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Modeling Adoption of Personal Electric Vehicle Colombia 2022-2025

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The following work seeks to identify the factors that affect the adoption of electric vehicles in Colombia, analyzing hypothetical factors that allow modeling their future behavior to formulate strategies that favor their introduction on a larger scale in the country. The method of analysis includes literature studies and analysis of rapidly published information such as press announcements, reports, and market studies. As a result of this research, a cost efficiency study was developed, which was later contrasted with factors such as availability and strategies to serve the local market, to finally establish three product penetration models for imported economy vehicles, locally manufactured mid-priced vehicles, and imported high-end vehicles.

Keywords: electric vehicles; electric vehicle sales in Colombia; cost of electric vehicles; electric vehicle banking; automotive manufacturing; decarbonization, sustainable transportation, sustainable future; automotive imports.

1. Introduction

The academic literature prior to 2021 identifies and analyzes the factors that would control the adoption of electric vehicles globally through detailed analyses of some countries, but not Colombia. These factors include price sensitivity, trust in technology, infrastructure, incentives, prioritization of environmental impact, and associated benefits. The unique conditions generated by the COVID-19 pandemic, coupled with environmental resolutions to restrict the sale of combustion engine vehicles in the future, armed conflicts, and the implementation of recent sanctions that have pushed oil prices higher since February 2022, has raised global demand for electric vehicles more than forecast. Despite the fact that electric vehicles currently account for less than 1% of sales in the automotive sector in Colombia (ANDEMOS Interactive Reports, 2022), they have been gaining great popularity and the country has some incentives to promote their adoption.

Colombia is a country that firmly believes in fulfilling the obligations agreed in the Paris agreement. We know that in transport there is a great opportunity to reduce CO2 emissions, taking into account the geographical characteristics and low industrialization of the country, which make the automotive sector a large contributor to net carbon emissions1. The national

government has implemented policies to encourage this transformation, such as reducing the import tariff rate for electric vehicles2, however, the purchase of electric vehicles is mainly concentrated in cities such as Bogotá and Medellín, measures with a very low impact compared to those implemented in other countries. Specific benefits such as tax incentives3, use privileges, registration permits, relatively low cost of electricity and positive environmental impact, discussed by Ling et al, (2021), Kristin et al (2016), Joram et al (2016) and Spena et al (2016), are mainly equivalent in Colombia to the exclusion of the pico y placa and to a lesser extent to zero import tariffs. Meanwhile, the less favorable factors for the adoption of electric vehicles such as lack of confidence in the technology, lack of short-term vision of economic benefits and little sensitivity to environmental impact (Sany et al, 2013) seem to be present in the rest of the country and in the minds of most consumers. Currently, there is a general perception that finds more disadvantages than benefits in the purchase of electric vehicles, it is stated that their economy of use has little influence and that those inclined to buy them are people with a high level of education and environmental sensitivity, who are concerned about the externalities of oil. However, in countries such as Malaysia, the brand is the most important thing and the electric range remains the biggest obstacle to purchasing (Shrilatha et al, 2021). Similarly, Bi et al (2021) point out the importance of the origin of the brand and the manufacture of the vehicle, while Kang et al (2016) and Spena et al (2016) examine how consumers are really sensitive to price and the availability of charging points. Data collected in 2019 by the International Council for Clean Transportation show the phenomenon of electric vehicle purchases by cities as shown in Figure 1.

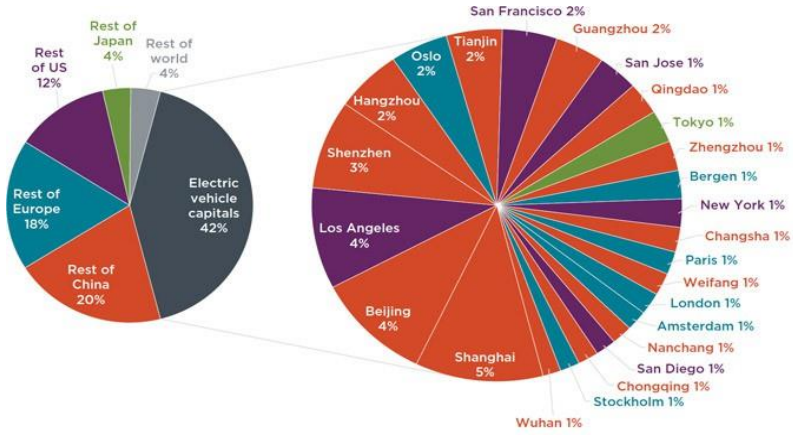

Figure 1. Electric vehicles in 25 electric vehicle capitals as part of the global stock.

Source: ICCT Briefing | Electric vehicle capitals: cities aim for all-electric mobility (2019) 4

The study of the factors that affect adoption takes more interest from the royalty project Experimental Development of an Electric Vehicle Prototype in the Automotive Sector of the Department of Valle del Cauca, which seeks to develop the electric vehicle industry in the country, due to the importance that the creation of local plants that take advantage of the simplicity of the electric vehicle would mean for the region. the reduction in the number of parts and the absence of the combustion engine; technological barriers to local production. This represents an opportunity for regions such as Valle del Cauca, Medellín and Bogotá, which already have a history in automotive manufacturing.

