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Public Policies and Pillar Technologies in Electric Vehicles: International Lessons for Mexico

Políticas públicas y tecnologías pilares en vehículos eléctricos: lecciones internacionales para México

Adriana Martínez Martínez,[1] & Paula C. Isiordia-Lachica[2]

ABSTRACT
The article examines the relationship between public policies aimed at promoting the adoption of electric vehicles and the evolution of their key technologies, particularly batteries and charging infrastructure, to identify relevant lessons for Mexico. Methodologically, a narrative review of scientific and grey literature published between 2008 and 2024 was conducted, allowing for a comparative analysis of international experiences. The results show that the expansion of electric vehicles has depended not only on technological progress but also on its integration with fiscal and financial incentives, infrastructure investment, regulation, research capabilities, and public-private partnerships. Among the study's limitations is the fact that the qualitative approach does not allow for estimating causal effects or measuring the relative weight of each policy instrument. The study concludes that the contextualized adaptation of international strategies can strengthen the adoption of electric vehicles in Mexico and contribute to the design of more coordinated public policies.

Keywords: 1. electromobility, 2. electric energy, 3. transport infrastructure, 4. development policy, 5. technology transfer.

RESUMEN
Se examina la relación entre las políticas públicas orientadas a la adopción de vehículos eléctricos y la evolución de sus tecnologías clave, particularmente baterías e infraestructura de carga, para identificar lecciones relevantes para México. Metodológicamente, se realizó una revisión narrativa de literatura científica y gris publicada entre 2008 y 2024, que permitió desarrollar un análisis comparativo de experiencias internacionales. Los resultados muestran que la expansión de los vehículos eléctricos ha dependido no solo del progreso tecnológico, sino de su articulación con incentivos fiscales y financieros, inversión en infraestructura, regulación, capacidades de investigación y colaboración público-privada. Entre las limitaciones del estudio destaca que el enfoque cualitativo no permite estimar efectos causales ni medir el peso relativo de cada instrumento de política. Se concluye que la adaptación contextualizada de estrategias internacionales puede fortalecer la adopción de vehículos eléctricos en México y aportar elementos para el diseño de políticas públicas más articuladas.

Palabras clave: 1. electromovilidad, 2. energía eléctrica, 3. infraestructura de transportes, 4. política de desarrollo, 5. transferencia de tecnología.

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[1] (Corresponding author) Universidad Nacional Autónoma de México (https://ror.org/01tmp8f25), adriana.martinez.wurtz@unam.mx, https://orcid.org/0000-0003-0639-4007

[2] Universidad de Guanajuato (https://ror.org/058cjye32), pc.isiordia@ugto.mx, https://orcid.org/0000-0001-6403-3264

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INTRODUCTION[3]

Since the 2010s, concern about climate change has intensified, along with the growing urgency to reduce greenhouse gas emissions. According to Jaramillo et al. (2022), the transport sector accounted for approximately 23% of global energy-related CO_2 emissions in 2019, and road vehicles represented nearly 70% of the direct emissions of the sector. This high contribution has prompted renewed interest in the electrification of transport as a technological alternative for reducing emissions.

In this context, the production and adoption of electric vehicles (hereafter EVs) have emerged as a central strategy for addressing the environmental and energy challenges of the twenty-first century (Leurent & Windisch, 2011). Some authors argue that EVs powered by renewable energy represent the most promising technological solution (Santamarta, 2009). However, others have pointed out that the adoption of EVs responds more to geopolitical, economic, and commercial considerations than to ecological ones (Freyssenet, 2011). In any case, both public policy and technological innovation are playing an important role in the transformation of the automotive industry.

According to the International Energy Agency (IEA), the importance of electric vehicles (EVs) is reflected in their rapid global expansion. In 2024, global EV sales surpassed 17 million units, accounting for more than 20% of total light-duty vehicle sales. Trends observed in the first quarter of 2025 indicate a year-over-year increase of approximately 35%, with more than 4 million units sold; accordingly, total sales for that year were projected to exceed 20 million EVs, reaching a market share of over 25%. China continues to lead this transition, with sales exceeding 11 million units in 2024 and projected to approach 14 million in 2025. Under a stated policies scenario, the IEA estimates that by 2030 EVs could account for approximately 40% of global light-duty vehicle sales, thereby consolidating their role as a central component of international decarbonization strategies (IEA, 2025).

This growth has been driven largely by robust regulatory frameworks in major economies, such as the Fit for 55 package of the European Union (European Commission, 2021) and incentives established under the Inflation Reduction Act of 2022 (Internal Revenue Service, 2023) in the United States, both of which continue to strengthen EV demand and expand charging infrastructure. These policy measures have fostered more dynamic markets, greater regulatory certainty, and stronger incentives for the industry to accelerate the transition toward low-emission technologies.

In Mexico, EV production has shown sustained growth as a result of expanding automotive investment oriented toward the North American market. According to specialized industry reports, domestic EV manufacturing reached approximately 206 000 units in 2024, driven primarily by models such as the Ford Mustang Mach-E, Chevrolet Blazer EV, Chevrolet Equinox EV, and Jeep

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Wagoneer S, assembled at various plants across the country (Martínez, 2024). Looking ahead, sectoral analyses suggest that production could surpass 250 000 units by 2025; although modest in global terms, this level positions Mexico as a key supplier of EVs to the United States, given a competitive manufacturing base and integration into the regional value chain (Gallego Llano, 2025).

