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Electric Vehicles and Their Charging Stations

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Abstract

By the end of the 20th century, the automotive industry faced new challenges, making the development of electric vehicles essential. The advantages of these vehicles are evident, particularly in their ecological benefits—such as reducing emissions, as electric vehicles do not produce exhaust, thereby improving air quality and decreasing environmental pollution. Additionally, they operate almost silently, reducing noise pollution and creating a more peaceful environment. Electric vehicles are also more energy-efficient than internal combustion engine vehicles, conserving energy and lowering costs. This paper focuses on studying the role, significance, development foundations, and outcomes of electric vehicles in the modern world. It examines the need for and the current dynamics of infrastructure development related to electric vehicles. Through qualitative and quantitative research methods, the paper assesses the degree to which Georgia aligns with other countries in terms of electric vehicle development, accessibility, and mobility. It explores the innovative advancements and the current state of development in Georgia in relation to the acquisition and movement of electric vehicles. Key findings show that the rise of electric transportation is largely influenced by governmental policies and infrastructure development. Countries such as Norway, Germany, the Netherlands, China, and Sweden have pioneered EV adoption through financial incentives, subsidies, and robust charging networks. These nations have set ambitious goals for transitioning to electric vehicles, such as Norway's goal of 80% EV purchases and Sweden's aim to have all new vehicles be emissions-free by 2030. In

contrast, Georgia's growing legislative framework supports the adoption of electric vehicles, with tax exemptions and infrastructure investments aimed at reducing urban air pollution.

Keywords: Electric vehicles, Internal combustion engine vehicles, Environmentally clean environment, Electric vehicle infrastructure, Electric vehicle charging stations, Electric batteries, transmission

Introduction

The development of electric vehicles has a fascinating and extraordinary historical trajectory. Notably, the invention and use of electric transport date back much earlier than that of internal combustion engine vehicles. The first electric transport is believed to have been invented in the 1830s. The pioneers of this groundbreaking project were the Scotsman Robert Anderson and the Dutch inventors Sibrandus Stratingh and Christopher Becker. Their innovations paved the way for subsequent practical advancements, exemplified by the American Thomas Davenport and the Scotsman Robert Davidson, who developed road vehicles powered by non-rechargeable electric motors. The field gained popularity and significance in the latter half of the 19th century, particularly with French inventors Gaston Planté and Camille Faure enhancing electric battery capacity.

At the beginning of the 20th century, the promotion of electric vehicle production was notably led by Great Britain and France. During the same period, American inventors A. Riker and W. Morrison created six-passenger electric vehicles, which became the "first pioneers" in establishing New York's commercial taxi structure.

In the early 20th century, electric vehicles had distinct advantages over other types of transportation, as they did not produce emissions, specific noises, or intense vibrations, which were common with vehicles powered by oil distillates. Additionally, electric vehicles faced fewer technical issues with various control mechanisms; for example, they did not require a transmission system, whereas gasoline-powered vehicles relied heavily on this device for driving, which often caused undesirable interruptions due to its complexity. These advantages remain relevant in the modern era, highlighting the need to prioritize the development, frequent use, and essential role of electric vehicles today.

The operation of electric vehicles required the establishment of appropriate service infrastructure. This issue is also one of the subjects of our research. Projects aimed at designing efficient charging mechanisms and selecting suitable locations have always been significant and hold a special place in urban development plans for populated areas. Therefore, this paper examines the foundations of the development and prioritization of electric

vehicle infrastructure by comparing examples from foreign countries and Georgia.

The study also investigates and analyzes additional measures that the government could implement to facilitate electric vehicle acquisition for consumers, making it accessible to all.

Norway

In Norway, the development of electric vehicles and related infrastructure serves as a model for other countries. This success is attributed to several factors. Over 80% of vehicle purchases are electric, making Norway a global leader in EV adoption. The country offers a variety of electric vehicle brands, providing consumers with the freedom to choose a model that best suits their preferences. Additionally, a well-developed infrastructure with numerous charging stations supports the widespread use of electric vehicles (Electric Vehicle Market in Norway, 2022).

With government support, Norway has implemented a wide range of financial and non-financial incentives for purchasing electric vehicles, including tax exemptions, free parking, access to bus lanes, and other movement privileges (National Transport Plan 2022–2033, 2021).

Consequently, significant attention is devoted to the expansion of the electric vehicle charging network. Norway has numerous public and private charging stations, which facilitate both the mobility and charging of these vehicles (Charging Infrastructure in Norway, 2023).

