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Review

Challenges and Opportunities for Electric Vehicle Charging Stations in Latin America

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Abstract: This research addresses the challenges and opportunities for electric vehicle charging stations in Latin America. The transition to electric mobility is crucial to reduce greenhouse gas emissions, modernize the quality of life in urban areas, update public policies related to transportation, and promote economic development. However, this is not an easy task in this region; it faces several obstacles, such as a lack of liquidity in governments, a lack of adequate infrastructure, high implementation costs, the need for clear regulatory frameworks, and limited public awareness of the benefits of electric mobility. To this end, the current panorama of electric mobility in the region is analyzed, including current policies, the state of the charging infrastructure, and the prospects for growth regarding electric vehicles in Latin America. Factors that could lead to their successful implementation are promoted, highlighting the importance of public policies adapted to Latin American countries, collaboration between the public–private industry, the industry's adoption of new technologies in this region, and the education of the population, and the benefits of these policies are considered. Successful case studies from the region are presented to provide us with an idea of practices that can be carried out in other countries. The implementation of a charging system in Latin America is also studied; the successful implementation of charging systems is found to depend largely on the existence of integrated public policies that address aspects other than the charging infrastructure. Finally, the value of the work and the research findings are presented to indicate what this study can help with. These strategies are key to overcoming the challenges and maximizing the benefits of electric mobility in Latin America.

Keywords: grid-connected charger; electric vehicles; charging station; charging infrastructure; policy; electric mobility

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1. Introduction

Sustainable mobility is increasingly playing a strategic and important role as a key element in the economic development and quality of life in cities, as well as contributing to the mitigation of climate change and improvements in air quality [1,2]. The various regulatory changes that are taking place, driving change in mobility habits and providing the means necessary for this change to occur, are positioning electric mobility as an alternative at global and national levels [3,4]. The future of driving is closely linked to electric vehicles (EVs); people are increasingly being encouraged to change their travel habits and the trend is to opt for electrification. However, for these changes to reach all users and represent a true automotive revolution in the short term, certain technical, technological, and administrative aspects must evolve, which should be emphasized. Countries in Europe, North America, and Asia have led this transformation, implementing ambitious policies,

offering tax incentives, and developing robust infrastructures to facilitate the mass adoption of EVs [5–12].

In the field of EV charging infrastructure, we believe that the most important thing is the expansion of the electric charging network and improving its management and accessibility. An aspect related to this topic is geographic coverage; it is essential to expand the availability of charging points in different geographic areas, including both urban and rural areas [13,14]. The lack of a charging infrastructure for electric vehicles is a major barrier to the mass adoption of electric vehicles; therefore, expanding this coverage is essential to encourage their use. Regarding the standards and compatibilities established to facilitate the charging of electric vehicles, it is necessary to establish common standards such as OCPP 2.01, ISO 15118-2, etc., and ensure interoperability between different charging service providers [15,16]. This implies the adoption of standardized charging plugs and protocols so that EV owners can charge their vehicles at any charging point. Improving charging speed is another important aspect. At present, there are different levels of charging, from slow charging (used mainly in homes) to fast charging (used at public charging stations) [17,18]. The expansion of fast charging stations, which allow for a vehicle to be charged in a matter of minutes, is absolutely necessary to make charging more attractive and competitive compared to filling up a car with gas. It is important that charging points are installed both in public spaces (streets, public parking lots, etc.) and in private spaces (homes, offices, shopping centers, etc.). By facilitating access to charging and making it easy and fast, the worries of EV owners will be eliminated [19,20]. The development of intelligent load management systems is another key aspect at present. This involves using technologies that allow for load demand to be balanced, preventing the electrical grid from becoming overloaded at times of high demand and optimizing the use of renewable energy. In addition, intelligent, easy, and accessible load management would facilitate scheduled charging, charging at times of lower demand, or load management through mobile applications through its established standards and ease of use.

The development of such an infrastructure not only represents a step forward in terms of environmental sustainability, but also offers economic and social benefits. Job creation, the development of new technological industries, and an improvement in urban quality of life are just some of these potential benefits [21–23]. However, these benefits come with significant challenges, ranging from financing and technological development to the need to establish adequate regulatory frameworks and foster public acceptance.

The establishment of public EV charging stations (EVCS) may have a wider impact on nearby communities, particularly regarding the economic vitality of the surrounding businesses. Some of the benefits of EVCS are the convenience and flexibility they offer. EVCS provide convenient charging solutions so that car owners do not need to frequently look for gas stations, and having a wider distribution network of charging piles increases the flexibility of the charging options. EVs replace traditional fuel vehicles and reduce exhaust emissions. EVCS use renewable energy for charging, reducing the associated carbon footprint. Smart electric vehicle charging piles can take advantage of low-peak electricity prices and can use charging pile monitoring functions to understand charging consumption and costs in real-time. The installation and development of electric vehicle charging piles support the construction of a sustainable transportation system, and the expansion of the distribution network of EVCS can provide the necessary infrastructure for the popularization and development of electric vehicles in the future.

This article aims to analyze the main challenges and benefits associated with the implementation of charging systems for electric vehicles in Latin America. Using a detailed approach, the current state of the charging infrastructure in the region will be explored in Section 2. The obstacles that must be overcome to allow for its development will be identified and the potential advantages of a well-implemented charging system will be discussed in Section 3. In addition, success stories will be presented, and practical recommendations will be offered to advance the creation of a robust and accessible charging

infrastructure, allowing the region to take full advantage of the benefits of electric mobility; this is presented in Section 4.

2. Electric Mobility in Latin America

Electric mobility has experienced a growth of more than 260% in the most representative countries of Latin America (Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru, and Uruguay) in the last two years. During the first half of 2023, Mexico experienced a 30% increase in electric vehicle sales; Chile registered a cumulative increase of 17% between January and April; Ecuador and Uruguay stood out with a growth of 80% and 68%, respectively, in the first four months of 2023. Costa Rica showed significant growth, doubling its number of electric vehicles during this semester. These data reflect a marked trend of the adoption of electric vehicles in the region, driven by a combination of factors, including concern for the environment, reduced battery costs, and the increase in the availability of electric vehicle (EV) models. In Figure 1, a diagram of the electric and hybrid car market in Latin American countries is presented. However, the electric vehicle market is still in its infancy compared to developed countries. This is why these countries were chosen for the study. Furthermore, the electric vehicle charging infrastructure in Latin America is in the active development phase. The availability of charging stations is a crucial factor in the success of electric mobility in the region.