Although there is an initial penetration of electric vehicles in major cities, the factors driving this adoption are not reproducible in the rest of the country. As stated by Spena et al (2016), Kan et al (2016) and Ning et al (2020), this is due to the effect of price on quality, the volume of initial users and resistance to technological change, together with the lack of knowledge of the technology and its benefits (Shetty et al, 2020). All these trends conspire to limit the purchase and as a consequence the electric vehicle is relegated to being the second or third vehicle in the home (Musti and Kickelman, 2011). And this, only where environmental interests, brand reliability and access to own charging systems influence.

To better understand the phenomenon of early adoption, Priessner and Hampl (2020) classify users into three categories: The first group are "non-buyers, price-sensitive", the second "self-sufficient buyers" and the third "buyers with high economic rationality". The latter two groups generally do not need the product to outperform the dominant technology in all but in some vital aspects. As stated by Franke et al (2015), this is the case for family users with electric technology, and more specifically when there is a significant appreciation for aspects such as zero emissions and environmental sustainability (Adnan et al, 2017). On the other hand, electric performance and home charging, in addition to favorable financing rates, seem to be enough to overcome the relatively low mileage range per charge, high acquisition costs, dispersed charging network, and resale price with little history in the market.

To ensure a rapid and massive adoption of electric vehicles in Colombia, they must far exceed existing technology, this margin of technological improvement is important and is known as the cost of change. For users to make a leap en masse, the superiority of the new must be clear enough to eradicate the fear of the different. It is therefore important not to focus on early users as indicated by Febransyah (2021), where emotion is the main factor in acquiring an electric car, as is the case in Malaysia, but rather the projection of the technology to surpass the current one, in this case, internal combustion vehicles. On the other hand, in Colombia there are no definitive initiatives and plans to build and assemble electric vehicles, some short reports seem to allude to it, but without presenting concrete evidence beyond the filing of a bill in the Senate to create incentives of this type5.

Considering now the general characteristics of an electric vehicle in the national market to stimulate mass adoption, it is necessary to take into account the great diversity of products that exist: cars, campers, pickup trucks, crossovers, from low-cost to high-end vehicles. To simplify the analysis, we focus on an electric vehicle for personal use, which is not necessarily an entry-level vehicle, but can be for family or commercial use and is technically feasible both in the city and on the highway. This vehicle must have a minimum range of 350 km to avoid the phenomenon of range anxiety6 and according to a cost comparison study carried out by Torres-Pamplona et al (2021) it should cost about 90 million Colombian pesos (adjusting to current prices in July 2022).

The range of the vehicle plays a very important psychological role and influences the buyer's peace of mind, even when the vast majority of private vehicle trips in Colombia do not exceed 100 km of daily travel (they average ~60 km per day or 15,000 km per year). In addition, vehicles with high range are not charged every day, but 2 to 3 times a week, and therefore, they will experience a slower deterioration of their battery. This would help maintain the value of the vehicle over time and make its market value more predictable. This guarantee of future

value opens the doors to the establishment of a used vehicle market, as well as its banking, since vehicles with predictable residual values are ideal for financing. That is why, although it sounds not optimal to install extra range capacity, it is essential to do so to ensure the traditional market mechanisms necessary for the high penetration of a product, as well as bank financing.

In summary, for Colombia to quickly adopt electric vehicles, it is necessary to look for options that can enter the market before 2025, with an estimated cost of 90 million, ranges of 350 km of autonomy (an arbitrarily established but reasonable value for the adoption strategy in the market), a battery with a minimum of 8 years of useful life with 80% residual charge or 280 km of residual range. Creating a starting price metric per range kilometer, if you opt for the margin above 90 million and 350 km of average range, the value is 260,000 COP per km of range or 0.26 mka (million per range kilometer). However, this index over time would go down, since the future value of the vehicle, although speculative, tends to depend on the degradation of its battery, the less wear it suffers, the greater the value of the vehicle over time. Assuming that the electrical systems suffer little degradation, and that the body is of excellent construction (such as the large-format castings7 used by Teslas), it is very likely that this index will be sustained in the first eight years or decline very slightly. It is worth clarifying, not all vehicles will have these characteristics, especially the low-priced ones imported from China.

Table 1 illustrates the partial supply of electric vehicles sold in Colombia. It can be seen that practically none of them have the characteristics mentioned above, however, some Chinese brands are approaching the goal of 260,000 COP/km of range or 0.26 mka and almost achieve the ideal price-range ratio for Colombia (to better visualize this relationship the difference factor is presented). It should be clarified that this table has left out micro car brands or as "quadricycles" are classified in the country, brands with low total volumes or zero sales registered in 2021 and 2022 to date, and some luxury brands.

Table 1. Comparison of relevant characteristics for the adoption of electric vehicles in Colombia.