As of 2020, 54% of newly sold vehicles in Norway were electric, with this percentage increasing in 2021 and 2022 (Electric Vehicle Sales Statistics, 2022). Recognizing this success, Norway continues to invest in and support innovations for the advancement of electric transportation.

Federal Republic of Germany

Germany is the largest market for electric vehicles in Europe, with an actively developing network of charging stations and strong government support for electric transportation. This progress can be attributed to several factors:

The government has implemented financial assistance, including incentives and subsidies for purchasing electric vehicles. Additionally, manufacturers receive benefits and low-interest loans to boost electric vehicle production (Promotion of Electric Vehicles in Germany, 2023).

Germany is actively working on expanding its electric vehicle charging network. Through joint efforts between the government and the private sector, numerous public and private charging stations have been established, making vehicle charging more accessible nationwide (Charging Infrastructure Expansion, 2023).

Major automakers, including BMW, Volkswagen, Mercedes-Benz, and Audi, have heavily invested in electric vehicle development. They have expanded their model ranges and advanced new technologies to improve the durability and efficiency of electric vehicles (Electromobility in the German Automotive Sector, 2022).

The country aims to reduce carbon emissions and transition to renewable energy sources. As part of this policy, promoting and encouraging the use of electric vehicles play a significant role (Federal Environment Agency, 2023).

Germany aims for half of all new car sales to be electric by 2030 and plans to introduce additional support measures to achieve this goal (2030 Mobility Strategy, 2023).

Netherlands

The use of electric vehicles and the development of related infrastructure in the Netherlands have progressed rapidly and successfully due to several key factors:

The government has established substantial financial incentives and subsidies for purchasing electric cars, including tax breaks, low-interest loans, and subsidies. Restrictions have also been set for fuel-based vehicles entering low-emission zones (Financial Incentives for Electric Vehicles, 2023).

The Dutch population is known for its high environmental awareness. Also, the society actively supports eco-friendly transportation and is willing to embrace and use new technologies.

The country has a wide network of electric vehicle charging stations, including numerous public and private stations, as well as fast-charging stations on highways and in cities (Electric Vehicle Charging Infrastructure, 2023).

Many companies and organizations actively promote the use of electric vehicles. Some companies offer electric vehicles to their employees, while others invest in building charging stations (Corporate Investments in Electric Vehicle Infrastructure, 2022).

The market offers a wide range of international electric vehicle brands, providing consumers with diverse options and contributing to market growth (Market Overview of Electric Vehicles, 2023).

The Netherlands is actively integrating electric buses and other public transport, promoting eco-friendly transportation (Green Transport and Urban Mobility, 2022).

Furthermore, electric vehicle development in the Netherlands aligns with the European Union's strategy for reducing carbon emissions and promoting sustainable transportation (EU Strategy for Sustainable Mobility, 2022).

In 2020, electric vehicle sales in the Netherlands increased annually and, by 2021, the country was one of the leaders in electric vehicle adoption in Europe. This trend continues with ongoing investments and support for innovation in the electric transportation sector (Electric Vehicle Sales in the Netherlands, 2023).

China

China is the largest market for electric vehicles globally, offering numerous locally produced models and rapidly developing infrastructure. The recent rapid and large-scale growth of electric vehicles and related infrastructure in China is due to several factors:

The Chinese government actively supports the electric vehicle industry through policies, subsidies, and regulations. In addition, a national strategy has been established to increase energy independence and environmental cleanliness.

Subsidies, tax benefits, and various financial assistance programs for purchasing electric vehicles play a significant role in market development, helping consumers and businesses to transition to electric transportation (Policies for New Energy Vehicles, 2023).

The government invests heavily in local manufacturers, supporting further growth, technological innovation, and production expansion (China's Support for Local EV Manufacturers, 2023).

China has the world's largest network of public charging stations, which continues to expand to better meet consumer demand. Investment in renewable energy, such as solar and wind, is directly linked to the electric vehicle industry, supporting the development of environmentally clean charging infrastructure.

Many companies, including NIO, Xpeng, and BYD, have introduced innovations in electric vehicle manufacturing, investing in new technologies that enhance the competitiveness of their products in the global market.

In 2020, China was the world's largest producer and consumer of electric vehicles. The country continues to invest and innovate to further advance its electric vehicle industry and create a sustainable transportation system (Global Electric Vehicle Outlook, 2023).

Sweden

The popularity of electric vehicles in Sweden is growing, with significant progress in related infrastructure. Several key factors contributing to this development include:

The government has introduced a wide range of financial and regulatory incentives to promote electric vehicle purchases, including tax

breaks, low-interest loans, and subsidies (Incentives for Electric Vehicles, 2023).