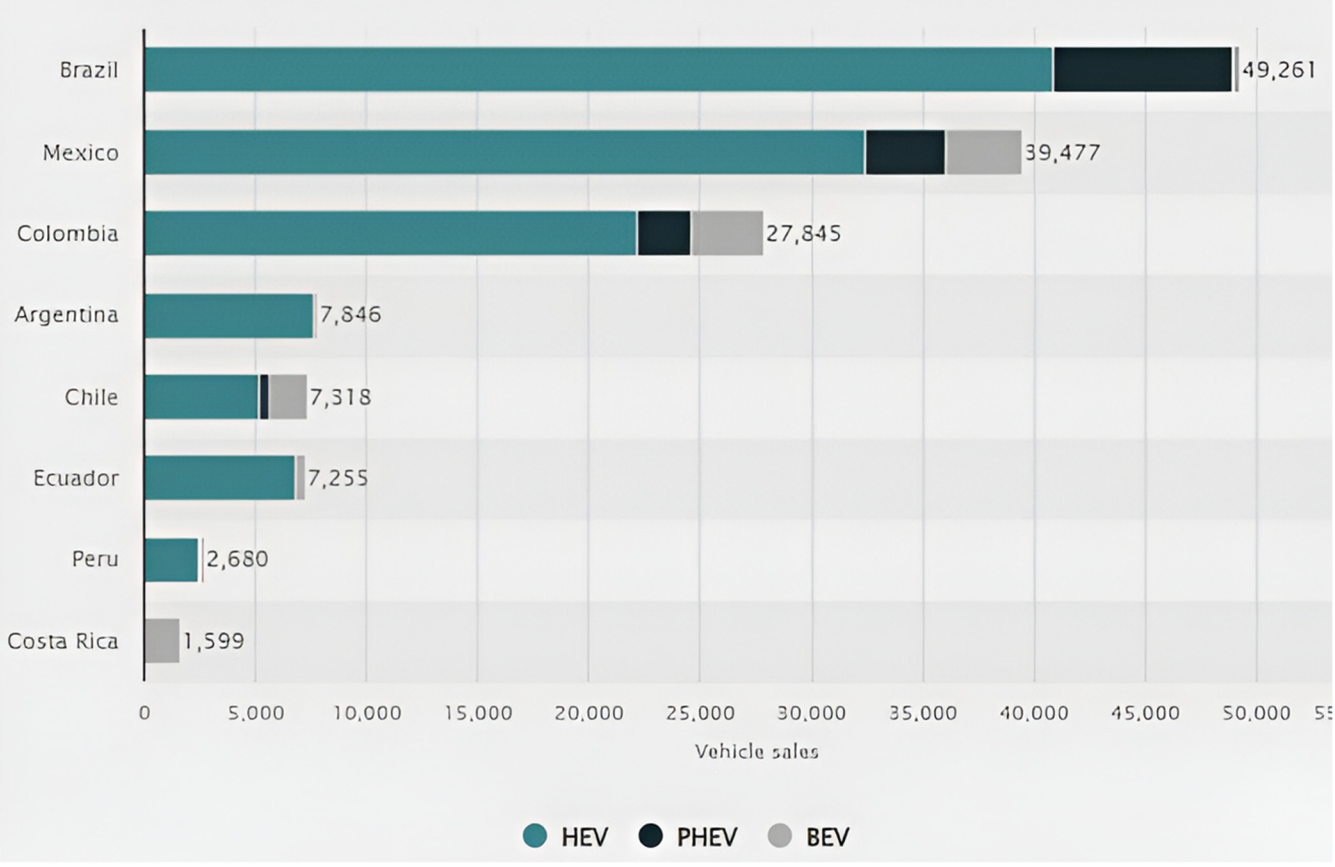


Figure 1. Diagram of the electric and hybrid car market in Latin American countries.

2.1. Current Infrastructure

Electromobility requires a good supply of charging stations and public connectors for the operation of electric vehicles. Different types of connectors for this type of mobile are available on the market: Type 1, Type 2, Schuko, Tesla, GBT and CHAdeMO are the main ones. Details of the public access charging points are provided below, with information

taken from Electromaps and from the different government reports [24,25]. Figure 2 shows the charging stations in Latin American countries.



Figure 2. Charging stations in Latin American countries.

2.1.1. Argentina

There have been important announcements regarding the development of a charging infrastructure (which is still non-existent in the country) as well as the launch of the first electric models (from Renault and the Chinese company, BAIC). Particularly, in terms of regulations, the design of guidelines, and procedural guides, Argentina has made important progress in regulating a market that does not yet exist. The Argentine automotive market is almost totally dominated by locally produced vehicles, or those produced within the Mercosur multilateral system, as well as imports from Mexico, with which Argentina is a trade agreement providing tariff exemptions [26–32].

In the hybrid segment, the main vehicle being sold is the Toyota Prius. At the same time, high-end products such as the Porsche Cayenne Hybrid can be found, as well as the recent launch of the Mercedes Benz C 350e and its plug-in hybrid version. Lexus has

announced that it will enter the Argentine market at the end of 2018, and its G540h hybrid is already available for reservations. As these are premium vehicles, they are not expected to make significant penetration into the market given their low inelastic demand. Due to the tax benefits of these vehicles, the possibility of other mass models in the European/North American markets entering Argentina in the coming years has been suggested. However, it is estimated that their entry will be delayed due to the fluctuations that the automotive market recently suffered in this country. Toyota has suggested that, by 2025, in accordance with the changes in the generation of the Hilux, they will begin to manufacture a hybrid version of the best-selling pick-up in Argentina. This suggests that the hybrid market may grow in the medium term. One obstacle that Argentina still faces regarding the introduction of electric vehicles is the need for charging infrastructure, which is practically non-existent at present. In certain cities in the region, the car manufacturers have installed public chargers in their dealerships to promote their portfolio of electric vehicles (such as BMW, BYD, Nissan, and KIA). However, this is not the case for Renault, which was the first company to market an EV (Kangoo ZE) in Argentina, at the beginning of 2018. The strategy of providing public chargers aims to create electric corridors. However, until the end of 2018, there was no major progress in the installation of a charging network for electric vehicles, nor were any deadlines or short-term objectives established [26–29].

Under these conditions, the market for alternative vehicles, particularly electric and plug-in hybrids, will see a massive take-off in Argentina after 2025. Given the strong fluctuations in vehicle sales and the growth trends of the last decade, Frost and Sullivan believes that, by 2025, the Argentine market will reach total sales of between 1 and 1.1 million vehicles, of which approximately 6700 will be hybrid or electric cars. This would represent around 0.6% of the total market [27,30].

Argentina has 23 charging locations and 37 connectors, of which 27 are type 2, four are CCS2, and three are CHAdeMo. The investments in electric routes by Scame, Vulletic, and Chargebox, and the chargers installed at Axion service stations, stand out in the public access infrastructure expansion plans. In addition to these, there is work being carried out in the provinces of Río Negro and Neuquén. YPF is also working on two electric corridors. One would link Buenos Aires and Córdoba, and the second would link the south of the province of Buenos Aires, promoting connectivity with the Atlantic Coast. To carry out this project, the Argentine oil company awarded four manufacturers a contract to supply more than 30 fast chargers [26–32].

2.1.2. Brazil

Traditionally, this market is highly linked to the local industry, which has developed strongly in recent years, driven by promotional policies by the Brazilian government and the strength of its local consumption (around 89% of Brazil's sales are locally produced vehicles). During the rise of the so-called BRIC countries, the Brazilian automotive industry received strong investments to increase its production capacity to five million units per year, making it one of the five powers in terms of automotive production globally. Currently, Brazil is operating at 50% of its capacity, so it is working on strengthening trade ties with other countries, especially in LAC, such as Argentina, Colombia, and Mexico, to increase its exports while the local market recovers. Another possibility would be that this installed capacity could be used, for example, to produce electric vehicles. Looking at EV sales, unlike in 2014 (when the market was limited to pilot programs, with the most typical being taxi fleets and some B2B programs), in recent years, EVs have started to penetrate the consumer market. As in most Latin American countries, charging infrastructure and high vehicle prices have been the main constraints to the introduction of these vehicles to the general public. It is worth noting that EVs barely represent 0.01% of total car sales in Brazil [33–41].

Over the past few years, there has been a greater development of infrastructure, which has led to an increase in presence of this type of vehicle and their rapid adoption by both companies and consumers. In fact, excepting BYD, most of the activities of automotive

companies are oriented towards introducing their EVs at the consumer level, and working together with governments and companies to improve the charging infrastructure [33–37].