This manufacturing momentum creates opportunities for the domestic automotive industry and reinforces its role in the reconfiguration of electromobility supply chains, while also highlighting the need to articulate public policies that support the transition, particularly in charging infrastructure, workforce development, and local supplier development. Taken together, these trends confirm that EVs represent not only a technological shift, but also a structural transformation of the global automotive industry and national energy strategies.

The objective of this article is to analyze how the core technologies of EVs—batteries and charging infrastructure—have evolved in interaction with public policies that promote production and adoption, emphasizing global strategies and opportunities for Mexico. The article contributes to a comprehensive understanding of EVs by linking technological advances in batteries and charging infrastructure with the public policies that enable them. In addition, it provides a comparative perspective on how different countries have implemented strategies to support EV adoption, identifying lessons applicable to the Mexican case. This approach highlights both technological barriers and strategic opportunities for the energy transition in the transport sector.

The article is structured into seven sections beyond the introduction. The first outlines the methodological design. The second presents an analysis of the evolution of the two technologies considered central to EVs: batteries and charging infrastructure. The third examines public policies in seven countries that have strongly promoted EVs. This is followed by a brief discussion of the relationship between technological development and public policy. The fifth section addresses the case of Mexico. The sixth presents five stylized facts, and the final section offers concluding reflections, research findings, study limitations, and directions for future research.

METHODOLOGICAL DESIGN

This study uses a qualitative, exploratory approach to examine the relationship between technological advances in the core components of EVs—batteries and charging infrastructure—and the public policies that have driven development and adoption. A narrative review of the scientific literature was conducted, focusing on publications from 2008 to 2024. The year 2008 was selected as it marks a turning point in the advancement of EVs, when the role of these technologies in addressing climate change began to gain prominence in public policy discussions. The research process is outlined below.

Information Search Process

A comprehensive review of scientific literature, technical reports, and strategic documents from international organizations, including the World Bank and the International Energy Agency, was conducted to identify and synthesize key information on core technologies and public policies related to EVs. This review supported the development of a solid conceptual foundation for the analysis, with a focus on technological advances and their connection to government strategies. Scientific literature was sourced from the Springer, MDPI, Emerald, and ScienceDirect databases.

The search was conducted using the following keywords: "electric vehicles and technological evolution," "electric vehicles and public policy," "batteries and technological evolution," "charging infrastructure and technological evolution," "leading countries and electric vehicles," and "Mexico and electric vehicles." These keywords were used in both English and Spanish to ensure broad and diverse coverage of relevant literature.

Inclusion and Exclusion Criteria

Studies and reports providing empirical data, verifiable evidence, and relevant case studies were included to examine the relationship between the evolution of key EV technologies and public policies aimed at promoting development and adoption. In contrast, opinion pieces lacking empirical support and publications not directly aligned with the objective of the study or the analytical categories were excluded.

Review Process

An initial screening was conducted based on article titles and abstracts. This was followed by a detailed review of full texts to assess relevance and quality. Selected studies were then analyzed and categorized according to thematic focus. The analysis centered on two main dimensions: *1)* core technologies: battery evolution (types, advances in energy density, sustainability, and recycling) and charging infrastructure (fast charging, wireless charging, and integration with renewable energy); and *2)* public policy: fiscal and financial incentives, environmental regulation, infrastructure development, and public-private collaboration mechanisms.

Country Selection

Seven countries leading EV adoption—Norway, China, Japan, the United States, Germany, France, and the Netherlands—were selected to identify patterns of success and contrast them with the Mexican context. This analysis made it possible to assess how public policies have shaped the development of core technologies and to determine which strategies can be replicated or adapted according to the institutional, technological, and infrastructure conditions of each country.

Synthesis of Information

The findings were incorporated into a critical synthesis that identifies stylized facts on EVs, connects them to broader patterns, and supports the formulation of recommendations to strengthen public policy and advance core technologies. This methodological design ensures a comprehensive and detailed review of the scientific literature consulted, providing a solid foundation for the conclusions and recommendations presented in the article.

TECHNOLOGICAL EVOLUTION OF ELECTRIC VEHICLES: PHASES AND KEY TECHNOLOGIES

The evolution of EVs began in the 1880s with the invention of the first electric vehicle, capable of reaching a speed of 14 miles per hour, marking the starting point of this technology (Saaid et al., 2024). In 1890, William Morrison introduced the first EV in the United States, followed by Ferdinand Porsche, who presented the P1 model in 1898, advancing experimentation in this field. In 1914, Thomas Edison and Henry Ford attempted to popularize an affordable EV model, but the rise of internal combustion engines limited further development (Joseph et al., 2019). Although EVs were popular in the late nineteenth century, the mass production of gasoline-powered vehicles by Karl Benz and Henry Ford displaced them from the market (Hayslett et al., 2020). The modern era of EVs began with the launch of the Toyota Prius in 1997, followed by the entry of Tesla in 2006, which transformed the technology and helped popularize electric vehicles (Joseph et al., 2019).

The technological evolution of EVs can be divided into four phases that reflect advances in two key technologies: batteries and charging infrastructure. The focus on batteries and charging infrastructure is based on their central role in the technical viability and adoption of EVs. Batteries constitute the core component, determining range, costs, and efficiency, while charging infrastructure is essential to ensure a convenient user experience and enable widespread adoption of this technology. Focusing on these two technological pillars allows for a more targeted and in-depth analysis, consistent with the objective of providing a rigorous and well-grounded assessment. By delimiting the scope, the analysis avoids dispersion into related areas, such as large-scale energy storage systems, which, although relevant to the energy transition, fall outside the specific scope of EVs.

