EVALUATION OF THE ECONOMIC VIABILITY OF PURCHASING AN ELECTRIC VEHICLE IN PORTUGAL

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ABSTRACT

Every day news show that the environment is being destroyed due to human intervention. Green house gas emissions have been increasing excessively and much hasn't been done to avoid this. With this scenario, electric vehicles appeared many years ago and were always seen and presented as a green solution. However, they have been repeatedly put aside in detriment of internal combustion engine vehicles.
Portuguese governments have already acknowledged the importance of this matter and have already invested, as well as other European and American countries, on this technology. It is noticeable, due to the issues previously referred, that the interest on this technology has been increasing. Therefore, it is important to evaluate if it is viable to purchase an electric vehicle when compared to a conventional vehicle, in the Portuguese context.

INTRODUCTION

We are living in a technologic revolution. Every day, new products, improved technologies or new discoveries are announced. With this, both the economies and greenhouse gases (GHG) emission have been growing, resulting in an increasingly severe environmental degradation.
In the USA, around 30% (USEPA, 2011) of its GHG emissions comes from the transport sector, while in the European Union this value is roughly 20% and in Portugal 25,1% (PORDATA, 2011). It is foreseen that these values will increase in the future, and may double by 2050, if measures are not put in action (Fulton, Cazzola, & Cuenot, 2009). Hence, finding alternatives to the current transport solutions is crucial for a sustainable future. In this regard, the electric vehicle (EV) emerges as the greener solution for this problem. Several automakers have already presented their electric vehicles and many more are to come.
EVs are seen as the vehicle of the future because they are emissions free (while it travels). Besides this, it has the same features as a conventional vehicle, without part of its costs or environmental disadvantages. However, EVs present characteristics that are seen as disadvantages: its low autonomy and higher purchasing cost, when compared with a conventional vehicle. Due to the low maturity and high prices of its batteries, their prices are still above of what is considered as affordable.
With this study, it is intended to evaluate the economic viability of an acquisition of a electric vehicle in Portugal. It is one of the European countries that still are under a financial aid program and that face a severe crisis. For this evaluation, a model, in which two vehicles that exist in Portugal were compared, was used: Renault Fluence (Dynamique version) and Renault Fluence Z.E. (Expression version – electric vehicle). The vehicles have the same characteristics with the exception that the second has an electric motor instead of an internal combustion engine (ICE). For this comparison, criteria such as the fuel and electricity cost, vehicle's consumption, taxes or the purchasing of a home charger for EV were considered. Following the approach of Prud'humme and Koning (2012), the goal was to determine what is the excess cost for the consumer, for the society and the impact on CO_2 emissions with the acquisition of an EV. Furthermore, the history of the EV was also briefly reviewed. It is shown that this is not the first time that the EV is being discussed. It has appeared almost two centuries ago but it has continuously been turned down. Also, its advantages and disadvantages are brought to discussion ahead.
The remainder of the paper is organised as follows. Section 2 explores EV history, running from its appearance to the present. Section 3 presents the Economic Model developed and where the short and long term parameter analysis and a risk analysis were included. In the final section, conclusions taken from the model are presented.

ELECTRIC VEHICLE HISTORY

Worldwide, humans are becoming more and more dependent on their vehicles for any travel. Based on this fact, EVs are presented as green solutions, since they allow to overcome the main problem caused by conventional vehicles, its excessive emissions. Even though this problem is being addressed now, it exists for a long time, as well as EVs. However, it has always been put aside and never could compete with other vehicles.

EVs appearance

The first EV was built in 1834. Its creation was due to European and North American scientists. However, around 1895, the USA was the only country that invested more seriously on this technology (Chan, 2013). Back then, when compared to conventional vehicles, EVs were much more silent, didn't emit any gases and didn't vibrate like the steam/combustion competitors engines. A few years later, the first vehicle to reach a speed of 100km/h was created. Curiously, it was an EV (Chan, 2013). It is estimated that in 1900 roughly 4,000 cars were circulating in the USA and one third of these were electric vehicles, what demonstrates the impact that it had back then.

Decline of the EV

Between 1790 and 1860, the population in the USA grew roughly 3,000%, reaching 6 million inhabitants. Roads between the main cities began to be created and due to this development vehicles with a bigger autonomy were needed. This happening turned EVs path even rougher. Also, the discover of new oil wells decreased the gasoline prices which didn't made it easy for EVs. Henry Ford presented, in 1908, his black Ford T that deteriorated the fragile situation of the EV.
Without any relevant opposition and with the increasing appearance of oil stations, the internal combustion engine vehicles proliferated. In 1924, there were only registered 381 electric vehicles in the USA, that were rather insignificant when compared with the over 3 million ICE vehicles (Cowan & Hultén, 1996).