There are 284 charging locations in Brazil and 3800 connectors, of which 308 are type 2, 28 are CHAdeMO, 21 are type 1, 20 are CCS 2, 9 are Schuko (EU Plug), and 4 are NEMA 5-20 (US Plug). Last month, the first fast-charging station was introduced in Brazil, with the Shell Recharge brand. It is located on Avenida Profesor Celestino Bourroul, in the Limão neighborhood, in the north of São Paulo. According to Raízen, this point is the first of a network that aimed to have 35 stations spread throughout the country by March 2023.

There is a charging infrastructure for electric vehicles in 12 of the 27 states in Brazil, a situation that is not very common in markets that do not show a very high adoption of this type of vehicle. Most of the charging points are concentrated in the states of São Paulo, Santa Catarina, and Paraná. One relevant issue that has not yet taken an important role in the discussion regarding LAC is that of charging standards [34–38].

Hybrid and electric vehicles are expected to comprise around 1.8% of the total Brazilian market (around 61,700 units), which may seem relatively conservative, but as mentioned above, one of the restrictions to the adoption of this type of vehicle in Brazil is the significant push to use ethanol as a fuel [37–40].

2.1.3. Chile

According to the Superintendency of Electricity and Fuels, the country has 1032 public charging points, of which 405 are semi-fast, 194 are fast, 18 are ultra-fast and 2 are slow. These can be broken down into 329 type 2 sockets, 96 type 2 sockets, 79 Combo T2 sockets, 75 CHAdeMO sockets, 35 type 1 sockets, and 5 GB/T DC sockets. It is pertinent to note that Descon will link northern and central Chile with an intelligent route of chargers for electric vehicles. The expansion plan will be financed as a result of a project accelerator and will take around eight months from July, the estimated start month. Nissan aims to add between 12 and 14 new points during the year. This action is part of a commitment made by the automaker following the Public–Private Agreement regarding electromobility in Chile that was signed at the beginning of 2022 [42–54].

At the national level, there are already projects to expand public charging infrastructure networks in Valparaíso and other major cities in Chile. In 2016, Chilectra became a direct part of the Enel group (Enel Distribución Chile). This company is currently among the main agents promoting electric mobility technology in Chile and in other countries in the regions in which it is present. Its work is linked to the promotion of projects aiming to increase visibility in partnership with other agents (local municipalities, Renault, Nissan, Mitsubishi, BYD, Petrobras, the Copec and Shell gasoline companies, etc.). This mainly involves the installation of a charging infrastructure, as well as granting incentives for electric buses. The great challenge in establishing an extra-urban charging infrastructure network in Chile is its great geographic length, extending across the entire Andes mountain range, which makes it difficult to establish “green routes”. This challenge is shared with Brazil and Argentina, and has prevented the incorporation of +50 kW chargers or ultra-fast chargers from becoming widespread. However, various companies have commited to installing chargers: Enel Distribución planned to establish 40 electric charging stations by the end of 2018. Engie has committed to developing +100 charging points throughout the country and Chilquinta Energía will join the electric charging station business [45–54].

2.1.4. Colombia

Colombia has 206 charging locations and 480 connectors, of which 135 are type 2, 111 are type 1, 85 are Schuko (EU Plug), 44 are NEMA 5-15 (US Plug), 26 are CHAdeMo, and 14 are CCS2. The Autopistas del Café, the Caldas Hydroelectric Power Plant (CHEC), the Pereira Energy Company and the Quindío Energy Company (EDEQ) recently presented the Eje Cafetero electrocorridor. This offers electric vehicle users the possibility of using three fast charging stations at the La Manuela dairy farms in Manizales; Caldas, El Privilegio in

Santa Rosa de Cabal; and Risaralda and the Jardín Filandia in Quindío. It extends 256 km and its main purpose is to position the Coffee Axis as a sustainable destination [55–65].

In general, charging stations are located in recreational areas such as shopping malls, parks, universities, and the José María Córdova airport in Medellín. Some of these sites offer additional incentives, such as exemptions from paying for parking (commercial center Oviedo in Medellín and Salitre in Bogotá), in addition to the non-monetary incentives of having specific parking spaces for electric cars. In addition, there are private charging stations, such as those that Celsia installed in the central offices of Bancolombia in Medellín and Bogotá for the exclusive use of its employees [56–61].

The charging is achieved through a smart card that links the vehicle's license plate with the owner's address so that the fees for vehicles recharging at public stations are transferred to the electricity bill at the driver's home (EPM). At other stations, payment for recharging takes place through mobile applications such as EVA (Centro Comercial Unicentro in Bogotá). In other cases, recharging is free. Colombia is one of the countries in the region that shows the greatest commitment to promoting electromobility. The high level of concern about the increasing environmental pollution in the cities of Medellín and Bogotá, together with the objectives of COP21, have reinforced the commitment to focus on the use of cleaner transportation at a national level. The market has grown in recent years and although market penetration remains low, there is both regulatory and market readiness to replace internal combustion engine vehicles with hybrid or electric vehicles. There are still some important actions to be taken so that promotion and incentive policies are better coordinated and have a greater impact on the market and on the emission reduction objectives; however, the foundations are in place for the use of EVs to continue growing in the short-term while technologies advance so that prices become comparable with those of internal combustion vehicles. The biggest barrier to the growth of hybrid and electric vehicle sales in Colombia remains, and will continue to be, their high sales price. By 2025, around 2800 hybrid units (including PHEVs) and 2700 electric vehicles will be sold in Colombia, a total of 5500 units, which represents 1.6% of the total market [55–64].

2.1.5. Costa Rica

In December 2017, a law was passed in Costa Rica that eliminated virtually all taxes on electric vehicles. In Costa Rica, like in Colombia, reducing carbon emissions is the main reason for promoting and incentivizing electromobility. In the case of Costa Rica, the objective is to become a carbon-neutral country by 2022. The Law of Incentives and Promotion for Electric Transportation was valid until 2023 for vehicles and will be valid until 2028 for parts and assembly systems. This law only considers battery electric vehicles (BEV) in all their modalities: bicycles, motorcycles, cars, minibuses, buses, and trains. The law details the functions of the Ministry of Environment and Energy (MINAE), which is the entity in charge of monitoring and evaluating such vehicles, as well as promoting training and conducting educational campaigns to encourage the acquisition and use of electric vehicles. An important element is that the MINAE is also in charge of coordinating all efforts related to electric mobility between the different institutions. These two points are fundamental since, in other countries, commissions must to be obtained to prevent the efforts of different institutions from being isolated, or different institutions moving in different directions. Although information campaigns may seem irrelevant, in countries such as Mexico and Ecuador, the lack of clarity and knowledge about such incentives has been noted as an inhibitor of these markets [66–74].

Regarding infrastructure, this law assumes that all levels of the government will be responsible for making the necessary investments for the promotion and strengthening of the use of electric vehicles in terms of charging infrastructure and additional lanes and parking spaces, among other factors. Regarding the charging infrastructure, the objective regarding the installation of chargers for national highways is for one charger to be present every 80 km, while in rural areas a charger must be installed at least every 120 km [67–71].

The 271 locations house around 440 connectors that are divided into 197 type 1, 83 NEMA 5-15, 47 CCS1, 46 CHAdeMO, 31 GBT/T (DC), and 15 Type I (AU, NZ, CN Plug) connectors. It is worth noting that the Costa Rican Institute of Electricity (ICE), which has the largest network of fast chargers in Costa Rica, is looking for investors for a second fast charging network in the country. Charging for electricity used for recharging is only allowed for those companies that have a concession to sell electricity; these are allowed to partner with other entities in the installation of charging centers. The law stipulates that there must be charging centers not only in the parking lots of government entities, but also in public parking lots and shopping centers [69–73].