The phases into which the evolution of EVs is divided not only show how these technologies have matured over time, but also reflect the influence of public policy. These phases make it possible to understand how batteries and charging infrastructure have evolved into central pillars of electric mobility and energy sustainability, as described below.

Phase 1. Early Technologies and Prototypes (Before 2010)

During this stage, EVs were uncommon and were regarded more as a conceptual solution than a practical alternative to fossil fuel-based transportation. Research on environmentally friendly vehicles began in the 1970s, focusing on alternative energy sources to replace internal combustion engines (Shin and Lee, 2024), although during the following decade battery research was constrained by technological and environmental limitations (He et al., 2022). Between 1990 and 1997, automobile manufacturers concentrated on early iterations, including lead-acid and nickel-metal hydride batteries (Faria and Andersen, 2017; Liu et al., 2023).

Faria and Andersen (2017) note that between 1998 and 2005, frustration with early EV experiences led to a shift toward fuel cell technologies. From 2006 to 2009, interest in electric and hybrid technologies reemerged, supported by technological progress and a clearer understanding of battery performance. During this period, energy storage systems remained underdeveloped, characterized by limited capacity and short lifespans (Shin & Lee, 2024).

Regarding charging infrastructure, Moustafa (2024) identifies the period from 1993 to 2006 as an initial stage focused on establishing basic charging systems. Infrastructure remained largely undeveloped, and charging stations were limited to experimental applications, primarily in homes or research centers (Mizushima et al., 1980). These early efforts were aimed at making EVs a viable alternative to conventional vehicles.

Phase 2. Commercial Expansion and Battery Improvements (2010-2015)

Commercial EV production began to gain momentum, particularly in developed markets such as Europe, the United States, and Japan. In 2010, the adoption of lithium-ion (Li-ion) batteries marked a major technological milestone for EVs (Shin & Lee, 2024). This battery type emerged as the standard, offering higher energy density and significantly reducing vehicle weight, which represented a turning point in commercial viability (Dambros Telli et al., 2024). By 2011, efforts also began to focus on battery recycling and to place greater emphasis on sustainability (Bründl et al., 2024).

Li-ion batteries have driven the production and sales of EVs due to high energy density, long lifespan, and low self-discharge rates (Dambros Telli et al., 2024; Ortiz, 2024). At the same time, the first networks of fast-charging stations began to emerge, supported by public policy initiatives such as the EV Everywhere program in the United States and incentive schemes in Europe (Ortiz, 2024). However, energy storage systems remained at an experimental stage, with prototypes primarily focused on urban applications (Dall-Orsoletta et al., 2022). This period represented an intermediate stage in the development of charging infrastructure (Moustafa, 2024).

Phase 3. Consolidation and Mass Adoption (2016-2020)

During this period, EVs moved beyond a niche innovation and began to consolidate as a viable option for mass consumers. Technological progress in EV batteries accelerated, driven by two main factors: concerns over fossil fuel scarcity and efforts to reduce greenhouse gas emissions. This shift was supported by a significant decline in the cost of Li-ion batteries. At the same time, networks of fast and ultra-fast charging stations expanded across urban areas and major highways, improving accessibility and encouraging broader EV adoption. In parallel, energy storage systems based on second-life batteries were introduced, primarily for urban and renewable energy applications (Bründl et al., 2024).

Phase 4. Innovation and Sustainability (2021-present)

Currently, technological innovation is increasingly focused on sustainability and the circular economy. In recent years, significant investments in research and development have targeted improvements in battery chemistry, energy density, and battery pack size. Emerging innovations, such as the use of graphene, are being explored to enhance storage capacity and reduce charging times (Mallick & Gayen, 2023; Sampson, 2024; Jabbar et al., 2024).

Effective thermal management is also critical to limit battery degradation and extend operational life (Dambros et al., 2024). In addition, Dall-Orsoletta et al. (2022) argue that batteries retaining more than 80% of capacity can be redeployed in urban electric mobility and renewable energy storage applications.

Charging infrastructure has evolved toward more advanced systems characterized by interoperability, higher charging speeds, and the emergence of wireless charging technologies (Shin & Lee, 2024). At the same time, large-scale energy storage systems, such as second-life batteries integrated into smart grids, are playing an increasingly important role in the transition toward a more sustainable energy model (Dall-Orsoletta et al., 2022).

Finally, advances in battery and charging technologies are fundamental to EV development, given the reliance on high-capacity batteries. Current next-generation battery technologies offer improvements in thermal efficiency, compact design, durability, and cost reduction (Itani & De Bernardinis, 2023). In this regard, continuous progress in these components is critical to enhancing range, safety, and economic viability of EVs across different markets.

Key innovations in battery technology center on continuous improvements to enhance performance and lifespan through advances in battery chemistry, efforts to increase the amount of energy stored per unit of volume or weight (energy density), and the development of faster charging methods to improve convenience and reduce downtime (Sampson, 2024; Jabbar et al., 2024; Mallick & Gayen, 2023; Dall-Orsoletta et al., 2022; Greaker, 2021).