Brand	Price (million COP)	Range (km)	MKA (million/km of range)	Difference factor
BMW iX	469,9	620	0,76	2,9
BMW iX3	289,9	450	0,64	2,5
BYD Yuan 300	114,9	300	0,38	1,5
BYD yuan 400	129,9	400	0,32	1,3
BYD Yuan Pro	139,9	400	0,35	1,4
BYD Tang EV	282,9	500	0,57	2,2
BYD Han	280,0	500	0,56	2,2
NISSAN Leaf	178,0	248	0,72	2,8
RENAULT Kangoo	131,5	170	0,77	3,0
RENAULT Twizy	56,0	89	0,63	2,4
RENAULT ZOE	133,5	255	0,52	2,0
ZHIDOU	58,4	150	0,39	1,5
JAC E2	100,0	231	0,43	1,7
CHANGAN E-Star	85,99	300	0,29	1,1
TESLA Model 3	305,0	550	0,55	2,2
IDEAL COLOMBIA	90,0	350	0,26	1,0

Analyzing the data presented above, it is observed that Changan E-Star, with its price of 85,990,000 COP and its validated range, by third-party tests, of 300 km is very close to the ideal set with a factor of 0.29 mka, 1.1 times above the ideal. It is evident that the scenario of mass adoption is possible and it is shown that some models are far from approaching the proposed indicators. Brands with a difference factor greater than 2.4 (red or orange) are far from reaching the ideal, those with a difference factor of less than 2.4 (yellow) have a chance and those with difference factors less than 1.7 (green) are very close to meeting the ideal for Colombia. Next, it will be analyzed from the work methodology why the best-rated vehicles in Table 1 have the potential to become widespread in the national market and the factors that can contribute to making it viable to reach the goal of 0.26 mka by 2025.

2. Methodology

What factors can contribute to the existence in Colombia of a vehicle with a cost of 0.26 mka or 260,000 COP/km of autonomy, with an eight-year battery life and high residual value? The analysis process is as follows:

1. Brands with a difference factor of less than 2.4 mka are selected to examine whether they qualify in all aspects of actual range and battery life, starting with the models closest to the finish line.

2. It analyzes the brands that are innovating and investing to achieve cost reduction and production at the necessary scale.

3. Market conditions that may advance or delay improvements in cost-performance metrics, as well as product availability for the region, a factor that has gained relevance in recent months, are examined.

Leaving aside design and utility factors, and assuming that any vehicle format, two-door, four-door, hatchback, or SUV is ideal to begin to achieve the goal of meeting the mass capacity and meeting the agreed CO2 reduction goals, then the requirements illustrated below in Table 2 must be met.

Table 2. Viability according to delivery capacity and guarantees/residual value

Brand	mka (million/km autonomy)	Rank	Capacity productive	Autonomy viability (km)	Life hood	d
BYD Yuan 300	0,38		300	8 years (500,000 km)	Loud	
BYD Yuan 400	0,32		400	8 years (500,000 km)	Loud	
BYD Yuan Pro	0,35		400	8 years (500,000 km)	Loud	
BYD Tang EV	0,57		500	8 years (500,000 km)	Loud	
BYD Han	0,56		500	8 years (500,000 km)	Loud	
RENAULT Twizy	0,45		89	2 years (50,000 km)	Stocking	
RENAULT ZOE	0,39		255	2 years (50,000 km)	Stocking	

ZHIDOU	0.42	120	4 years (100,000 km)	-
JAC E2	0.43	231	5 years	-
CHANGAN E-Star	0.29	300	8 years	Stocking
TESLA Model 3	0.55	450	8 years (240,000)	Loud

3. Results and Discussion

According to the results obtained in Table 2, subsequent analyses will focus on the BYD, CHANGAN, TESLA and RENAULT brands.

CHANGAN

Changan is a sizable Chinese company that began production in 2001 and in 2020 produced 2.5 million vehicles (working vehicles in the early years and later passengers8). In the2020 made alliances with Ford, Huawei and CATL9, which are necessary to scale, but seem not to be as efficient as the vertical integration of Tesla and BYD. The Changan E-Star vehicle will be presented in two bacterial versions: NMC (nickel manganese cobalt) and LFP (lithium iron phosphate). The latter is cobalt-free, which could explain the price of the vehicle and the 8-year warranty.

Changan with just 2% of the volume or 14,416 units in 202110 is not one of the most relevant electric vehicle producers in China. This poses challenges in supplying a global market. However, it is distributed in 8 points nationwide covering the cities of Barranquilla, Bogotá, Bucaramanga, Cali, Cartagena, Medellín, Pasto, Pereira and Valledupar. Table 5 shows the sales performance of the Changan brand in Colombia from 2021 to June 2022. Because Changan only sells one electric model in Colombia, sales are assumed to be for the E-Star.