Although the effects of this law have yet to be felt, in terms of infrastructure, the commitment on the part of private organizations as well as public entities is already beginning to be appreciated, and the public charging infrastructure network for electric vehicles in Costa Rica is beginning to expand rapidly. The main actor in planning and developing the installation of chargers for electric vehicles is the ICE Group, which recently made commitments to expand its fast-charging network, as well as to acquire a fleet of electric vehicles [71–74].

2.1.6. Ecuador

Ecuador's distinctive feature regarding the development of electromobility in the region is its early experience in the implementation of tax benefits for the import of hybrid vehicles, and the rapid interest on the part of the consumer public. Ecuador has the largest stock of hybrid vehicles in South America. It currently has an extensive repertoire of tax incentives that will continue to drive the deployment of electric mobility. However, some of its main challenges are the need to define a national charging infrastructure plan with specific agents to address it, adjust aspects of the nomenclature on plug-in hybrid vehicles, and expand the available supply of vehicles with this type of technology. Being a country with an electrical matrix of primarily renewable sources (hydraulic), it also has the potential to shift the energy demand for fuels from the transport sector towards non-polluting sources with the development of an electromobility strategy in line with the recently published National Energy Efficiency Plan [75–81].

In Ecuador, no actor has positioned itself as a promoter of a plan to install a charging infrastructure for electric vehicles at the national level or in the different municipalities. In this sense, it is expected that the new Law of Productive Investments, which includes benefits such as tax exemptions for the import of chargers, will boost this activity. To date, KIA and BYD have taken on the role of installing a public charging infrastructure to meet the demand required by the growing fleet of vehicles sold by both companies. Likewise, the placement of these charging devices was part of their brand positioning strategy, so most of these chargers are located in KIA or BYD dealerships, shopping centers, and areas with high vehicle traffic [82–86].

Ecuador has 59 charging locations and around 130 connectors, of which 40 are type 1, 16 are type 2, 14 are NEMA 5-15 (US Plug), eight are Schuko (EU Plug), six are type I (AU, NZ, CN Plug), and four are CCS2. Although, last year, Ecuador launched its National Strategy for Ecuadorian Electromobility (ENEE), in which one of the main axes is the development of a charging infrastructure, the reality is that little progress has been made regarding public charging points and their respective regulations [85–89].

In 2025, it is expected that, in Ecuador, the total vehicle market may reach just over 150,700 units sold, while the sales of electric vehicles could reach 14,950 units (including HEV, PHEV, and BEV), representing the highest total market penetration for EVs in the region and 9.9% of total vehicle sales in Ecuador [75–89].

2.1.7. Uruguay

This country presents a promising outlook for the development of electric mobility from various perspectives. Fundamentally, it is a country that, in recent years, has transformed its energy matrix, with more than 95% of its energy coming from renewable sources.

At the same time, the state energy company adopted a program to promote and develop electromobility, which includes increasing the visibility of the offer and establishing a program to develop a public charging infrastructure in cities and road corridors, as well as providing preferential tariff rates. Although reductions in internal taxes have been legislated since 2010, the tax incentive regime for electric cars was formed in 2015 with the decree of an exemption from tariffs and the Specific Internal Tax (IMESI). With the extension of tax incentives, some automotive companies have launched electric product portfolios in the local market, covering the passenger vehicle and light utility vehicle segments. However, the offer is still limited. There is also a program to electrify the fleet of taxis in Montevideo. For several years now, various local entrepreneurs (start-ups) have been working on different ways to promote electromobility with innovative initiatives. Although, to date, the existing fleet of electric vehicles consists mainly of B2B purchases (tenders for the purchase of taxis and utility vehicles for local electricity companies), the possible scenarios regarding the mass adoption of this type of technology are quite promising in the medium term for Uruguay [90–97].

Following the application of some incentives provided by the authorities for the more competitive marketing of electric vehicles, the offerings of this type of technology have expanded: EVs were non-existent before 2015, when the Ruffino Group, a local distributor of the Chinese Original Equipment Manufacturer (OEM) Gac Gonow, which specialized in utility vehicles, incorporated a portfolio of 100% electric products from eMIN [91–95].

In partnership with the state oil company ANCAP, since 2017, UTE has been developing a public charging infrastructure for electric vehicles at a national scale called "Ruta Eléctrica". This system of green routes will be added to the existing system of public chargers installed in Montevideo. In the first phase, the Ruta Eléctrica will cover the distance from Colonia del Sacramento to Chuy, passing through Montevideo and the entire coastal region of Uruguay. The final section of Chuy has yet to be completed, but the other charging stations are already in operation [90–97].

The chargers are located at ANCAP service stations, every 60 km, and are Type 2 of 22 kW and 43 kW chargers, depending on the location. As in other countries in the region, and as the market in Uruguay is in its nascent stage, the projection for sales of hybrid and electric vehicles is based on three different scenarios, which differ, depending on both internal conditions and the global environment, in aspects such as the price of oil, progress in the development of hybrid and electric technologies, and their price. Frost and Sullivan estimate that sales of hybrid and electric cars will reach around 4000 units in 2025, comprising 8.0% of the total market [92–96].

2.1.8. Mexico

The Mexican market is still far from reaching its full potential, because even though vehicle prices are lower than in other countries in the region, there is a significant difference between the prices of internal combustion vehicles and EVs (except in the case of the Ford Fusion hybrid model, which is manufactured locally), and there is also a limited supply of vehicles with these technologies, particularly electric cars. In 2018, there was a charging infrastructure network in Mexico of approximately 900 stations distributed throughout the country, although there is a greater concentration in Mexico City and in the states of Nuevo León and Aguascalientes. The installation of this infrastructure was carried out by both private entities, mainly the brands that sell electric cars in Mexico (BMW, Nissan, and Tesla), and public entities, such as the Commission Federal Electricity (CFE, the state-owned company in charge of the generation, transmission, and distribution of energy in Mexico). Initially, when Nissan and BMW brought their first electric models to Mexico, they also began to install charging stations in all dealerships of both brands nationwide, which provided a greater degree of confidence to consumers regarding range anxiety, which was considered a major inhibitor of the market in other regions worldwide [98–104].

Subsequently, the CFE joined the efforts to promote electric vehicles in Mexico in two major areas: the installation of charging stations and increasing the ease of installing

independent energy meters directly in the homes of consumers so that the consumption of electricity related to vehicle charging does not interfere with the existing differentiated consumption rate for homes in Mexico. Regarding the development of a charging infrastructure, CFE invested in a joint installation, with BMW and Nissan, of 32 electric charging stations located in Mexico City and on the main highways of the country [105–109].

It should be noted that although the development of the charging infrastructure in Mexico was led by private companies (Nissan, BMW and Tesla), it is extremely important that other entities, both public and private, have joined, since this is how the infrastructure expands. It is not only important that different entities work together to install charging stations; the effort must go one step further to ensure that this effort is coordinated and that the growth of the network is not only efficient in terms of numbers but also in charging standards, so that more vehicles can use these charging points. Unlike other countries in the region, the development of charging infrastructure network is no longer a challenge for Mexico since EV users have also advanced in their learning about these vehicles (as in other global markets) and trust that electric vehicles depend more on domestic nighttime recharging than on the charging infrastructure in public places during the day. Mexico has 315 charging locations and 2083 connectors, of which 287 are Tesla Dest. Charger, 206 are type 1, 137 are Tesla Supercharger, 17 are type 2, 15 are Schuko (EU Plug), and 14 are CHAdeMO. The German manufacturer BMW is continuing with its expansion plans in Mexico. The firm is concentrating its efforts on establishing a charging infrastructure, and has ambitious projects. The challenge for Mexico, whose charging infrastructure could provide a point of reference for other countries in the region, is the standardization and optimization of this infrastructure. Around 57,200 hybrid and PHEV cars and 4200 electric cars will be sold in Mexico in a year. This is a total of 61,400 vehicles, representing around 2.9% of the total vehicle market in this country [98–113].