Technological advances in charging infrastructure are associated with the development of smart charging services designed to optimize energy distribution and balance supply and demand through the use of local renewable energy (Shirley et al., 2022), as well as dynamic inductive charging, which involves the exploration of dynamic charging lanes based on wireless inductive technology, characterized by higher initial costs and longer payback periods compared to conventional fast-charging stations (Suomalainen & Colet, 2019).

At the same time, the expansion of EVs introduces new challenges for the energy sector, particularly as it contends with the complexities associated with implementing automation (Grzesiak and Sulich, 2023). In addition, emerging technologies such as wireless charging and V2G (Vehicle-to-Grid) systems are reshaping charging infrastructure (Mo et al., 2022), while the integration of IoT and artificial intelligence is creating new opportunities for the management and optimization of electric mobility (Kampker et al., 2022).

According to Raad et al. (2024), future developments will place greater emphasis on scalability and infrastructure planning to accommodate emerging innovations, such as faster charging technologies and extended vehicle range. Overall, the four phases in the evolution of core EV technologies reflect a cumulative pattern of knowledge and technological progress, rather than isolated periods of innovation, as illustrated in Table 1.

Table 1. Evolution of Electric Vehicles and Core Technologies

Phase	Characteristics of EVs	Core Technologies	
		Batteries	*Charging Infrastructure*
1. Early technologies and prototypes (before 2010)	EVs were not very common. R&D focused on lead-acid batteries and the idea of electric mobility as an ecological alternative.	First rechargeable lead-acid batteries: heavy, low energy density, and limited range.	Basic and experimental charging systems. Limited installations, mainly in homes.
2. Commercial expansion and battery improvements (2010–2015)	Production begins, especially in developed countries. EVs gain attention as a real alternative.	Intensive research on lithium-ion batteries. These become the standard due to higher energy density and reduced battery weight, leading to improvements.	First charging station networks, driven by public policies in Europe and the United States.
3. Consolidation and mass adoption (2016–2020)	EVs become a viable option for mass consumers, along with a reduction in technological costs.	Decrease in lithium-ion battery costs.	Fast and ultra-fast charging networks expand in urban areas and along major highways.
4. Innovation and sustainability (2021–present)	Accelerated technological advances in batteries and new materials. Focus on sustainability and the circular economy.	Development of solid-state batteries and exploration of technologies such as graphene.	Intelligent charging infrastructure: interoperability, faster speeds, and emerging wireless charging.
Key technological innovations		Battery chemistry: focus on performance and durability. Energy density: increasing the amount of stored energy.	Charging technologies: fast and smart charging methods to improve convenience and reduce downtime; intelligent charging and dynamic inductive charging.

Source: Own elaboration based on the research conducted.

Based on the information presented in Table 1, several relevant trends can be identified in the evolution of key electric vehicle technologies, particularly in batteries and charging infrastructure, as well as in the increasing complexity of the systems associated with their development and adoption. These trends show that the advancement of both technologies has been progressive and closely interdependent over time. Likewise, they indicate that their evolution has responded not only to the need to improve the technical performance of electric vehicles, but also to the requirements of infrastructure, sustainability, and technological integration associated with their adoption:

1. Accelerated evolution and cumulative patterns: The evolution of EVs reflects a cumulative pattern, in which each technological phase builds upon previous advances in batteries and charging infrastructure. From early lead-acid batteries used in initial prototypes to solid-state batteries and emerging developments such as graphene-based applications aimed at improving energy density, sustainability, and cost reduction.

2. *Charging infrastructure as a key factor:* Charging infrastructure has evolved from basic and experimental systems (1993–2006) to fast and ultra-fast charging networks. Advances in interoperability and emerging technologies, such as wireless charging and intelligent systems, aim to optimize the user experience and reduce downtime.

3. *Emphasis on sustainable innovation:* In recent stages, research has prioritized sustainability, highlighting technologies such as solid-state batteries, the reuse of batteries in energy applications, and thermal management to extend component lifespan. These innovations aim to minimize the environmental impacts of electric vehicles.

4. *Interaction between technological advances:* Developments in batteries and charging infrastructure are closely interconnected, as battery capacity directly influences the demands on charging infrastructure, while innovations in fast and wireless charging drive adoption by improving accessibility and convenience.

5. *Increasing technological complexity:* The incorporation of technologies such as IoT, artificial intelligence, and V2G systems has added new layers of complexity, making electric vehicles not only a mechanical advancement but also an integral node within the modern energy grid.

PUBLIC POLICIES TO PROMOTE THE PRODUCTION AND ADOPTION OF ELECTRIC VEHICLES

This section examines the public policies implemented by seven leading countries in promoting electric vehicles, as well as the actions undertaken in Mexico. These leading countries have implemented comprehensive policies to promote the production and adoption of electric vehicles (EVs) and are at the forefront of this technology. Therefore, analyzing the policies they have implemented is important so that more lagging countries can learn from them and adopt and adapt the most innovative practices (Fekete et al., 2021). These policies include fiscal and financial incentives, investments in charging infrastructure, and other measures (Table 2).

Table 2. Incentives Provided by Leading Countries Promoting Electric Vehicles

	Types of incentives						
Country	*Financial and fiscal*	*Infrastructure*	*Behavioral incentives*	*Regulations and standards*	*Indirect incentives*	*Awareness and education*	*Public-private collaborations*
Germany	Direct subsidies. Tax reductions.	Installation of charging points in urban areas.	Not applicable.	National electric mobility strategy.	Investment in battery development.	Educational initiatives to promote transition.	Pilot programs with manufacturers.
China	Subsidies for the purchase of EVs.	Large-scale charging infrastructure.	Preferential access in urban areas.	National EVs adoption targets.	Investment in research and development.	Mass awareness programs.	Collaboration between government and local companies.