Sweden is actively expanding its network of electric vehicle charging stations. Numerous public and private charging stations across the country provide convenient and quick charging options for users (Charging Infrastructure in Sweden, 2022).

The Swedish population is highly environmentally conscious, valuing ecological sustainability and readily adopting eco-friendly transport options (Sweden's Environmental Policy, 2023).

Both local and international automakers are active in Sweden, producing and selling electric vehicles. This offers consumers a diverse range of options and boosts market competitiveness (Electrification Strategy, 2023).

The government aims for all new vehicles sold by 2030 to be emissions-free, a goal that requires substantial investment and a strategic plan focused on developing electric transport and expanding infrastructure (Sweden's Climate Policy Framework, 2023).

Several companies in Sweden are developing innovative technologies to enhance the efficiency and appeal of electric vehicles, including advancements in battery and charging infrastructure (Battery Innovation and Development, 2023).

Sweden is actively promoting the development of electric buses and other environmentally friendly public transport options, supporting urban ecological cleanliness and transportation efficiency (Sustainable Public Transport Initiatives, 2022).

Electric vehicle sales in Sweden have shown consistent annual growth, continuing through 2021 and 2022. These developments position Sweden as one of Europe's leading countries in electric transportation (EV Market in Sweden, 2023).

Georgia

In Georgia, initiatives by the legislative and executive branches, as well as local governments, aim to increase demand for technology-oriented vehicles among the population and reduce air pollution from the transportation sector in urban areas. Significant steps have been taken in facilitating the import of electric vehicles (including motorcycles, mopeds, and quad bikes) and the establishment of charging stations.

Under Georgia's Tax Code:

According to Article 161¹, Paragraph 1, Subparagraph "g," goods auctioned, sold directly, or otherwise realized to satisfy tax liabilities or other monetary obligations (excluding criminal and administrative sanctions) are subject to VAT, with the VAT amount paid to the budget by the authorized

entity handling the sale. However, passenger vehicles under HS Code 8703 and motorcycles/mopeds under HS Code 8711 are exempt from VAT (Georgian Parliament, www.matsne.gov.ge, 2010).

Article 172, Paragraph 1, Subparagraph "ch" exempts electric buses (including electric minibuses) under HS Code 8702 40 000 00 from VAT with the right to deduction (Georgian Parliament, www.matsne.gov.ge, 2010).

According to Article 173, Subparagraph "z," the import of passenger vehicles under HS Code 8703 and motorcycles/mopeds under HS Code 8711 is exempt from VAT, and under Subparagraph "h²," electric buses (including electric minibuses) under HS Code 8702 40 000 00 are also exempt from VAT (Georgian Parliament, www.matsne.gov.ge, 2010).

Article 194, Paragraph 5, Subparagraph "l" exempts left-hand drive electric vehicles under HS Codes 8703 and 8711 from excise duty, without the right to deduction (Georgian Parliament, www.matsne.gov.ge, 2010).

Article 199, Subparagraph "zh" exempts electric vehicles under HS Code 8703 from import duties (Georgian Parliament, www.matsne.gov.ge, 2010).

Since March 1, 2014, the "Law of Georgia on Road Traffic" established by Parliament introduced Appendix No. 1 (Road Signs), which designated the informational sign 7.20.1, "Electric Vehicle Charging Station," identifying areas specifically for charging electric vehicles, marked with road signs (Georgian Parliament, www.matsne.gov.ge, 2013).



7.20.1

Electric Vehicle Charging Station

Appendix No. 2 (Road Markings) established horizontal marking 1.24.4, which designates a parking space on the road specifically for electric vehicle charging. This road marking may be applied with or without a green background (Georgian Parliament, www.matsne.gov.ge, 2013).