2.2. Current Policies and Regulations

The development of a charging infrastructure in Latin America is closely linked to current public policies and regulations, which vary considerably between countries. Some governments have taken the lead by implementing regulatory frameworks and policies that promote electric mobility, while others are beginning to design more comprehensive strategies.

Chile has been a pioneer in the region, taking a proactive approach with its "National Electromobility Strategy", which includes tax incentives, reduced import taxes on electric vehicles, and specific programs to develop a charging infrastructure. Colombia has also adopted progressive policies, such as tax exemptions for electric vehicles and law 1964 of 2019, which promotes the use of electric vehicles and the construction of a charging infrastructure. In Mexico, despite the absence of a unified national policy, some states and cities have implemented incentives at the local level, such as exemptions from certain taxes and the creation of exclusive lanes for electric vehicles. Brazil, being the largest economy in the region, has started to introduce incentives, although it still faces regulatory challenges in facilitating the expansion of charging infrastructure [114–117].

On the other hand, countries such as Argentina and Peru are lagging in terms of implementing specific policies and regulations for electric mobility, which has resulted in a slower infrastructure development. In these countries, the lack of a clear regulatory framework and incentives has been a major obstacle to the expansion of the charging station network [114–117].

In some cases, such as in Chile, Costa Rica, and Colombia, these policies are the result of inter-ministerial coordination among the State (between energy, transport, and environment sector), together with a multitude of actors such as energy-generating and -distribution companies, automobile manufacturers, the academic sector, oil companies, and the mining sector, among others. These intersectoral coordination frameworks are the goals of other countries. In Brazil, however, the different States have developed alliances and individual pilot projects, although a relatively well-coordinated policy is observed at the national level. In the case of Argentina, the Argentine Association of Electric and

Alternative Vehicles (AAVEA) has, for years, supported, through its civil organization, debate and dialogue with different state, union, academic, and private sectors. In Uruguay, in addition to car manufacturers and entrepreneurs (start-ups) focused on electric mobility, the state-owned electricity distribution company (UTE) is the main actor articulating and developing the electromobility policy. However, at a regional level, as a whole, automotive companies are the leaders in promoting electromobility and the development of a charging infrastructure, and they present a joint vision of deploying electric mobility solutions. The fundamental objective is that the States in each country capture this multiplicity of local–global agents and manage to coordinate intersectoral working groups for the execution of specific commitments, regulations and agreed-upon standards within the framework of a joint strategy. Figure 3 presents a summary of the situation in each country regarding the regulations and incentives in place to promote the electric vehicle market in the region.

	Argentina	Uruguay	Brasil	Paraguay	Chile	Ecuador	Colombia	Costa Rica	México
Tariff Discount/Exemption	X	X	X	X	N/A	X	X	X	X
VAT Discount				X		X	X	X	
Discount/Exemption on other internal taxes		X		N/A	N/A	X	X	X	X
Discount/Exemption on registration/ownership/circulation		X	X			X		X	X
Preferential or free electricity rates	X*	X		X*	X*			X	X
Priority lanes/congestion zone						X	X	X	
Preferencial Parking					X*	X	X	X	
Electric Taxis program		X	X		X	X	X	X	X

Figure 3. Summary of regulations and incentives in Latin American countries.

2.3. Current Trends and Projections

Current trends suggest an acceleration in the growth of electric mobility in Latin America in the coming years, driven by growing environmental awareness, decreasing battery technology costs, and an increasing supply of electric vehicles by automotive manufacturers [56].

In Latin America, the sale of battery electric vehicles (BEV) has been constantly and exponentially increasing in recent years. Colombia is positioned as one of the leaders in registrations of this type of vehicle in the region, with more than 3000 units being registered in 2022. One of the causes of these results for the Colombian automotive sector is the existing incentives for the purchase and ownership of electric vehicles. Mexico, Chile, and Costa Rica are other clear examples of the increase in the sale of electric cars due to the implementation of public policies. The Latin American countries whose economy depends most on the hydrocarbon sector are leading the way in the provision of a range of hybrids, vehicles that combine an internal combustion engine and an electric one. Brazil and Mexico lead in this area, with the highest volume of sales of hybrid vehicles (HEVs)

in 2022. However, these two powers of the region have lagged behind in the incorporation of completely electric cars in their vehicle fleet.

One of the factors hindering the adoption of electric vehicles in the Latin American market is the high price of the models, which are mostly imported, as well as the lack of tax incentives and, above all, the lack of an adequate charging infrastructure. The use of electric vehicles in public transport systems is not new in large Latin American cities. Since the last century, inhabitants of the region's metropolises have had access to underground train systems or metros, light rail, and trolleybuses that run on electricity. In recent years, the decision was made to modernize urban road transport fleets. In this regard, Colombia is one of the countries that invests the most in the electric segment of public transport on wheels, with more than 1500 electric buses in operation, followed by Chile and Mexico.

Infrastructure for EVCs is essential to the expansion of electromobility in Latin America. The number of EVCs is expected to rise significantly in the next few years. More time is required before the levels of development observed in nations in the US or Europe are observed; in these countries, there were approximately 160,000 EVCs at the start of 2023.

The goal is to improve charging infrastructure and enhance the user experience, not only through the implementation of high-speed charging and smart charging, but also through the expansion of technologies such as wireless charging and the integration of electric vehicles with smart grids (Smart Grids), i.e., the ability of EVs to communicate and collaborate with existing electrical infrastructure [101].

The integration of renewable energies, such as solar energy, will assist in this. However, significant challenges will remain, especially in the implementation of electric mobility in urban and rural environments.

Countries such as Chile, Colombia, and Brazil are expected to continue to lead the development of charging infrastructure, with a focus on expanding networks in urban areas and key transportation corridors. The projection for Mexico is similar, with sustained growth being projected in the largest cities and the possible integration of charging stations into long-range road infrastructure projects. In addition, countries such as Ecuador and Costa Rica, which have a strong commitment to sustainability, are expected to significantly increase the installation of charging stations, supported by their energy policies and the promotion of renewable energy sources [56,101,102].

At the regional level, the electric vehicle fleet is expected to grow exponentially in the next decade, which will boost the demand for charging infrastructure. However, to achieve these objectives, it is crucial for governments to step up their efforts to create a coherent regulatory framework and promote public and private investment in charging infrastructure [101,102].

This outlook underscores the need for concerted action between governments, the private sector, and international organizations to overcome existing challenges and take advantage of the opportunities that electric mobility offers for Latin America.

3. Challenges in the Implementation of a Charging System in Latin America

3.1. Infrastructure and Technology

The implementation of an adequate charging infrastructure for electric vehicles in Latin America and the Caribbean faces several technical and logistical challenges, mainly derived from the geographic and urban diversity of the region [115,118].