EV reappearance

In the 1970's, the EV was pointed out as a possible solution for the oil crisis in the USA. CO_2 emissions were also rapidly increasing and the growing energetic needs led to the search of viable alternatives. 160 million dollars were invested in the development of batteries and EVs. Due to the need for immediate answers for the crisis, wasn't granted much time for the development of this solutions leading to the failure of the programme (Cowan and Hultén, 1996). The high costs and the low autonomy removed whichever interest might have existed in that time. Japan, one of the first countries to invest on the EV, saw the first results more recently, in 1997, where Toyota sold roughly 18,000 Prius.

EV nowadays

Prud'homme and Koning (2012) refer that in 2010 several new EVs were present by the majority of the automakers. Nissan LEAF introduction increased the total of EVs circulating around the world to 50,000 vehicles.
It might be a coincidence the fact that when huge crisis appear, every country and government tries to find new ways to balance its accounts. One way to promote this is to stabilize the balance of trade. Recognizing EVs as alternatives to ICE vehicles and as a solution for many problems, lead many countries to invest huge amounts of capital on this technology. Due to its unique characteristics, EVs might become the vehicle of the future. However, because of its history, it still is too early to predict whether and when EVs will succeed.

ECONOMIC MODEL

As mentioned before, the economic model developed in this paper was based on the work of Prud'homme and Koning (2012). The model is meant to determine the consumer excess cost (CC) (Equation 1), the excess cost for society (CS) (Equation 2), and the possibility of increasing or decreasing the CO_2 emissions (G) (Equation 3), which it will be referred onwards as CO_2 gain. In the consumer excess costs are considered the value that the consumer would have to pay for the EV (CVE), and for the vehicle with ICE (CVM), assuming from the beginning that the cost of the EV will always be higher than the ICE vehicle.

$$CC = CVE - CVM \quad (1)$$

Table 1 sums up all the parameters considered for the estimation of CVM and CVE.

Table 1 • CVM and CVE Analysis parameters
Adapted from Prud'homme and Koning (2012)

CVM	CVE
Acquisition cost Fuel cost Fuel taxes Other fuel costs Local pollution costs	Acquisition cost Home charger cost Battery cost Electricity cost

The costs for society come from the economic costs plus all the externalities, such as fuel taxes (which include the Special Tax on Oil Products, ISP, and Value Added Tax, VAT) minus the local pollution costs. The society costs are a result of an acquisition of an EV and an ICE.

$$CS = CSVE\text{-}CSVM \quad (2)$$

The gases emissions are also calculated (G) and it is assumed that EVs emissions (GVE) are smaller than ICE's (GVM).

$$G = GVM - GVE \quad (3)$$

The fourth criteria demonstrate the marginal cost of not emitting a ton of CO_2 (CT) (Equation 4):

$$CT = CS / G \quad (4)$$

The emissions that were considered are relative to the emissions of the vehicle during its trips. The first two criteria were calculated using the present value of the cost flow during the investment period using as the discount rate the standard rate utilized in the European Union (r=5%) (URA - DGPRCE, 2003).

For this analysis, two criteria associated to the utilization of these vehicles were considered: the total distance travelled (d) and its life cycle. After research, it was concluded that in Portugal it is possible to acquire different batteries with different purchase prices for different levels of utilization. The first kind of battery has a cost of 79€ per month and allows its user to travel for 10,000km (d) per year. The second hypothesis has a cost of 122€ per month and tolerates a utilization of the EV for 25,000km (d) during a year. This difference allows the analysis of the two vehicles in different circumstances and with similar conditions, in an attempt to prove if it is better for the user a bigger or lower utilization of the EV.

For the ICE vehicle cost, its initial purchase cost and other costs associated with fuel consumption (like the fuel costs, taxes and others) were considered. Regarding the EV, it was also considered its initial purchase cost, the costs of renting the battery, the costs of consumed electricity and the cost of installing a home charger. This was contemplated due to the fact that, even though Portugal has a network of chargers spread across the country, it might not be able to supply all the demand in case of massive utilization. Therefore, so that every user can charge its car, and not depend uniquely on the current chargers that exist, it was considered the possibility of installing a home charger.