1.24.4

According to Article 125², Paragraph 2 of the Code of Administrative Offenses of Georgia, parking at an electric vehicle charging station within the administrative boundaries of Tbilisi without connecting to a charging device will result in a fine of 100 GEL. Under the first note of this article, in cases of administrative violations defined by this provision, the structural unit of the Tbilisi Municipality's Mayor's Office designated by the representative body of Tbilisi Municipality, or an authorized individual or legal entity, has the right, in accordance with Article 290⁶ of this Code, to tow the vehicle to a designated secure location or to immobilize the vehicle's wheels with a special device, provided that the parking sign indicates this action (Presidium of the Supreme Council of the Georgian SSR, 1984). According to Article 2 of Resolution No. 24-80 of the Tbilisi City Council, dated July 27, 2018, titled "On Defining the Permit Conditions for Passenger Transport by Taxi (Category M1) within the Administrative Boundaries of the Capital of Georgia," electric vehicles with only electric motors and a maximum power output exceeding 4 kW are exempt from paying the permit issuance fee for Category "A" and "B" taxi permits within the capital of Georgia until December 31, 2029 (Tbilisi City Council Resolution, www.matsne.gov.ge, 2018). Based on Article 125², Paragraph 2 of the Georgian Code of Administrative Offenses (Presidium of the Supreme Council of the Georgian SSR, 1984), the Tbilisi City Council's Resolution No. 33-99, dated December 27, 2016, titled "On Approving the Rules for Regulating Vehicle Parking within the Administrative Boundaries of Tbilisi City and Setting Fees for Parking, Towing, Storage, and Wheel Blocking," established the fees for towing and storing vehicles at designated secure locations, as well as the fees for wheel immobilization, in cases of administrative offenses.

Additionally, under Article 4 of Resolution No. 33-99, electric vehicles with only electric motors and a maximum power output exceeding 4 kW are exempt from paying for time-limited and zonal parking within Tbilisi's administrative boundaries. According to Subparagraphs "e" and "v" of Article

8, Paragraph 1 of the parking regulation rules established by this resolution, the Tbilisi City Government is authorized to designate special parking spaces and conditions for: electric vehicles (with a maximum motor power exceeding 4 kW) that use these spaces exclusively for charging, and electric taxis (with a maximum motor power exceeding 4 kW) (Tbilisi City Council Resolution, www.matsne.gov.ge, 2016).

According to Tbilisi City Council Resolution No. 33-99, dated December 27, 2016 (Tbilisi City Council Resolution, www.matsne.gov.ge, 2016), and Decree No. 06.01.98 of the Tbilisi City Government dated February 8, 2017, "On Defining Parking Spaces within the Administrative Boundaries of Tbilisi City," charging locations for electric vehicles (with a maximum motor power output exceeding 4 kW) and parking spaces for taxis (including electric taxis with a motor power output exceeding 4 kW) have been designated (Tbilisi City Government, 2017). Furthermore, Decree No. 19.670.876 of the Tbilisi City Government, dated June 19, 2019, "On Defining Zonal Parking Spaces within the Administrative Boundaries of Tbilisi City," designates parking spaces for taxis, including electric taxis (with a motor power output exceeding 4 kW) (Tbilisi City Government, 2019). These combined legal acts, effective within Georgia, including Tbilisi's administrative boundaries, establish favorable conditions to promote the import of electric vehicles into the country.

Table 1 illustrates the comparison of the adoption of electric vehicles (EVs) and the development of EV infrastructure in countries mentioned in the text.

Table 1. Comparison of Electric Vehicle Adoption and Infrastructure in Leading Countries

| Country | % EV Market Share | Government Incentives | Charging Infrastructure Development |
|-------------|-------------------|---|---|
| Norway | 80% | Tax exemptions, free parking, bus lane access | Extensive, numerous public and private stations |
| Germany | Largest in Europe | Subsidies, tax benefits, low-interest loans | Expanding rapidly with public-private efforts |
| Netherlands | Growing rapidly | Financial incentives, low-emission zones | Wide network, including fast-charging stations |
| China | Largest globally | National strategy, financial assistance | Largest global network, expanding rapidly |
| Sweden | Growing annually | Tax breaks, low-interest loans, subsidies | Expanding nationwide |
| Georgia | Increasing | VAT exemptions, tax benefits | Developing with specific legal framework in Tbilisi |

Conclusion

Based on the findings of this research, we can conclude that electric vehicles, despite their long history, represent a forward-looking innovation that has become a defining achievement of the 21st century and an essential

part of humanity's future. Their growing popularity and increased usage are directly linked to reductions in global air pollution, improvements in ecological conditions, and the mitigation of health risks associated with poor air quality. Economic factors, business success within the industry, and the enhanced travel comfort for consumers also play an important role in their adoption.

The current situation suggests that, in the near future, the production of electric vehicles will become a key component of the ongoing technological boom, making them accessible to all. This progression will be accompanied by improvements in battery capacity and the development of advanced infrastructure for fast and efficient charging.

Challenges related to electric vehicle charging must be addressed through advancements in charging technologies and the expansion of charging infrastructure.

To support this growth, effective government policies are essential for systematically developing and optimizing charging infrastructure, ensuring convenient, fast, and eco-friendly transportation options. Additionally, a comprehensive regulatory framework with flexible incentives should be established to facilitate electric vehicle ownership and operation, making this mode of transportation accessible to all.

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