Geographic diversity: The region presents a wide variety of terrains, from densely populated urban areas to remote rural areas. This geographic diversity complicates the planning and installation of charging stations, especially in rural and mountainous areas where connectivity to the electrical grid is limited. In addition, the existing infrastructure in some cities is not prepared to support the additional demand that a network of charging stations would generate, requiring significant upgrades to urban electrical grids [115,118–120].

Maintenance and technology: Charging stations require regular maintenance and access to advanced technology to ensure their operability and efficiency. The limited availability of technology and know-how in some parts of the region makes it difficult

to maintain and upgrade charging stations. Furthermore, the lack of standardization in connector types and charging power can lead to interoperability issues between different stations and vehicles [115,118–120].

Connectivity and digitalization: Integrating charging stations with smart energy management systems is another challenge, especially in countries with less developed telecommunications infrastructures. Digitalization is crucial for charging network optimization, demand management, and integration with renewable energy sources, but its implementation can be costly and technically complex.

3.2. Cost and Financing

One of the main challenges in the expansion of the charging infrastructure in Latin America is the high cost associated with the installation, operation, and maintenance of charging stations. The cost of installing charging stations, especially fast-charging ones, is high. This includes the costs of acquiring the equipment, the civil works required for their installation, and the connections to the electrical grid. In areas with a weak electrical infrastructure, the costs can be even higher due to the need to strengthen the grid [114,115].

Securing the necessary financing for these investments is a significant challenge, especially in the context of fiscal constraints and competition for public resources in the countries of the region. Sources of private financing are also limited, as investors may perceive charging infrastructure as a high-risk market due to uncertainty about the adoption of electric vehicles and long-term profitability [114,121].

For the business model, developing a viable business model for charging stations is another challenge, especially in areas where the adoption of electric vehicles is still low. Without a critical mass of users, charging stations could operate at a loss for a prolonged period, which discourages private investors.

The issue of asset ownership is crucial when assessing business models and future policy interactions for enterprises that operate in a variety of market functions. Certain businesses, such as ChargePoint and SemaConnect, concentrate on setting up and running a network of charging stations but do not maintain network ownership. This strategy is known as the "network-operator model" by Jonas et al. [120], wherein the business creates and manages a network but sells the hardware to host locations, who handle the billing and charging station access. Using this strategy, host sites can determine their own rates and payment schedules and keep their earnings after deducting operator fees. In these situations, the network operator transfers the business risk to the host organizations.

As an alternative, several businesses create, run, and own their own charging networks, such as EVGo and Blink Network. This strategy, which Jonas et al. [120], refer to as the "owner-operator model", is a vertically integrated collection of operations where the charging company sells and owns the hardware, controls access and invoicing, and receives payments from the infrastructure. The owner-operator business model is comparable to that of a conventional mobile telecommunications provider that makes infrastructure investments and bills customers for the services the infrastructure provides. The network operator may collaborate with a private host in these situations to set up charging stations, but they still have control over the pricing and are subject to revenue risk.

In contrast to the network operators mentioned above, owner-operators may be better positioned to profit from future increases in charging demand or from favorable legislative changes, even though the negative risk resulting from poor utilization could pose a barrier to the adoption of this system.

More integrated approaches exist beyond the owner-operator model, as demonstrated by businesses such as Tesla and Aerovironment, which operate in all four market functions, from manufacturing the equipment to setting up and maintaining networks to collecting revenue, although not always in an integrated manner. Companies are required to recoup their charging infrastructure expenses through user fees under these arrangements. As an alternative, Tesla provides free charging by including the expense of building the network of charging stations into the initial price of its cars. Managing a completely integrated EV

value chain may also prove to be a challenge for large equipment manufacturers who build, own, and run charging equipment, for instance, if they want to continue concentrating on their main business of unmanned aircraft and missile systems.

In addition to these strategies, Tesla and Better Places experimented with the separation concept. In this business model, the EV and battery are separated; the car is bought, while the battery is leased. This battery is simply swapped out when it needs to be recharged, eliminating the need to wait at a service station. The battery is now a standardized container that is rented as needed, so the consumer basically only buys the charge itself. Chinese automakers NIO and BIAC are re-examining the use of this strategy when implementing the model in China. Industry analysts are looking for new, more lucrative ways to guide the market as China reduces the governmental subsidies to EV manufacturers and EVSE providers.

The separation model may be a feasible path according to Yang et al. [121], who advise increased collaboration between the government and the participating enterprises as well as standardization in battery design. Although this strategy is still in its infancy, considering that China has the world's largest EV market and still continues to face profitability challenges, and the government is cutting back on financial assistance, this unorthodox method may at least be worth further investigation. China is home to several distinct business models. The second-biggest supplier there, the state-owned China Grid Corporation, operates on the owner-operator model. However, the biggest supplier of EV charging stations, TGOOD, manufactures, installs, and runs charging stations and equipment similarly to Tesla. Due to its market dominance in China, TGOOD is probably one of the biggest suppliers of this kind of service worldwide [121]. Although they have a much smaller market share, major automakers like BYD and SAIC also use the Tesla model. Although there are regional monopolies, the Chinese market is rather crowded. The main distinction between business models in China and those found elsewhere in the world is the strong backing provided by the federal, provincial, or state governments, whether in the form of subsidies, laws, or state-owned businesses. Additionally, State Grid and Potevio, the second and fourth biggest EVSE suppliers, are state-owned.

3.3. Regulation and Public Policies

The lack of clear and effective regulatory frameworks is a major obstacle to the implementation of charging infrastructure in Latin America. Many Latin American countries lack integrated policies that comprehensively address electric mobility and charging infrastructure. Existing policies are often fragmented or insufficient, making long-term planning and attracting investment difficult [114].

The lack of adequate incentives, such as subsidies, tax exemptions, or differentiated energy rates for charging stations limits the financial viability of projects. In addition, the absence of clear regulations regarding the installation and operation of charging stations can generate uncertainty among developers and operators [114,115,119].

The implementation of charging infrastructure requires coordination between different levels of government (national, regional, and local), which can sometimes be complex. A lack of alignment between national and local policies can slow down infrastructure development and create bureaucratic barriers.

3.4. Public Acceptance and Awareness

Public acceptance and awareness of electric mobility are essential for the success of the charging infrastructure, but in this region, these aspects still represent considerable challenges. Although environmental awareness is on the rise, there is still significant skepticism among the public about the viability and convenience of electric vehicles. Factors such as "range anxiety" (concern about how far an electric vehicle can travel on a single charge) and the perception that electric vehicles are expensive and impractical are significant barriers to their adoption. There is lack of accurate and accessible information about electric mobility and charging infrastructure, which is also a challenge. Many consumers are

unfamiliar with the benefits of electric vehicles and the location and availability of charging stations, limiting their willingness to make the transition [122–126].

Related to car culture, in many countries in this region, car culture is deeply entrenched, with internal combustion vehicles still being the norm. Changing these attitudes requires significant efforts in education and awareness, in addition to economic incentives and improvements in the charging infrastructure.

These challenges underscore the need for a comprehensive and coordinated approach to the implementation of a charging infrastructure in Latin America, including concerted efforts focusing on infrastructure, financing, regulation, and public awareness.

3.5. Benefits of a Well-Implemented Charging System and Its Environmental Impact

This region has great potential to increase its solar power capacity by a factor of 40 by 2050. Green hydrogen, in combination with solar power generation, thus represents an opportunity for Latin America, not only as a solution for "energy storage" in more remote areas, but also to accelerate the transition to low-emission transport. Even though almost all of Costa Rica's energy is generated from renewable sources, 42% of total GHG emissions in Costa Rica come from vehicles that use fossil fuels. In Paraguay, 89% of the total emissions from the energy sector are linked to transport [117,126–130].