Baseline case

For the analysis, it was considered a timeline of 15 years, where the vehicles were utilized for 10,000km and 25,000km, according to the type of battery. It was also considered a 5% social rate of discount, as stated before.

According to the data provided by Renault, the price of the ICE vehicle is roughly 26,000€ (PVM) and the EVs 28,000€ (PVE). Also, the former has a fuel consumption of 4.5 l/100 km (according to EEC standard Nº 93/116). The EV presents an electricity consumption of 140 Wh/km. Both values are presented by Renault and represent the utilization of the vehicles in a controlled environment and in specific conditions. However, when they are working in considered normal conditions, its consumptions are rather different. Taking this into account and following Prud'homme & Koning (2012), it was estimated that the "real" consumption was slightly higher than what was communicated (roughly 15% to 20%). Therefore, the consumptions considered were 5,2 l/100km (yVM) for the ICE and for the EV 18 kWh/100km (yVE). The annual cost of the battery rental is 948€, for the first scenario, and 1.464€ or the second one.

In Portugal the fuel prices are slightly above the European average (Europe, 2013). For this exercise, it was considered the average annual retail prices of the diesel oil, supplied by APETRO (Portuguese Association of Oil Companies). This indicated that the diesel price was 0.643€ per litre, tax free, representing roughly 44% of the final price. The remaining percentage is distributed by taxes (44%), storage, distribution and commercialization (10%) and biodiesel incorporation (2%). Given that these values are relative to the year 2012 and considering an increase of 5%/year, the diesel price to consider is 0.675€/litre (PC), to which are added the taxes, VAT - 23% - and ISP (Special Tax on Petroliferous Products) – 0.36753€/litre. ISP is a tax defined by the government that corresponds to 367.53€/1,000 litres (RMRCFF, 2013). Besides these values, it is still needed to consider costs associated to the commercialization of the fuels. This value was defined as being 0.15€/litre (T), without any yearly changes.

Regarding the price of electricity, it was decided to consider the average price in 2012. This value was 0.2063 €/kWh and it already included taxes (DGEG, 2013). This value is one of the highest in Europe and represents only 43% of what the consumer pays. The other 57% represent other costs linked to the network maintenance, renewable energies and others.

The local pollution costs considered were the same as in Prud'homme and Koning (2012). This value is the result of a French study, where the cost's value in 2000 was considered as being 0.01€/km. Reflecting a decrease on vehicle emissions, this value also decreases 4.5% per year, reaching, for year 0 in this model, the value of 0.0055 €/km (CPL) (Boiteux, 2001).

For a better understanding of the impact of these particular vehicles in the environment, it is essential to calculate these vehicles emissions. According to Prud'homme and Koning (2012), a litre of diesel oil contains 2.6kg of CO_2 (evm). Considering the assumed consumption for the Renault Fluence (5.2l/km), and assuming that this vehicle travels for 10,000km and 25,000km, the total amount of CO_2 emitted by this vehicle is 20,280 kg (20.3 ton.) and 50,700 kg (50.7 ton.), respectively. For the estimation of EVs emissions, it was necessary to obtain the total amount of CO_2 emitted during the production of the electricity that is consumed by every user (APA, 2013; DPE, 1994-2011). Considering that in 2011 52,460 GWh were produced and 14,256.34 Gg of CO_2 were emitted, it can be concluded that the amount of CO_2 emitted per kWh is 246.55 g/kWh (c).

Concluding the model presentation, Table 2 summarises all the parameters and values used for the study.

Based on these parameters, and assuming that these values remain constant, it is possible to state that the acquisition of an EV in Portugal does not represent an advantage for the average consumer, as it was a priori expected and is in line with the findings of Prud'homme and Koning (2012). Also, the cost per CO_2 ton emitted is very high, showing that there's still a lot of work ahead. As shown in Tables 3 and 4, the excess costs are still considerably high, even though it is possible to conclude that higher the distance travelled by both vehicles, better is the result for the EV.

Sensitivity analysis

If it is considered that the parameters will remain constant for the following years, the acquisition of an EV will not be viable and will not be able to conquer a significant market share. As so it is very important to make a sensitive analysis in order to understand the impact of changes in some critical parameters, as well as to identify in what conditions the EV could be a viable option for consumers. Following the suggestion of Prud'homme and Koning (2012) the sensitivity analysis was performed distinguishing the short term impacts from the long term ones. The justification for this reasoning is that it is most likely that changes in some parameters (e.g. fuel or electricity prices) can happen in the near future, whereas the impact of changes in other variables (e.g. EVs price and efficiency) will be felt in the long run.