(continues)

Country *(continuation)*	*Types of incentives*						
	Financial and fiscal	*Infrastructure*	*Behavioral incentives*	*Regulations and standards*	*Indirect incentives*	*Awareness and education*	*Public-private collaborations*
The United States	Federal and state tax incentives.	Expansion of the EV charging network.	Use of HOV lanes (High Occupancy). Preferential parking. Restricted traffic zones.	Emissions standards and efficiency regulations.	Funding for battery development.	Educational campaigns at state level.	Joint support between government and private sector.
France	Subsidies for the purchase of EVs. Tax exemptions.	Investment in charging stations.	Preferential parking in certain areas.	Emissions reduction policies.	Support for battery research.	Sustainable mobility campaigns.	Residential charger programs.
Japan	Subsidies for the purchase of EVs, with amounts of up to 850 000 yen, prioritizing vehicles that promote emissions reduction and cybersecurity.	Extensive network of charging stations, including fast chargers.	Access to exclusive parking and preferential entry in urban areas.	Stricter emissions standards and the promotion of renewable energy for EV charging.	Subsidies for the development and production of EV batteries, such as the 120 billion yen granted to Toyota.	Public awareness campaigns on the benefits of EVs and educational programs on sustainable mobility.	Partnerships with automotive companies for the development of technologies and the expansion of charging infrastructure.
Norway	Tax exemptions on purchase and circulation.	Extensive fast-charging networks.	Access to exclusive lanes, free parking.	Ban on the sale of new internal combustion vehicles starting in 2025.	Support for companies adopting electric fleets.	Awareness campaigns on the benefits of EVs.	Partnerships for infrastructure development.
The Netherlands	Incentives for charging infrastructure and tax benefits.	Extensive network of public charging stations.	Tax incentives for zero-emission vehicles. Access to exclusive lanes and free parking.	Policies promoting low-emission vehicles.	Subsidies for research and technology.	Educational programs for citizens and businesses.	Public-private partnerships in infrastructure.
Mexico	Exemption from the New Car Tax (ISAN) for electric vehicles. Tax deduction of up to 250 000 pesos on the purchase of electric vehicles.	Investment in charging stations in urban areas and highways.	Exemption from driving restrictions such as the "Hoy No Circula" program[4] and access to exclusive lanes in some cities.	Implementation of official standards for vehicle energy efficiency and emissions.	Incentives for companies adopting electric fleets and preferential electricity tariffs for EV charging.	Awareness programs on electric mobility and the environmental benefits of EVs.	Collaborations with the private sector for infrastructure development and the promotion of electromobility.

Source: Own elaboration based on Fekete et al. (2021), Martínez-Lao et al. (2017), Schlüter and Weyer (2019), International Press (2024), and Bai et al. (2025).

[4] Translated as "Today Do Not Circulate."

The selection of the countries considered is based on academic criteria that allow for a representative and well-founded comparison. First, these countries stand out for their global leadership in electromobility, as Norway, China, the United States, Germany, and Japan have implemented comprehensive and diverse policies, reflecting successful and scalable approaches to promoting the adoption of electric vehicles. Second, these countries offer a diversity of political and economic models, combining mature market economies, such as Norway, Germany, and Japan, with more state-interventionist schemes, as in the case of China. This allows for an analysis of how political and economic structures influence the design of public policies. Third, the inclusion of Mexico provides a relevant comparative reference, enabling the identification of areas of opportunity and the examination of how certain policies could be adapted to an emerging context with structural constraints, but with significant potential in automotive production.

The identified measures can be grouped into seven categories: *1)* fiscal and financial: policies aimed at lowering the upfront cost of acquisition or the total cost of ownership of electric vehicles through direct subsidies, tax exemptions, or reduced transport-related fees; *2)* infrastructure: refers to the development of public charging networks and subsidized installation of residential chargers; *3)* behavioral incentives: preferential access to dedicated lanes, free or discounted parking in urban areas, and exemptions from certain traffic restrictions; *4)* regulations and standards: establishment of mandatory targets for EV sales and gradual restrictions of fossil fuel-powered vehicles; *5)* indirect incentives: investment in research and development to improve battery and EV technologies, as well as subsidies for companies adopting electric fleets; *6)* awareness and education: programs aimed at promoting the benefits of this technology and encouraging the transition toward more sustainable mobility; and *7)* public-private collaborations: joint initiatives between governments and firms to expand infrastructure and facilitate adoption.

Overall, government initiatives to support the production and adoption of EVs vary across countries and regions, but they generally focus on economic incentives, infrastructure development, battery recycling, regulation, and the promotion of research and development. Singh et al. (2024) note that, due to high costs, electric vehicles remain largely unaffordable for low-income populations; therefore, fiscal incentives or purchase subsidies are recommended. The following section highlights some key initiatives across different parts of the world.

In Europe, Norway has offered, since 1990, a combination of tax exemptions (including a 25% VAT exemption and other taxes applied to vehicle purchases), financial incentives, and benefits such as free access to toll roads and parking, as well as access to public transport lanes. These measures have led to more than 50% of new vehicles being electric. Norwegian authorities have strongly promoted EVs in response to environmental concerns (Wirth, 2016).