In short, the issue of transport is often seen as a challenge, but it can also be an opportunity when looking to reduce emissions quickly in the Latin American region.

One of the main benefits of a well-implemented charging system is its significant contribution to reducing carbon dioxide (CO_2) emissions and other pollutants, which helps to mitigate climate change and improve air quality in cities.

Electric vehicles generate zero direct CO_2 emissions, which contributes directly to the reduction in global greenhouse gas emissions, especially in regions where transport accounts for a significant share of these emissions. By reducing dependence on fossil fuels, the adoption of electric vehicles can play a crucial role in meeting international emissions reduction commitments, such as those set out in the Paris Agreement. Electric vehicles do not emit air pollutants such as nitrogen oxides (NOx) and fine particulate matter (PM10 and PM2.5), which are common in internal combustion vehicles. This has a direct impact on public health, as it reduces the incidence of respiratory and cardiovascular diseases associated with air pollution [127–130].

The main source of environmental noise in cities vehicle traffic (Figure 4). It is known that the type and size of streets influence the noise levels, and with the introduction of electric propulsion vehicles into circulation, it is expected that, in the future, environmental noise levels will be reduced. In these vehicles, the engine is very silent, and noise from the tires is the main source of noise. Various studies indicate that a reduction in noise levels only occurs for speeds below 50 km/h. Electric vehicles are much quieter than their internal combustion counterparts, which contributes to a reduction of noise pollution in urban areas. This improves the quality of life in cities, creating quieter and more habitable environments [121–132].



Figure 4. Environmental benefits that can be implemented in the charging station infrastructure.

Electric vehicle production in Latin America has seen significant growth in recent years, driven by investments from both local and international companies. The expansion of electric vehicle production in Latin America is not only transforming the automotive industry, but is also having a significant economic impact. The multi-million USD investments by several companies that are setting up in the region are creating thousands of jobs and encouraging the development of new local supply chains. In addition, the adoption of electric vehicles is beginning to reduce the dependence of countries in the region on fossil fuels, which could translate into substantial economic savings in the long term. In Chile, the entry of BYD Auto is not only revolutionizing the automotive market but is also driving the development of a charging infrastructure and related services, creating an ecosystem that could attract even more investment and stimulate the economy. Mexico has become an epicenter of electric vehicle production in Latin America. This growth was driven by the arrival of industry giants such as Tesla and Jetour, which made multi-million USD investments to set up assembly plants and strengthen the infrastructure needed for EV production. These investments not only increase the production capacity, but also generate employment and develop local supply chains, strengthening the national economy. Stellantis, another major player in the automotive industry, has announced plans to produce hybrid and electric vehicles in Latin America. Its focus is on developing models specifically tailored to the needs of the local market, including the creation of "bio-hybrids", a new generation of vehicles that combine alternative fuel and electric power technologies. This strategy not only diversifies the product offerings, but also positions Stellantis as an innovative company in the sustainable mobility sector. The implementation of an electric vehicle charging system can also generate a series of economic benefits, both at the macroeconomic level and in terms of local development [114–117].

Furthermore, the construction, operation, and maintenance of the charging infrastructure for electric vehicles can create a large number of direct and indirect jobs. These jobs are not only generated in the installation phase of the charging stations, but also in the manufacturing of equipment, software development, maintenance services, and other related sectors [114].

In addition, to increasing the growth of existing industries, electric mobility opens the door to the development of new industries, such as battery production, research and development regarding charging technologies, and the manufacture of specific components for electric vehicles. In addition, startups and technology companies that specialize in electric mobility and energy management solutions can find an expanding market in Latin America.

To attract the necessary investments, a well-implemented charging system can attract both domestic and foreign investments. Multinational companies in the automotive, energy, and technology sectors can be encouraged to invest in the region if there is a solid infrastructure and a favorable regulatory environment for electric mobility.

Another benefit is savings in operating costs. In the long term, electric vehicle users can benefit from lower operating costs, as electricity is generally cheaper than fossil fuels, and electric vehicles require less maintenance. This can translate into significant savings for companies that operate vehicle fleets and for individual consumers.

4. Case Studies for the Implementation of a Charging System in Latin America

Across Latin America, some countries and cities have made significant progress in implementing electric vehicle charging systems, providing valuable experiences that can serve as a model for other parts of the region.

4.1. Leadership in the National Electromobility Strategy by Chile

The state and characteristics of the transport sector in Chile in 2017 were analyzed, focusing on the opportunities presented by its electrification. With this, and after a participatory process, the first national Electromobility Strategy was developed, where long-term goals were established as follows: for 40% of private vehicles and 100% of urban public

transport to be electric by 2050. Electromobility and actions to promote energy efficiency in transport were established as some of the main factors that will allow Chile to achieve carbon neutrality by 2050, contributing to nearly 20% of the CO_2 reductions necessary for this. This state policy that aims to create a roadmap for the advancement of sustainable transportation that will directly benefit Chile. In order to produce the required rules for the safe and sustainable growth of electric mobility, new problems are presented, with the goal of promoting the use of more ecologically friendly and efficient automobiles. Lastly, Chile has objectives and aspirations to hasten the adoption of electric mobility, setting forth national policies, roadmaps, and international agreements pertaining to this.

Chile's success lies in the creation of a solid regulatory framework, the establishment of clear, long-term objectives, and collaboration between the public and private sectors. The integration of electric mobility with renewable energy policies has been key to its effective implementation. Other countries can learn from the Chilean experience, especially in terms of long-term policy formulation and the importance of charging infrastructure for public transport.

4.2. Commitment to Sustainability by Costa Rica

Costa Rica, a country known for its focus on sustainability, adopted electric mobility as a central part of its environmental policy. Since 2006, the purchase of EVs in Costa Rica was incentivized through tax rebates that exempt them from the "selective consumption tax" (which could range from 30% to 54% of the total value of a vehicle). Taxes on hybrids were also reduced from 15% to 10%. In 2015, debate began over a proposed bill on the incentives for and promotion of electric transport and, in January 2018, the government enacted the Law of Incentives and Promotion for Electric Transport, which offers tax exemptions and benefits for the import and purchase of electric vehicles, as well as for the installation of charging stations. The country also developed a growing network of public charging stations, driven by the state electricity company, which operates in conjunction with renewable energy sources [114].

Costa Rica demonstrates the importance of economic and regulatory incentives to encourage the adoption of electric vehicles and the development of a charging infrastructure. The integration of electric mobility policies with the energy sector and the use of renewable energy reinforces the sustainability of the system. The Costa Rican experience can serve as an example for countries that want to encourage the adoption of electric vehicles through proactive government policies and the use of clean energy.

4.3. Expansion of Charging Infrastructure in Key Cities in Colombia

Colombia has made significant progress in electric mobility, especially in cities such as Bogotá and Medellín. Bogotá has implemented policies for the adoption of electric buses in its public transport system and encouraged the installation of charging stations in strategic locations. In 2019, the city of Medellín launched a project to develop an "Electric Route" that includes the installation of fast-charging stations along major urban and suburban roads. Colombia's experience highlights the importance of public policies at the local level and coordination between municipal and national governments. In addition, it highlights the need to develop a charging infrastructure in urban and suburban areas to support the widespread adoption of electric vehicles. Other countries can emulate Colombia's strategy to implement electric routes and promoting electric public transport [56].