Social rate of discount

The social rate of discount reflects the way as future results must be valued in relation to the actual benefits and costs. There are different opinions regarding the social rate of discount that must be considered depending on the type of project or the countries where they are developed. In this particular case, the rate of 5% was chosen, because it is a rate that it's the standard rate for EU financed projects (URA - DGPRCE, 2003). For the sensitivity analysis undertaken, a change of the discount rate for 3% and 7% was considered. Considering this, it can be concluded that the acquisition of an EV in Portugal is most benefited by higher rates of discount. In both scenarios, the reduction of CC and CS are not significant, decreasing less than 10% (see Graph 1 to Graph 4).

Fuel costs

Given the current economic instability, fuel prices fluctuate very frequently (BP, 2013). In this case, it was considered an increase on the fuel price of 5% per year. If it is considered an even more uneven scenario, where prices rise 10%, the difference between the studied vehicles in all criteria increases in the second scenario. In the first case, the excess cost for consumer rounds 6,000€ whilst CS is roughly 2,000€. In the 25,000km scenario, CC and CS are approximately 5,000€, and the cost per CO_2 ton decreases almost 75% (see Graph 1 to Graph 4).

Table 2 • Parameters

PARAMETER	VALUE
Total of years (t)	15
Discount rate (r)	5%
Traveled distance (d/yr)	10,000
Diesel oil litre price (PC)	0.675
Internal Combustion Engine	
Acquisition cost (PVM) in €	26,000.00 €
Vehicle efficiency (yVM) in litre/km	0.052
Fuel price without other costs (€/litre)	0.675 €
Change in fuel price (%)	5%
VAT (23%)	0.15525 €
Change in VAT(%)	0%
Special Tax on Petroliferous Products (ISP)	0.36753
Other fuel costs (T)	0.15 €
Changes in local pollution costs (%/year)	-4.50%
Local pollution costs (CPL) (€/km)	0.0055
CO_2 emissions (evm), in kg/lit	2.6
Electric vehicle	
Acquisition cost (PVE) in €	28,000.00 €
Home charger cost in €	1,000.00 €
Battery rental (B) in €/year	948
Vehicle efficiency (yVE) in kWh/km	0.18
Electricity price (PE) €/kWh	0.3163
Change in electricity price (%)	0%
Amount of CO_2 in electricity (c) in g/kWh	246.55

Table 3 • 10,000km results.

10.000 KM RESULTS	
Excess cost for consumer (CC) in €	8,048.73 €
Excess cost for society (CS) in €	8,358.68 €
Gain of CO2 (G) in tons	13.62
CO_2 cost per ton in €/t (CT)	613.56 €

Table 4 • 25,000km results.

25,000 KM RESULTS	
Excess cost for consumer (CC) in €	6,217.87 €
Excess cost for society (CS) in €	6,992.74 €

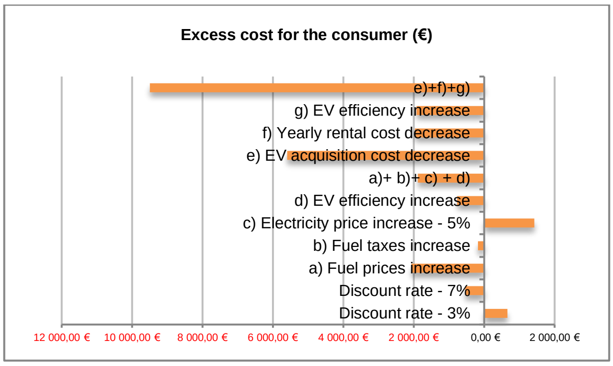
25,000 KM RESULTS	
Gain of CO2 (G) in tons	34.06
CO_2 cost per ton in €/t (CT)	205.32 €

Fuel taxes

Portugal is one of the countries with higher taxes rates on fuels and its increase is seen as not very likely to happen in the next few years. In the chance it might occur, it was considered a 5% increase. With it the difference between the baseline case and CC is not significant, decreasing 3% and 9% in the first and second scenario, respectively. Neither CS nor G are affected by this variation, because it only impacts the customers.