Table 3. Changan Sales in Colombia 2021 – 2022

BRAND	**2021**	**2022**	**Variation 2021-2022**
CHANGAN	49	14	-71.4%

Source: ANDEMOS Interactive Reports (2022)

TESLA

As can be seen in Figure 2, Tesla is the No. 1 producer of electric vehicles worldwide with almost one million units produced in 2021 (936,172), followed by BYD with almost 600,000 units, while Changan is listed with 97,911, a tenth (see Figure 3). Tesla has 6 factories, three in the United States (Fremont, Nevada and Austin), and others in Shanghai and Berlin. In addition, it is a company that is revolutionizing manufacturing methods and has become a benchmark for the high level of performance and innovation of its more than 10 models on offer.

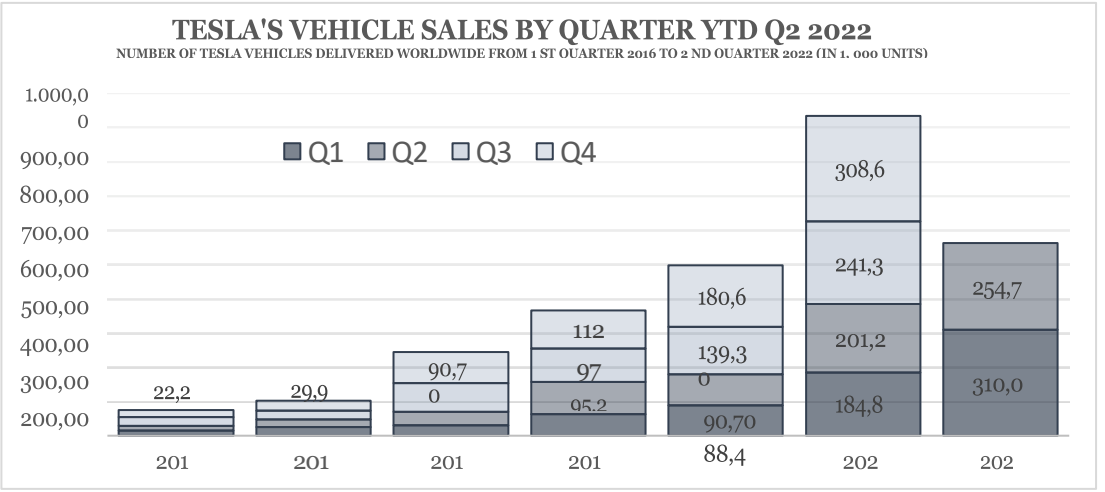

Figure 2. Tesla vehicle sales by year (quarterly deliveries)

Source: Tesla, (2022)11

Tesla delivered 254,700 vehicles in the last quarter of 2022 while it was finishing two new factories in Berlin and in Austin12, Both factories are starting to deliver Model Y13 vehicles, and as we see in Figure 2 sales of the latter model are increasing rapidly and today it has almost a full year of orders14.

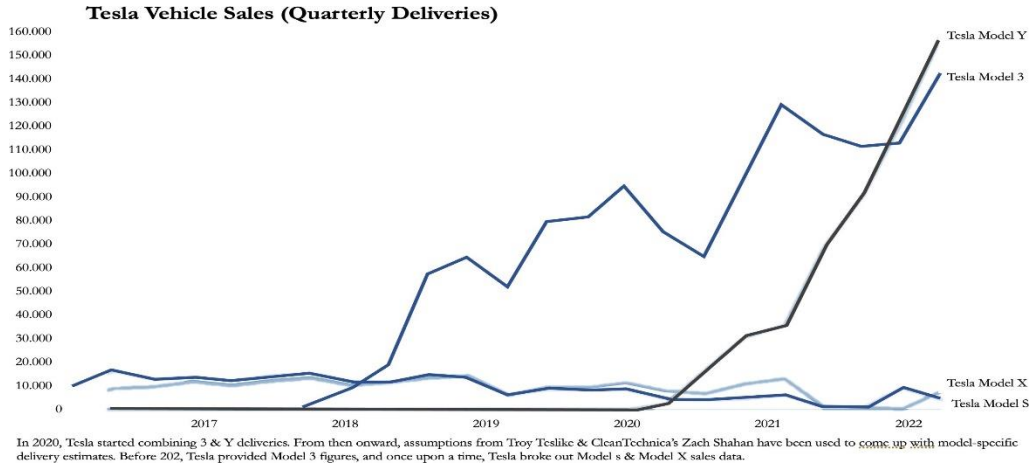

Figure 3. Tesla Model Sales (Quarterly Deliveries)

Source: Tesla, CleanTechnica (2022)15

Considering that Tesla's mka is 0.55 (higher than ideal), and that its vehicles are more in demand in markets with more incentives and purchasing power, the massification of these vehicles in Colombia does not seem viable. Table 4 shows the sales performance of the Tesla brand in the last 18 months in the country.

Table 4. Tesla sales in Colombia 2021 – 2022

BRAND	2021	2022	Variation 2021-2022
TESLA	11	3	-72.7%

Source: ANDEMOS Interactive Reports (2022)

BYD

This brand was one of the first to arrive in Colombia, establish its dealer network and promote its electric vehicles aggressively through programs such as the electric taxi program in Bogotá16 and then inMedellín17. BYD today has the widest range of offer with seven models and has five dealerships in Bogotá, Medellín and Pereira.