In the United States, the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) have implemented stricter emissions standards to encourage the adoption of electric vehicles. At the federal level, until recently, buyers of new electric vehicles could access a tax credit of up to 7 500 dollars under the Inflation Reduction Act of 2022 (IRS, 2023), provided that the vehicle met North American assembly requirements and battery content provisions in effect through September 2025, when the full application of these criteria concluded. Following this period, the continuity and scope of such incentives have been subject to regulatory adjustments and processes of legislative reinterpretation. In addition, several states continue to implement complementary programs, including sales tax exemptions, state-level credits, and rebates for installing charging infrastructure, which further encourage the adoption of electric vehicles and strengthen the expansion of supporting networks.

Regarding charging infrastructure, the U.S. government has proposed significant investments through an ambitious plan to expand the EV charging network, aiming to install 500 000 stations by 2030 (IEA, 2024). China, in turn, has implemented aggressive policies to promote EVs adoption, including subsidies for both producers and consumers (Salgado-Conrado et al., 2024), which has led to a substantial increase in EV sales. The Chinese government also provides significant purchase subsidies, although these have gradually declined in recent years.

In terms of infrastructure, the National Charging Network has developed an extensive network of charging stations and continues to expand it, with the goal of reaching more than 4.8 million charging stations by 2030. Finally, with regard to regulation, China has established a New Energy Vehicle (NEV) quota system, which requires manufacturers to produce a certain percentage of electric vehicles. Likewise, several Chinese cities are implementing zero-emission zones, where only this type of vehicle is permitted.

In Japan, the government provides subsidies for the purchase of EVs and for the installation of charging stations in homes and businesses. EVs are also subject to significant reductions in acquisition and ownership taxes, and the country has invested in expanding its fast-charging network, with the aim of increasing the number of charging stations in both urban and rural areas. In addition, Japan has a national strategy to reduce CO_2 emissions and promote the adoption of EVs as part of its climate commitments (International Press, 2024).

The set of measures implemented in several countries aligns with the proposals of Santamarta (2009), who argued for the need to introduce tax incentives for the acquisition of EVs, both for consumers and for companies purchasing fleet vehicles, as well as support for the development of infrastructure such as charging points and complementary facilities, including battery-swapping stations.

According to Anilan and Vij (2024), the appropriate type of incentives depends on the stage of electric vehicle adoption within a given context. In the early stages, subsidies and tax incentives are most effective; however, their impact tends to diminish in later stages, while the development of public charging infrastructure becomes essential for the sustainable adoption of EVs. Rietmann and Lieven (2019), in turn, argue that public-private collaboration can enhance the effectiveness of these policies. The countries discussed demonstrate that a combination of fiscal and financial incentives, infrastructure development, and supportive regulations can effectively promote the adoption of EVs.

Public policies play a crucial role in promoting the adoption of this technology. In the European Union, CO_2 emissions regulations and emission reduction targets have accelerated the uptake of EVs (Leurent & Windisch, 2011). In the United States, the federal government has implemented tax incentives and supportive policies to encourage EV adoption (Internal Revenue Service, 2023); however, the limited availability of charging infrastructure—particularly for households without access to home charging and in regions with low densities of public stations—remains a significant barrier to widespread adoption (Pezeshknejad et al., 2026; Hanig et al., 2025). Finally, in China, government subsidies and restrictions on internal combustion vehicles in major cities have driven the growth of the EV market (Kampker et al., 2022).

It should be noted, however, that some of the incentives summarized as examples in Table 2 have been recently modified or adjusted. Notably, these include the elimination of national subsidies in China and Germany, as well as new eligibility criteria for federal incentives in the United States. All of this reflects the ongoing evolution of electromobility policies at the global level.

LINKAGES BETWEEN PUBLIC POLICIES AND TECHNOLOGICAL DEVELOPMENT

The relationship between the development of the two core technologies—batteries and charging infrastructure—and the public policies implemented can be synthesized through two main analytical dimensions. Public policies have contributed, on the one hand, to advancing technological innovation in batteries; on the other, they have supported the expansion and consolidation of charging infrastructure, a key element for their adoption.

1. Promotion of Technological Innovation Through Public Policies

a) Fiscal and financial incentives: Public policies have promoted the research and development of higher energy-density, recyclable, and more sustainable batteries through economic incentives targeted at firms and research centers. For example, in countries such as China and the United States, subsidies for battery manufacturing have accelerated technological innovation, reducing costs and improving market competitiveness (Ezell, 2024; Bai et al., 2025; IEA, 2025; Lombardo et al., 2025).

b) Environmental regulations: Strict regulations on greenhouse gas emissions have encouraged the transition toward electric vehicles. These policies have supported both the production of advanced batteries and the development of electric charging networks in key regions.

2. Charging Infrastructure: A Key Pillar for Adoption

a) Development of public and private charging networks: Public policies have facilitated the expansion of charging infrastructure through direct investments in fast and ultra-fast charging stations, as well as through public-private partnerships. This has enabled cities and major highways to achieve increasingly extensive coverage, improving the user experience.

b) Interoperability standards: In countries such as Norway and Germany, policies have promoted interoperability among different charging providers, facilitating the integration of technologies such as smart charging and V2G systems.