Electricity price

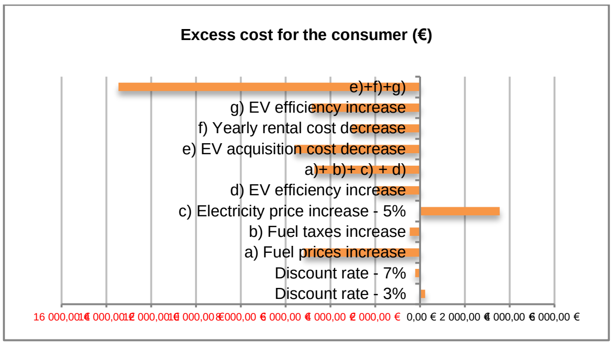
The rising price of electricity has an easily understood negative impact on CC and CS. In the first scenario, as it can be seen on Graph 1 and 3, it would increase both values nearly 1,500€ and in the second one 3,500€. This growth would also be noticeable on the cost per CO_2 ton.



Graph 1 • Excess cost for consumer – 10,000 km.

Simultaneous changes

All the changes considered for the different parameters caused slight variations on the final results. However, the isolated occurrence of each one of those changes is highly unlikely. Therefore, it is important to consider the occurrence of all the referred factors simultaneously. So it was studied an increase of 10% on fuel prices, 3% increase on fuel taxes, 5% increase on electricity price and an improvement on EVs efficiency by 10%.



Graph 2 • Excess cost for consumer – 25,000 km.

In the first scenario changes of around 20% in CC and CS and 10% in G were obtained. The other scenario shows much more meaningful percentages: CC decreases 75% and CS roughly 61%. Based on this results, it can be concluded that the viability of the acquisition of an EV begins to be possible, given this small but impactful changes.

Longer-term sensitivity analysis

The following parameters are considered “long term” because it is not predictable that, in the upcoming years, they change in a significant way.

EV acquisition cost

EVs are top notch in what concerns technologic development. However, their batteries besides presenting perceived low autonomies, are quite expensive. This fact itself increases the price of an EV for values higher than a conventional vehicle. In this particular case, a reduction of 20% in the acquisition price of Renault Fluence Z.E. decreases CC roughly 70%, just like CS, proving this that a slight decrease on purchase price can turn EVs into much more cost attractive vehicles.

Battery rental cost

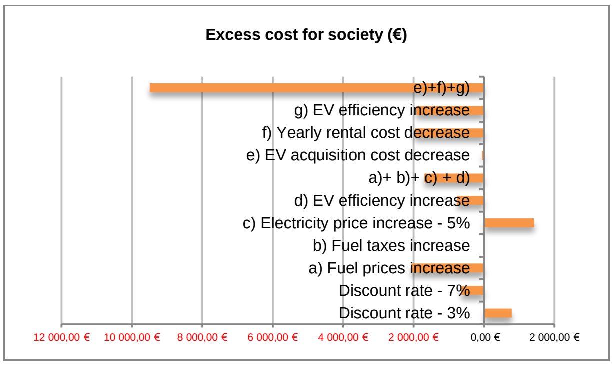
Considering a decrease on battery’s rental cost of only 20%, the costs on the first scenario decrease about 25% and, in the second scenario, the impact of this measure would represent a reduction of 50%.

EVs efficiency

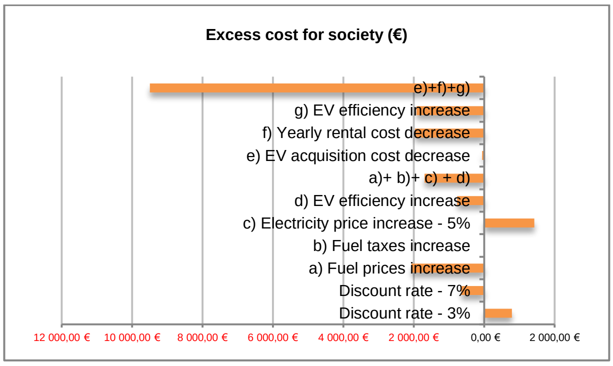
EVs efficiency is higher than a conventional vehicle. However, it is not big enough to increase EVs competitiveness. If it is considered an increase of 50% in EVs efficiency, a reduction of 25%, in the first scenario, is verified on CS and CC, which is pretty reasonable. In the second scenario, this value would decrease almost 80%, proving that if this scenario is achieved, it would increase considerably the odds for EVs, which can be seen on graphs 2 and 4.

Combination of variables

Just like stated before, it is important to consider the simultaneous occurrence of changes in these variables. Therefore, considering a decrease of 20% on EVs initial price and battery rent and an increase of 50% on its efficiency, the EV would become more cost effective. It can be seen in all graphs that, either for society or for consumers, the mix of these three hypothesis is highly favourable to all parts.



Graph 3 • Excess cost for society – 10,000 km.