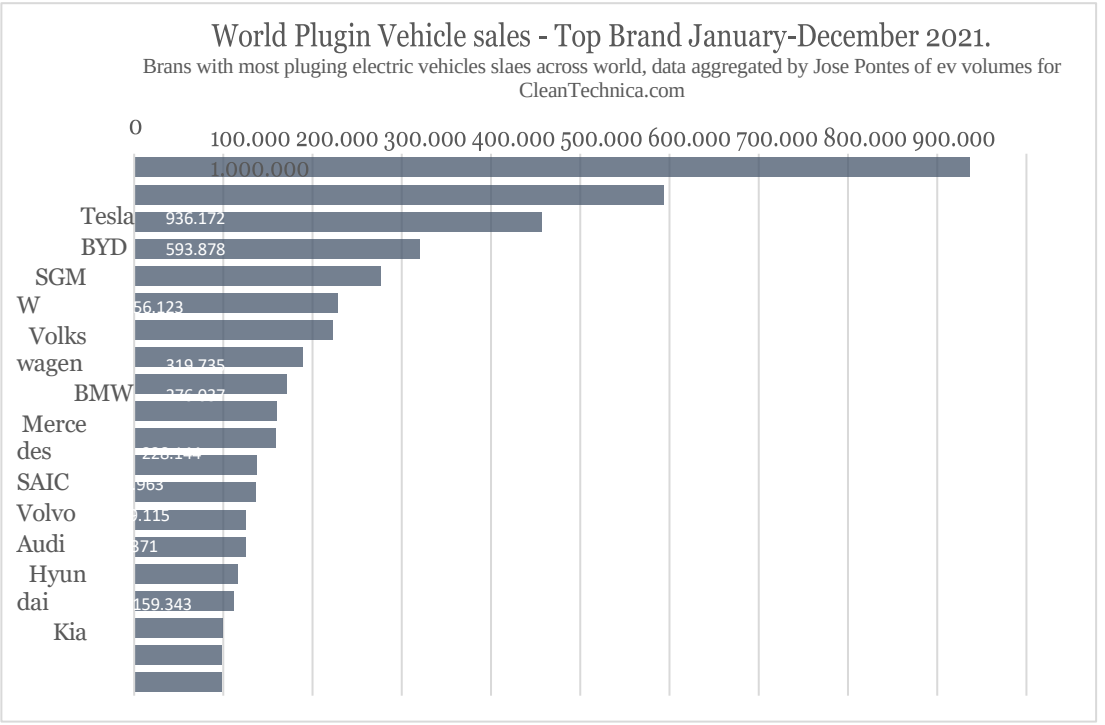

Figure 4. Worldwide sales of major electric vehicle brands (January-December 2021)

Source: Tesla, CleanTechnica (2022)18

Table 4. BYW Sales in Colombia 2021 – 2022

BRAND	2021	2022	Variation 2021-2022
BYD	49	14	-71.4%

Source: ANDEMOS Interactive Reports (2022)

NATIONAL ASSEMBLERS

Another option worth exploring is those vehicles that could be assembled in the country.

To do this, it is necessary to review the options of Renault and Colmotores.

RENAULT

Renault has committed to being 100% electric in Europe by 203019. This announcement, however, could imply a considerable delay in the supply of vehicles in Colombia given the priority that would be given to that continent. Additionally, it should be considered that such a strategy can increase the production of parts and open the way to assembly in Colombia for the first time. For this, Renault needs to vertically integrate its battery production (which could take about five years) and align its offer of electric models with the demand models in Colombia. The Renault Zoe, Twingo ZE and the Kangu are its main models. Figure 4 shows the growth of Renault's electric vehicle production.

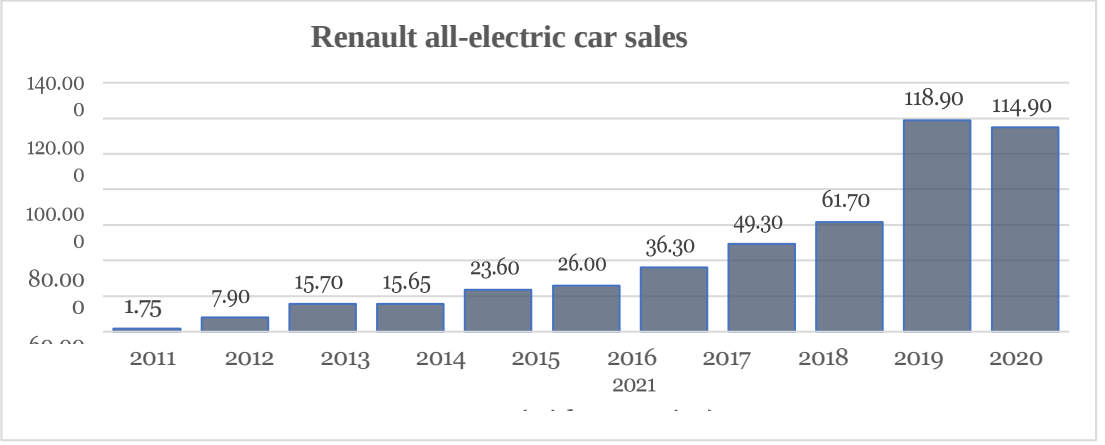

Figure 5. Renault electric vehicle worldwide sales (2011-2021)

Source: InsideEVs20

It is important to note that the figure of 114,900 units includes the hybrid vehicles produced, Renault does not specify the quantities of electric and hybrid vehicles in its public reports, but it is known that most of the low-emission units are sold in Europe. Due to the low volume of electricity and supply challenges, Renault does not seem viable for massification in Colombia. Below are Renault's electric vehicle sales in the country over the past 18 months.