3. Technological-policy Convergence for Mass Adoption

a) Cost reduction and accessibility: Government support through economic incentives and industrial policies has significantly reduced the costs of batteries (such as lithium-ion batteries) and charging infrastructure, making them more accessible to end users.

b) Circular economy and sustainability: Policies focused on battery recycling and reuse, such as those implemented in Germany, have established regulatory frameworks that ensure the sustainability of the technologies involved. This not only reinforces the social acceptance of EVs but also drives investment in cleaner and more efficient technologies.

In summary, public policies have been an essential catalyst for the development of the core technologies of electric vehicles by aligning technological objectives with sustainability and emissions reduction goals. However, the success of these policies depends on their ability to adapt to local contexts and to foster collaboration between the public and private sectors.

MEXICO: INITIATIVES TO PROMOTE THE PRODUCTION AND ADOPTION OF ELECTRIC VEHICLES

Policy transfer is a key process in the design and implementation of government strategies that draw on knowledge from other contexts. According to Van Gossum et al. (2009) and Clarke (2009), this process involves the adoption, adaptation, or inspiration from policies previously implemented in other settings, enabling governments to address common challenges more efficiently.

There are three main modalities: *1)* voluntary transfer, or lesson-drawing, which occurs when policymakers actively seek to learn from and adopt successful initiatives from other contexts to address existing problems; *2)* negotiated transfer, which involves a collaborative process in which policies are adapted through agreements among key stakeholders; and *3)* coercive transfer, which takes place when an external actor, such as an international organization, imposes policies as a condition for receiving support. Additionally, policy transfer may take different forms, including direct copying, emulation (adaptation with adjustments), the combination of elements from various policies, or inspiration without direct adoption.

Factors Influencing and Challenges in Policy Transfer

The success of policy transfer depends on several factors. One of the most important is the ideological and institutional compatibility between the country of origin and the recipient. For example, policies that have been effective in Norway may not be suitable for Mexico without adjustments, due to differences in economic capacity and infrastructure. Another key factor is resource availability, since implementing charging stations or subsidies for EVs, for instance, requires investment that must be appropriately prioritized. However, policy transfer also faces several challenges. Uninformed transfer can lead to policies being misunderstood or implemented without proper consideration of the local context. Incomplete transfer may omit key elements, thereby weakening effectiveness. Finally, inappropriate transfer occurs when adopted policies do not adequately respond to the needs of the new context.

Application of Policy Transfer to the Case of Mexico

To promote electromobility in Mexico, it is essential to learn from successful policies implemented in other countries, adapting them to local conditions. For example, charging infrastructure in China and fiscal incentives in Norway are models that can help guide the transition in Mexico. However, these policies must be adjusted to reflect socioeconomic inequality in the country.

Mexico should also consider negotiated transfer, involving key stakeholders such as automobile manufacturers, state governments, and energy companies to develop coherent policies. In addition, drawing inspiration from elements implemented in other contexts can foster innovation, such as the design of educational campaigns on the environmental impact of EVs. Table 3 summarizes the main modalities of policy transfer and their specific application in Mexico.

Table 3. Main Policy Transfer Modalities for Mexico

Modality	*Description*	*Example for Mexico*
Voluntary transfer	Active search and adoption of successful policies from other contexts.	Replicate fiscal incentives such as those in Norway, adapted to prioritize low-cost EVs.
Negociated transfer	Adaptation of policies through negotiation among key stakeholders.	Negotiate with national and international manufacturers to produce affordable and accessible EVs for the Mexican market.
Coercive transfer	Policies imposed by external actors, such as international organizations.	Adopt international emissions standards as a requirement to access climate financing.
Copying	Direct replication of policies from another context.	Introduce pilot programs that replicate subsidy schemes in highly polluted cities, such as the Valley of Mexico.
Emulation	Adaptation of policies while maintaining their core principles.	Adapt the Chinese model of public charging stations through public-private partnerships, aligning it with the national electricity infrastructure.
Combination	Integration of elements from multiple policies to create a new approach.	Develop a comprehensive program combining purchase incentives, charging infrastructure, and educational campaigns.
Inspiration	Use of policies from other contexts as a source of ideas without direct adoption.	Design environmental awareness campaigns inspired by European programs, highlighting economic and health benefits.

Source: Own elaboration.

Policy transfer in electromobility represents a strategic opportunity for Mexico to move toward a more sustainable model aligned with its international commitments. However, this process must be guided by a rigorous analysis of the modalities, factors, and challenges involved, ensuring context-specific adaptation that maximizes its impact. Adopting a comprehensive approach that combines incentives, infrastructure, and social engagement can position Mexico as a regional leader in the transition to electric vehicles.

STYLIZED FACTS DERIVED FROM TECHNOLOGICAL ADVANCEMENT AND POLICIES PROMOTING ELECTRIC VEHICLES

The analysis of electric vehicle (EV) development is grounded in a set of stylized facts that make it possible to identify key patterns and recurring dynamics in their technological and policy evolution. These facts, derived from the literature reviewed, highlight the most significant advances in core enabling technologies, as well as the role of public policy in fostering their adoption. Likewise, they provide a point of departure for understanding the barriers and opportunities faced by EVs across different contexts, particularly in countries such as Mexico, where the transition toward electromobility continues to present structural challenges. The five stylized facts identified are presented below.