Graph 4 • Excess cost for society – 25,000 km.

Risk Analysis

The values obtained on the previous analysis allow the reader to conclude about the impact that changes in each parameter of the model has on the final results. If, for example, the fuel price considered was unusually high, it would harm the outcomes and no reliable analysis would be obtained. However, this is a deterministic approach of risk. Therefore, in this subsection the results of a probabilistic analysis of risk are shown. For that purpose, the impact of two critical variables (electricity and fuel prices) was analysed. In particular, the impact of fluctuations on those prices on the cost for consumer and for the society was assessed, based on Monte Carlo simulations. These calculations were performed using historical data regarding electricity and fuel prices and identifying the distribution that best fits the data.

In the case of electricity prices, values of MIBEL – Iberian Electricity Market were considered, for a time range comprising last year's electricity price evolution, and a normal distribution was considered as the one that best fits the data. Therefore, it was found that in MIBEL the electricity price's standard deviation was 14.79€/MWh, which corresponds to about 31.5% of the average value. Therefore, an identical proportion for the standard deviation was used in our model, which meant a value of 0.064927€/kWh. The mean value used in calculations corresponded to the average price of electricity, 0.206€/kWh. The simulations were tested for both scenarios (10,000 km and 25,000 km).

Regarding fuel prices, the evolution of the price of the barrel of Brent, between January 2009 and August 2013 was considered. When performing the distribution fitting of the data, it was concluded that no clear distribution could be used with guarantees that represents the price evolution over time. As such, for simplicity, a triangular distribution was used, requiring only the minimum, maximum and the average value of the series. In this case, the minimum value was 32.8161€/barrel and the maximum 95.0338€/barrel. These values correspond, respectively, to 47.08% and 136.35% of the average value of 69.6979€/barrel. Extrapolating these proportions to the model used and taking into account 0.675€/l as the average value (baseline case value), it follows that the maximum a liter of fuel will cost will be 0.9293€/l and the minimum 0.3178€/l, which have been tested in both scenarios.

Results

From the probabilistic risk analyses, it was concluded that, for the first scenario, it is impossible for the EV to compete with a conventional vehicle. The minimum values obtained are positive, what indicates that the cost of acquiring an EV will always be superior to the one of purchasing a conventional car. Nevertheless, in the second scenario, there is a chance of this to happen (inferior to 5%), where the EV would cost less 2,000€ for the consumer and 870€ for the society. Somehow, this represents an optimistic view of the case. However, just like these values can favour the EV, there's also the possibility of the difference helps the devaluation of the EV. It is possible for the difference to grow to roughly 12,500€.

CONCLUSION

EVs have recurrently been set aside and not seen as a good choice. The higher costs associated to it and its perceived low autonomy are the main reasons why its sales are so small. However, there seems to be a growing interest on this technology, as main automakers and governments are investing on it and Portugal is also trying to keep the pace.

It is possible to determine that within the actual circumstances, it is not viable to purchase an EV in Portugal. Through the presented model, it can be said that only if a set of parameters happen to change the EV will become more cost effective. Although in the next years it is less likely for this to happen. One can also conclude that the higher utilization of the EV makes the acquisition more profitable.

As future work, one can state that an in-depth study on the CO_2 emissions that result from electricity production might be important, so that the real impact of its production can be determined more accurately. Also, an update on the values utilized might show what was already predicted, that the EV will become more cost effective. Other topic that deserves attention is the impact that a sudden change on the vehicles utilized worldwide, where an EV would replace every ICE, would have on the global CO_2 emissions. This study would also be helpful to determine if a general acceptance of EVs would benefit or harm the environment, considering the way each country obtains its own electric energy.

Portugal still has a long path to walk but, despite the crisis, the investment that was already made must not be forgotten. This investment on EVs infrastructures must keep going on, because a developed network of charging infrastructure is essential for consumers to travel larger distances.

There is no doubt that the EVs are the vehicle of the future and, even though it presents some downsides when compared with a conventional vehicle, it has everything needed to surpass ICEs. However, it is not possible yet to predict when EVs acquisition will become viable. Therefore, it is essential that the investment on this technology continues, not only through the development of the technology itself, but also by creating and developing awareness on the population worldwide because EVs will only begin to create an impact on the environment from the moment it starts to become a choice for everyone. Given the state of the environment nowadays, it is essential that new measures are taken, not only by trying to reduce the emissions of CO_2 and other gases, but also through the public, government and industry cognizance to this topic that to all concerns.

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