Table 5. BYW Sales in Colombia 2021 – 2022

BRAND	2021	2022	Variation 2021-2022
Renault	167	40	-72.0%

Source: ANDEMOS Interactive Reports (2022)

GM COLMOTORES

GM Colmotores, founded on July 27, 1956 as Fábrica Colombiana de Automotores S.A. (Colmotores) became the first car assembly company in the country. Today it is a subsidiary of General Motors (which owns 77%) and has an installed capacity to produce up to 110,000 vehicles a year, however, it does not assemble any electric version in the country. Its global production of electric vehicles had a 7.64% share of sales21, in part, thanks to its alliance in China with SAIC and Wulings.

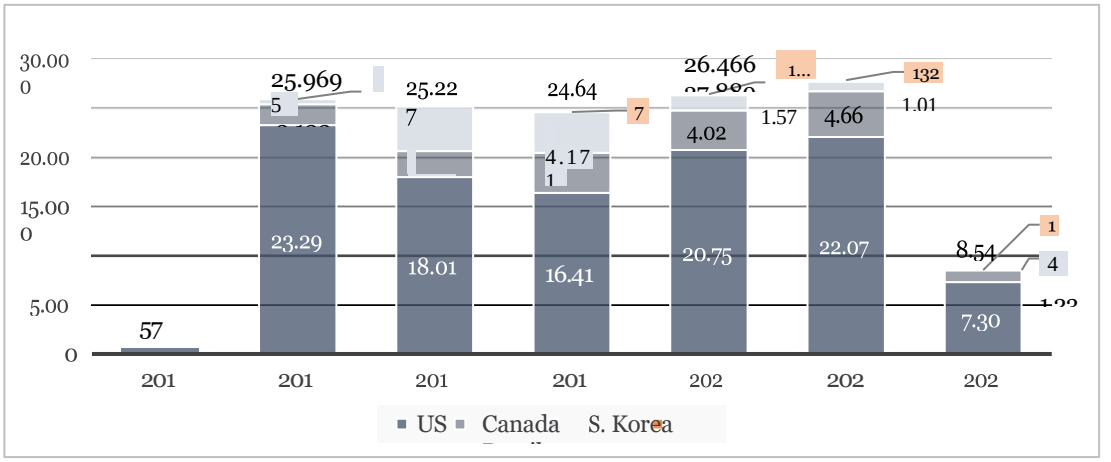

Figure 6. GM Electric Vehicle Worldwide Sales in United States 2016 – 2021

Source: GM Authority22

CHALLENGES TO THE SUPPLY OF ELECTRIC VEHICLES

Demand can be defined as the orders or intention of future orders and we will use the purchase intention or pre-sales/reserves as an indirect indicator of demand. As Figure 6 indicates, EV sales are concentrated in China and Europe, while the United States buys slightly more than the rest of the world, at 8% and 7%, respectively. We can assume that manufacturers are going to focus on these two regions, as 6.5 million units represent a little less than 1% of the global market. This means that Latin America and Colombia are at high risk of not being a focus market until the global percentage of penetration increases in magnitude.

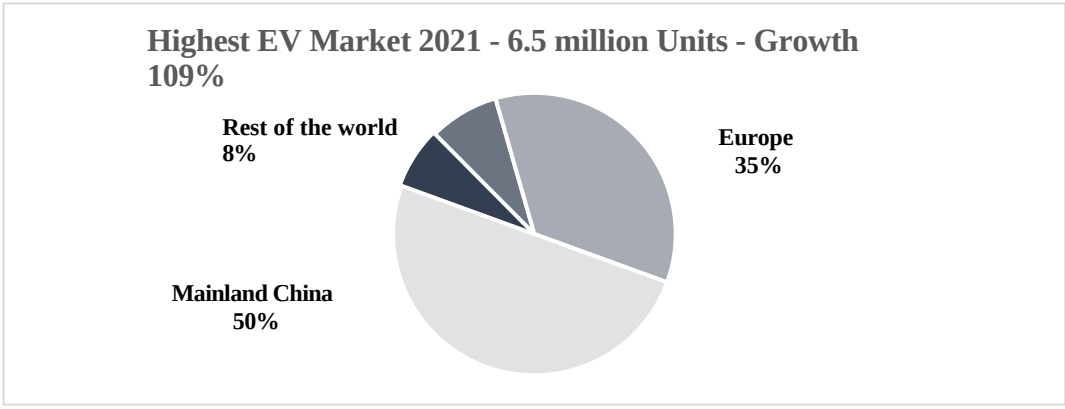

Figure 7. Geographical distribution of electric vehicle sales 2021

Source: Source: Canalys23

Finally, it is important to analyse the markets with the highest incentives for electric vehicles, Europe tops the list in incentives24, followed by China and the United States. These three markets today represent 93% of electric sales leaving the rest of the world with 7% (it should be noted that the rest of the world has 7% of the sales of electric vehicles).