Stylized Fact 1. Common Trends in Technological Evolution

Research on batteries and wireless or fast-charging systems remains a constant in technological advancement, while technologies such as V2G charging stand out as emerging innovations in several countries. In this regard, progress in battery development and charging technologies is central to the advancement of electromobility. Mexico could focus on adapting and adopting these technologies, seeking to integrate energy storage and generation capacities into EV systems.

Stylized Fact 2. Diversity of Public Policy Approaches Across Contexts

Leading countries (Germany, the United States, China, Norway, among others) adopt diversified policy approaches that reflect both environmental and economic objectives; however, each country relies on mechanisms tailored to its socioeconomic conditions and policy priorities. For example:

- Norway prioritizes fiscal incentives and policies that eliminate value-added tax (VAT) and reduce toll costs, reflecting both its capacity to implement aggressive measures and its strong environmental commitment.
- China employs a combination of direct incentives and stringent emissions regulations, leveraging its capacity for state intervention in a large-scale market.
- The United States combines tax incentives with environmental regulations, reflecting a more decentralized, state-level approach.

In general, the pattern underscores economic incentives, environmental regulations, and charging infrastructure as shared policy pillars; however, each country tailors these instruments to its political and economic context. This suggests that Mexico should design policies responsive to its economic conditions and infrastructure constraints.

Stylized Fact 3. The Importance of Charging Infrastructure as a Key Barrier or Enabler

Charging infrastructure is a recurring factor in the adoption of electric vehicles. Countries such as China and the United States have invested heavily in expanding charging networks to complement EV adoption incentives, whereas Mexico still faces limitations in this area. Charging infrastructure is critical and largely determines the feasibility of large-scale EV adoption. In contexts where infrastructure is insufficient, fiscal incentives and regulatory measures alone are not enough to drive uptake. This constitutes a key consideration for the development of electromobility in Mexico.

Stylized Fact 4. Differences in Policy Rationales for Promoting Electric Vehicles

In several countries, the adoption of electric vehicles is driven not only by environmental concerns but also by geopolitical and commercial considerations. Freyssenet (2011) suggests that EV adoption is linked both to strategic positioning and to the reduction of energy dependence, a pattern particularly evident in Europe and Asia. Electromobility, therefore, is justified differently across contexts: in Europe, it is primarily framed in terms of environmental sustainability and emissions reduction; in China, in addition to sustainability goals, it functions as an economic driver and a strategic effort to dominate the battery market. Mexico could orient its policies toward an economic growth strategy—particularly targeting the auto parts and manufacturing sectors—while integrating environmental objectives.

Stylized Fact 5. The Need for a Comprehensive and Multisectoral Approach

In countries with significant progress in electric vehicle adoption, collaboration among government, the automotive industry, the energy sector, and academia is essential. These actors play an active role in policy design as well as in the deployment of infrastructure and technology. Multisectoral integration and public-private collaboration are therefore critical. In Mexico, replicating this approach could facilitate the development of a more robust electromobility ecosystem, leveraging both domestic production potential and international partnerships.

CLOSING REFLECTIONS

The analysis of the interaction between core electric vehicle technologies (batteries and charging infrastructure) and the public policies that promote their production and adoption has made it possible to identify both significant advances and persistent challenges in the transition toward EV production and adoption. The main conclusions are presented below.

Findings, Limitations, and Future Research Directions

Technological advances in lithium-ion batteries have been instrumental in consolidating electric vehicles as a viable alternative, driven by improvements in energy density, sustainability, and cost, developments largely supported by public policies oriented toward technological innovation. In parallel, charging infrastructure has evolved toward fast and intelligent systems, incorporating emerging technologies such as dynamic inductive charging and V2G. These innovations have been enabled by targeted subsidies and regulatory frameworks in leading countries such as Norway, China, the United States, and Germany.

However, in Mexico, although electrification programs and fiscal incentives have been implemented, charging infrastructure remains insufficient, and public policies are not fully aligned with technological needs or the characteristics of the domestic market, thereby constraining the scope of EV adoption. The interaction between technological advances and public policy has proven crucial for overcoming barriers such as high upfront battery costs and limited access to charging stations. However, this relationship remains uneven in lower-resource regions, where significant gaps persist and hinder the large-scale adoption of electric vehicles.

This study has several limitations that point to future research directions. On the one hand, the analysis of the Mexican context relies primarily on secondary sources, which constrains the depth of the local assessment. In addition, the absence of quantitative data limits the ability to measure the direct impact of public policies on core technologies. Finally, although batteries and charging infrastructure are examined, other complementary technologies, such as large-scale energy storage systems and their integration with renewable energy sources, are not explored in depth.

Among the proposed directions for future research is the development of regional assessments in Mexico to identify specific barriers related to infrastructure, financing, and the regulatory framework. It is also recommended to conduct quantitative studies that evaluate the impact of public policies on technological development and the adoption of electric vehicles. In addition, it is essential to examine the role of the circular economy through policies that promote battery recycling and reuse, as well as to encourage multisectoral collaboration among government, academia, and the private sector to strengthen strategies for a more effective and sustainable transition to electromobility.

In conclusion, the development of core technologies and associated public policies has been fundamental to the global advancement of electric vehicles. However, in Mexico, it is necessary to articulate strategic efforts to overcome existing barriers and capitalize on identified opportunities, adapting international lessons to the local context. These actions will be critical for consolidating a sustainable and competitive energy transition in the country.

Translation: Evelyne Rosales Cortes.

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