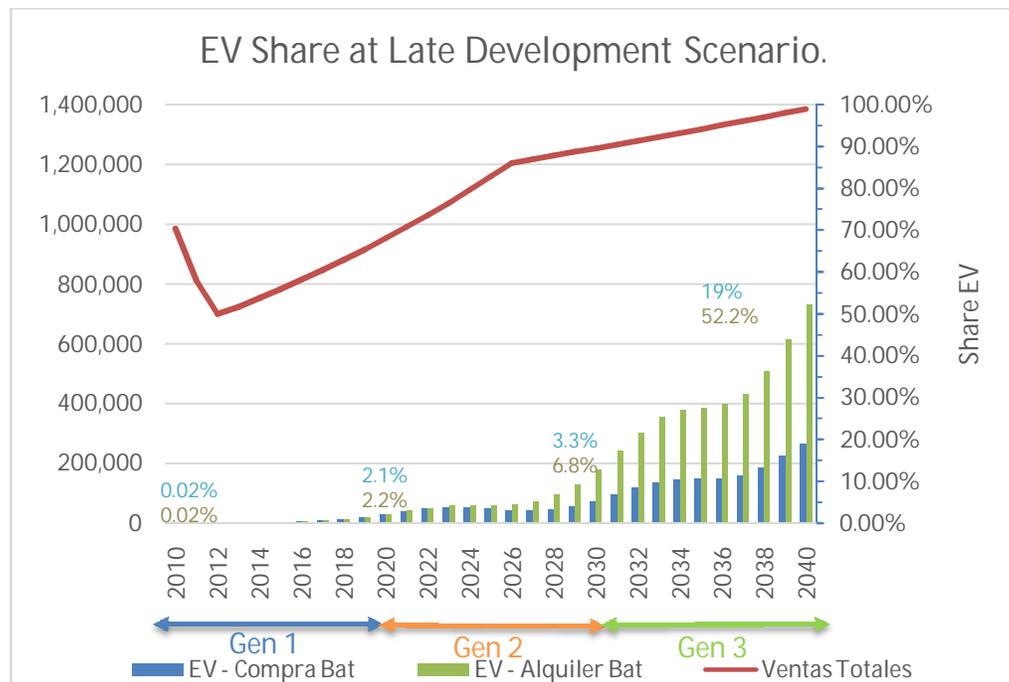


Figure 3: EV Share at Late Development Scenario

Conclusions

- 46% of Spanish drivers declared that they would choose an EV before an ICE in 2011. In the period of time for which data (2010-2013) are available, these positive attitudes have not translated into actual behaviors (ie 934 cars EV-PHEV registered in Spain in 2010-2012).
- The slow pace of EV expansion despite positive attitudes toward the product by conductors suggests that Spain is moving in a late development scenario with regard to the incorporation of new technology.

- The fact that Spain is placed on the late development/minimum development scenario now is reversible to the extent that stakeholders are mobilized to promote the expansion of EV.
- Scenario analysis indicates the power of contextual circumstances defining the rate of EV expansion.
- The most favourable situation for the incorporation of electric vehicles into the market would be under the conditions of battery renting, which reach a total share of 79% of registrations in 2040. On the other hand, if under the same conditions maximum diffusion scenario, the assumption of battery purchase will get total share would be 25% by 2040.
- For the "minimal development" scenario, sales with battery renting would be close to 20% of the national share sales and purchase batteries with 7.5% in 2040, mainly due to its higher price.
- There is a delay in the adoption of product that could affect future generations, as shown by the slow transitions in the generational models, if the stakeholder don't mobilize to promote the incorporation of EV vehicles into the Spanish market.
- The technical characteristics of EV seem to not have a clear relevance in changing preferences. An exception is the case of the possibility of charging the EV without having a garage, which seems essential for Spanish drivers.
- The late development scenario suggests that by 2028 between 300,000 and 450,000 drivers have adopted the new technology, depending on the case of acquisition of batteries (ie purchase / leasing). The accumulated number of adoptions could rise to about 4,000,000 in the case of battery rental if after a slow development in the medium term will give the necessary factors to promote a late development.
- The minimum development scenario under the assumption buying batteries portends the possibility of an indefinite delay in the expansion of EV if the contextual factors take negative values.
- The route of marketing of batteries (ie rent / purchase) cause very significant differences in the rate of adoption and this should be taken into account for the marketing strategy in Spain.

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