BATTERY AVAILABILITY

This issue, although fundamental, is quite extensive and complex, and is the new bottleneck for the production of electric cars appropriate to the Colombian market. Although prices have historically been decreasing, the high demand for batteries has generated new problems due to the time it takes to build new production lines and the processing of raw materials for it. So price stability or price rises favor adoption in markets with greater purchasing power. This is not conducive to the rapid adoption of electric vehicles in Colombia

MICROCHIP SUPPLIES AND INTERNATIONAL LOGISTICS

2021 was a very strange year for the automotive industry, the end of the restrictions imposed during the COVID-19 pandemic saw the return of automotive demand that could not be met due to the collapse of some supply chains, the most prominent being that of microchips for vehicle electronics25 . The lack of microchips and the increase in logistical times andcosts26 of transportation affected the availability of vehicles, even causing second-hand vehicles to increase in price27. These complications will have a negative effect on the availability of electric vehicles in the country.

CURRENT SALES IN COLOMBIA

Colombia closed 2021 with more than 1296 new electric vehicles (cars). According to ANDEMOS28 the list is headed by BYD and this is the sales ranking:

Table 6. Electric Vehicle Sales Colombia 2021-202

Position	Brand	Sales
1	BYD	370
2	RENAULT	178
3	DONGFENG	142
4	STARK	106
5	ZHIDOU	101
6	MINI (BMW)	90
7	BMW	70
8	NISSAN	57
9	CHANGAN	49
10	JAC	22

Data source: ANDEMOS Interactive Reports (2022)

The interesting thing about these figures, although they may seem low, is that total sales in 2020 were 589 units29 according to ANDI and Fenalco. This represents a growth of 2.2x or 120%. Good news, considering that until 2019 a total of 782 electric vehicles for personal use had been marketed, not including buses and trucks.

Table 6. Brands with the most electric vehicle sales in Colombia in 2022

Position	Brand	Sales 2021	Sales 2022
1	ZHIDOU	101	159

2	MINI	90	97
3	BYD	133	63
4	RENAULT	167	40
5	BMW	70	19
6	CHANGAN	49	14
7	NISSAN	57	12
8	DONGFENG	2	10

Data source: ANDEMOS Interactive Reports (2022)

By 2022 total sales will go at the pace of 2021, but there are new players like Zhidou and MINI that deserve to be mentioned. On the one hand, Zhidou is the most economical of the vehicles with the lowest performance, being only two-seater, while MINI is in the high price range, but enjoys an excellent reputation. There is not enough information yet about the new MINI 2023 models, as they have not yet publicly announced their battery, nor expected range.

ANALYSIS OF FUTURE CHALLENGES

The global production of electric vehicles today has some important challenges that affect their supply:

- Low availability of chips and electronics.
- Rising prices of raw materials.
- Limited battery production capacity, raw material shortages, and high costs.
- Market focus with better incentives and product margins.
- Unexpected growth in local demand for electric vehicles in the United States, China and Europe. High fuel prices and availability risk have boosted demand, as predicted by Hwang (2012).

As a result, the mka index increases.

The three scenarios for the massification of the private electric vehicle in Colombia are:

- Imported low-cost vehicle.
- Imported high-cost vehicle.
- Medium-cost vehicle imported or locally produced.

IMPORTED LOW-COST VEHICLE

From the list of vehicles offered, Changan seems to tick the boxes in the low price range being the most economical (85,990,000 COP). Assuming it meets the stipulated performance and quality, its sales performance is still a small fraction of BYD's sales. However, in the short term Changan and other brands such as Zhidou, with products in this range, can have a major impact and can be defined as entry-level products. Despite this, this strategy runs the risk of generating bad experiences in quality and support that will hinder the adoption of electric vehicles in the future.

MEDIUM-COST VEHICLE IMPORTED OR LOCALLY PRODUCED

This could be the strong market where BYD will be established. The price range and performance of their vehicles is perhaps the best in Colombia. Although sales volume remains relatively low, with less than 200 units per year, it is possible that an efficient market campaign could propel BYD to 1000 units sold per year by 2025. The challenges will be in the availability of vehicles, customer service, the increase in the fast charging network, being able to maintain or increase incentives, among others.

IMPORTED HIGH-COST VEHICLE

Tesla and BYD are the only high-cost brands with enough performance to justify their acquisition at some level of volume to highlight. A detailed analysis of costs and performance will be the subject of another analysis with usage, cost and resale data. Tesla has challenges to establish itself as a solution that moves Colombia towards zero-emission mobility taking into account that it does not have direct representation in the country, and although buyers of these vehicles do not see this as an inconvenience and work remotely with the brand, for the bulk of the public this does represent a disadvantage. with the high delivery times. and high prices generated by high global demand and currency exchange.