5. Perspective for the Implementation of a Charging System in Latin America

From these case studies, several good practices and lessons can be drawn that could be applied in other contexts within Latin America as the successful implementation of charging systems depends largely on the existence of integrated public policies that address not only the charging infrastructure, but also the promotion of electric vehicles, tax incentives, and integration with renewable energy. A holistic approach involving all relevant sectors is crucial to overcome these challenges and maximize the benefits. Collaboration between

the public and private sectors is essential for the development of a charging infrastructure. Governments can establish regulatory frameworks and offer incentives, while the private sector can provide innovation, investment, and technical expertise. This type of collaboration has proved effective in the countries that have made the most progress in the region [86,114].

It is essential that national and local governments develop regulatory frameworks that facilitate the installation of an electric vehicle charging infrastructure. This includes defining technical standards for charging stations, interoperability standards, and simplified procedures for obtaining installation permits. Public policies must be coherent at the national and local levels to avoid contradictions and facilitate investment. Governments can encourage the expansion of the charging infrastructure by implementing economic incentives, such as subsidies for the installation of charging stations, tax exemptions for the import of equipment, and preferential electricity rates for charging station operators. These incentives can reduce the upfront costs and make investing in charging infrastructure more attractive to the private sector. Electric mobility should be an integral part of urban mobility plans. Cities should include a charging infrastructure in their urban development and transportation plans, ensuring that charging stations are strategically located in high-demand areas and key transportation corridors. This will help optimize charging system efficiency and facilitate the mass adoption of electric vehicles [114,115,119].

Countries that have been successful in implementing charging systems have adopted long-term planning, with clear and well-defined objectives. This not only provides a roadmap for future development, but also builds confidence among investors and consumers. Since urban areas are often the first to adopt electric vehicles, initially focusing efforts on these areas can make a significant impact in terms of reducing emissions and improving quality of life. However, it is important not to neglect the eventual expansion into suburban and rural areas. The success of electric mobility also depends on public acceptance. Investing in education and awareness campaigns to inform the public about the benefits of electric vehicles and the charging options available is critical to increasing their adoption. Each country and city in the region has a unique context, so the solutions must be adaptable and flexible. What works in a highly urbanized city may not be suitable for rural areas. Policies and strategies must be tailored to local needs and characteristics [124,126].

Governments should promote strategic partnerships between the public and private sectors for the development of a charging infrastructure. This could include collaborative agreements with energy sector companies, electric vehicle manufacturers, and charging technology providers. These partnerships can share risks, leverage resources and expertise, and accelerate infrastructure deployment. Since many Latin American and Caribbean countries face fiscal constraints, it is crucial to leverage financing from international organizations, such as the Inter-American Development Bank (IDB) and the World Bank. These agencies can offer loans, grants, and technical assistance for charging infrastructure projects, especially in areas with a lower local investment capacity.

Public–private collaboration can facilitate the development of innovative business models, such as pay-as-you-go schemes, subscriptions to charging services, and renewable energy supply agreements. These models can help to ensure the financial sustainability of charging stations and increase their accessibility to users. Countries and cities are encouraged to adopt advanced charging technologies, such as fast- and ultra-fast-charging stations, which can significantly reduce the charging time for users. In addition, the implementation of smart charging systems, which optimize the use of the electrical grid and allow for the integration of charging stations, can help reduce the cost of charging [86,114].

Vehicle manufacturers take into account the safety and performance of EV batteries in order to guard against combustion, explosions, and other possible mishaps brought on by the battery's own malfunctions. From a safety perspective, a number of standards have also addressed the plugs and connectors, as well as the EVSE, providing electrical safety protection measures. For example, the Society of Automotive Engineering (SAE) released guidelines for plug-in electric vehicle (PEV) charging. The general electrical,

performance, and physical criteria for EV charging systems in North America are covered by the SAE J1772 standard [133–135]. EVs may completely utilize three-phase ac electricity to charge their batteries thanks to the SAE J3068 standard. A high degree of safety is offered. Policymakers and academic communities have also looked into the electrical safety issues surrounding EVCSs from the perspective of an EVCS operator. In addition to demanding that EVCSs undergo recurrent safety evaluations, guidelines were added mandating that the EVCS design adheres to the requirements of the previously described standard [136]. Ref. [134] talks about fire safety when charging EVs. An analysis of the transformer loss-of-life resulting from disorganized PEV charging in a parking garage may be found in [137]. Transformer aging and premature replacement can be prevented by integrating photovoltaic (PV) systems and using intelligent charging algorithms. Advanced EVCS communication systems open up new possibilities for the EVCS operator, as a communication-assisted protection approach can mitigate issues and guarantee a secure charging environment for the EVCS data and power quality assessments.

6. Value of the Work and Findings

Throughout this research, the main challenges and benefits associated with implementing an electric vehicle charging system in Latin America were presented. Although electric mobility has a bright future in Latin America, its success will primarily depend on how well governments, corporations, and citizens can overcome the present obstacles. There will be an increasing need for a sufficient charging infrastructure as more nations switch to electric automobiles. The region must transition to a more egalitarian and sustainable transportation system, with electric mobility playing a key role in lowering emissions and raising the standard of living for locals. This research addresses the challenges and opportunities for Electric Vehicle Charging Stations in Latin America. A transition to electric mobility is crucial to reduce greenhouse gas emissions, modernize the quality of life in urban areas, update public policies related to transportation, and promote economic development.

This research details how the development of charging networks for electric vehicles is one of the key pillars for the expansion of electromobility in Latin America. However, one of the major challenges is the profitability and accessibility of these infrastructures, especially in the public and business spheres. The debate surrounding the profitability and accessibility of charging networks in Latin America highlights the urgent need to find sustainable economic models and guarantee interoperability between different systems and networks. With the accelerated growth in electric mobility, the region must make strategic decisions to facilitate access to the charging infrastructure and ensure the economic viability of such projects in the long term. However, the growth of this infrastructure has not been sufficient to keep pace with the increase in the number of electric vehicles.

Education can support the adoption of electric vehicles, improve public awareness, and prepare the next generation of professionals to address the interdisciplinary challenges of sustainable energy systems. These educational dimensions are more prominently highlighted in [138]. Carrying out educational work that reaches citizens focusing on energy policies and the use of electric cars is an essential factor. This research attempts to carry out a survey of the available information on charging infrastructures in Latin America and see how this information could reach the society.

7. Conclusions

Latin America has a rare chance to spearhead the worldwide shift to clean and sustainable transportation by integrating a charging infrastructure with renewable energy sources. With an emphasis on public education, the development of regional standards, and technological innovation, the area could become a global example in the adoption of electric mobility. Latin America is located in a climate zone with increased solar activity, which is promising regarding the creation of solar energy that could partially or fully cover the needs of electric vehicle charging systems.

The area must build a strong and technologically sophisticated charging network, obtain sufficient funding, create effective regulatory frameworks, and raise public awareness of electric mobility, among other challenges. Nonetheless, there are a plethora of potential advantages of this, such as a reduction in greenhouse emissions, promotion of economic growth through the creation of new businesses and jobs, improvements in urban quality of life, and the integration of the charging infrastructure and renewable energy.

We have also examined successful examples from nations like Colombia, Chile, and Costa Rica, which provide important insights for other nations in the region. These incidents demonstrate the significance of long-term planning, public–private sector cooperation, and an integrated public policy.

The transition to electric mobility cannot be achieved without the active participation of all sectors of society. Governments must lead with clear and coherent public policies, establish economic and fiscal incentives, and foster public–private collaboration. Companies must innovate and collaborate to develop advanced charging technologies and sustainable business models. Finally, citizens must be aware of the benefits of electric mobility and be willing to adopt new forms of transport that benefit the environment and future generations.

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