So far in 2022, Tesla vehicles have increased in price (+14% between February 2021 and 2022, and 4% since the beginning of 2022)30, due to the high costs of the Autopilot function and the devaluation of the Colombian peso against the dollar. BYD, on the other hand, thanks to the introduction of its "Blade" battery (lithium-ferrous chemistry) in the high-end of SUVs and its local dealer network, seems not to have the obstacles that Tesla has. Both brands can have a positive indirect effect on the adoption of electric vehicles in Colombia and can become reference products, which improve the public's perception of electric vehicles.

Although it does not seem that there will be a Tesla presence in the short or medium term, Tesla will double the plant in China with the aim of increasing the supply of the international market, and in its alliance with CATL the LFP battery models will be cheaper with a small drop in performance (~15 km less range31). In addition, in its latest earnings announcement32, Tesla stated that it will close 2022 with double the production capacity of 2021, delivering up to 1.9 million electric vehicles in 2023.

4. Conclusions

- The Colombia market can reach mass adoption only when there is sufficient global production to serve the local market.
- Colombia reached more than 6,000 units of vehicles with the reduction of import tariffs, more than 4,000 of them electric and non-electric hybrids. Many of these come from different brands that sell few luxury units to non-representative customers who can choose by conviction, convenience in peak and plate or by tariff benefits.
- The options to stimulate mass adoption in the short term, by cost-performance indicators, are few. Variations in market conditions since the beginning of this analysis have affected its development. For example, the rise in prices of Lithium, Nickel and Copper that has occurred in the last 6 months has prevented batteries from falling in price, the

semiconductor crisis has affected the availability of vehicles and the increase in transport costs has increased vehicle prices.

• There is regulatory pressure to remove non-plug-in hybrids from tariff benefits33, because they do not meet the objective of reducing emissions and represent, according to the DIAN, the evasion of some 25 billion pesos34. This can become a factor and drive the adoption of more electric vehicles.

• Adding to the changing landscape, there is constant and systematic misinformation about electric vehicles. False claims such as that "producing the energy to charge electric vehicles pollutes more than extracting and burning fossil fuels" or that "the carbon footprint of its production is not recovered", added to a new trend of misinformation about the environmental impact of mining materials such as lithium, discourage the adoption of these technologies. It should be noted that, although every mining process has an impact, lithium represents less than 2% of the composition of the average typical battery35, which in turn represents less than 20% of the vehicle's weight on average. That is, 0.4% net of the vehicle's weight vs. metal extraction represents up to 40% of the weight in an internal combustion vehicle.

• Another major challenge is the frequent press announcements by manufacturers about new electric models that rarely offer detailed information on prices, product availability in the country, technical characteristics or delivery times. This generates expectations that cannot be met. For example, Toyota's announcement to sell up to 3.5 million electric cars in the 203036 appears to run counter to comments by Toyota's president Latin America and the Caribbean that the region is not ready to receive electric vehicles.37 Everything seems to indicate that brands such as Toyota want to project that they are at the forefront, but in reality they find it more profitable to continue selling their internal combustion vehicles in the region. Similarly, Ford announced the electric F150, but it is not clear where or how it will produce the batteries to deliver a high volume of trucks and GM stated that it will be 100% electric in 2030 in the United States and 2035 in the rest of the world 38, but until today it is unknown how it will produce its Ultium39 electric platform and batteryto reach production volumes in the short or medium term. The only thing that can be analyzed with some clarity is which manufacturers are the most efficient when it comes to producing electric vehicles, and that efficiency will translate into a good balance of price-performance and availability, the two key factors for adoption in Colombia.

• Chinese brands may be an option for Colombia, especially those that already have low costs. It is possible that BYD with new developments such as plants in Viet Nam and Brazil can offer a more competitive product in terms of price, since its high vertical integration can ensure availability in high volumes.

• In the high-end, Tesla is the most efficient manufacturer and its advances in China, giga factories, vertical integration, maturation of its 4680 format battery, giga castings, alliances with CATL and other innovations may allow it to increase the offer to serve the Colombian market.

• There is a good window of opportunity to establish a domestic player that takes advantage of the market window generated by the lack of specific supply and growing

international demand. A focused offer in the local market with efficient models and agile micro manufacturing would be the best option for Colombia. Some of these initiatives are seen globally today in emerging brands such as Arrival, Farady Future, Canoo and Aptera Motors, among others.

- The mka indicator can be useful as an instrument to measure the benefit and/or utility of electric vehicles, an mka below 0.26 does not seem to be a robust indicator of the adoption of electric vehicles in Colombia.

- Another theoretical and quantitative study that models the variables in the supply chain, production, product, user, financing, incentives, customer service and brand position, among others, is necessary to better predict the adoption of electric vehicles in Colombia.

RECOGNITIONS

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