

# Importance of Charging Infrastructure for the Public Adoption of Electric Vehicles - Recommendations for Turkey

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**Abstract**— As one of the major contributors to carbon emissions and one of the most crucial demands on a national and international level, transportation is going through significant change. The national energy action plans of nations include increasing the usage of electric vehicles (EV) in substitution of diesel and gasoline-powered vehicles. In order to solve the charging issue, which is considered to be one of the major barriers to the adoption of EVs, technological development and diffusion of EV charging station infrastructures are crucial and the social aspects of the problem should be investigated. Examples of the situation in Turkey and throughout the world are explored in this paper and recommendations for how EV charging stations could aid in the adoption of EVs are made.

**Keywords**—*electrical vehicle, charging station, public adoption.*

## I. INTRODUCTION

Despite new technologies being developed to reduce the harmful effects of greenhouse gas emissions from traditional energy sources on the environment and halt global warming, the transportation sector continues to account for a significant portion of these emissions [1-2]. Statistics show that until 2055, there will be a 77% increase in transportation-related emissions, which will have the consequence of expanding population and circulation [3]. The goal is to reduce emissions by 3% through 2030, despite the fact that the global transportation sector's average annual growth rate is 1.7%. Infrastructure requirements for low-carbon vehicle use, coupled with rules and financial incentives, are necessary for to reduce emissions by 3% [4]. Similarly, 15.3% of Turkey's 2020 total greenhouse gas emissions will be attributable to transportation-related emissions. Road transportation is responsible for 94.9% of greenhouse gas emissions in the transportation industry [5].

Many nations, including Canada, Mexico, France and Japan, have declared their intention to phase out internal combustion engines in order to meet their climate change goals [6]. By 2025, the Netherlands and Norway want to utilize only electric vehicles, followed by India in 2030, France in 2040 and England in 2030 [7]. As part of their efforts to meet climate change goals, various entities have expressed their intention to phase out internal combustion engines and exploring the utilization of alternative fuels can provide valuable insights into the potential attributes and

benefits of this transition [8]. By 2025, the Netherlands and Norway want to utilize only electric vehicles, followed by India in 2030, France in 2040 and England in 2030. To achieve this transition, there are still other elements [9]. Among the various factors, the primary considerations for achieving this transition include the widespread adoption of EVs and the establishment of accessible charging infrastructure, including stations and related facilities [10]. Future new customers, as well as economic and environmental benefits, can be generated by ensuring the long-term availability of EVs. Studies carried out in this area concentrate on topics including consumer behavior, EV legislation and the suitability of charging stations [11].

Turkey has made significant strides in recent years in increasing the use of electric vehicles and developing the required infrastructure and legislative guidelines for EVs. To study consumers' perceptions of EV stations, not enough studies have been done. This study's objectives are to examine the existing situation, investigate what has been done to raise societal consciousness through similar procedures in other nations and identify what must be done in Turkey to achieve these goals. A brief assessment of the analysis and evaluation techniques utilized in comparable social awareness research is also provided.

## II. PRACTICES OF SUCCESSFUL COUNTRIES IN EV ADAPTATION

Studies in the field reveal that socio-economic factors such as per capita income, population density, education level, urbanization rates, oil prices and renewable energy production are determinants of the electric vehicle market share. Consumer concerns, such as battery capacity and range, battery life and replacement cost, insufficient charging infrastructure, charging time, cost and infrastructure and high selling prices despite low operating costs, affect the adoption of EVs, as well as increasing urbanization, payment security and payment security. However, policies supporting e-mobilization as conveniences, tax reductions and incentives can increase the growth rate of the EV market [12].

Government policies are one of the primary elements in the adoption of EVs, even though many various applications for the transition and publication of EVs are evident in many different countries throughout the world. Governments can

lower the obstacles to EV adoption or increase their appeal [13-14]. This section describes the initiatives being taken in the top EV-using and EV-charging countries to adopt ecologically friendly electric vehicles.

Since 2015, Norway, a leader in the use of battery-powered EVs, has implemented significant incentive programs, like low tariffs on EV purchases. The primary inducements include free parking spaces and public amenities, tax reductions, emission obligations, vehicle scrap discounts, support for charging infrastructure, purchase assistance, insurance discounts and R&D assistance. In addition to them, the government collaborates and manages society and markets and it also arranges training to raise awareness of EVs [15]. Economic income is the most crucial component in EV adoption at the conclusion of the incentives remaining in place, according to studies for Norway. The incentive is modified over time. It has been found that ignorance is the main reason why senior people don't give up their habits and don't use EVs. Non-governmental organizations and EV businesses offer specific information because of senior citizens do not abandon their routines and do not use EVs [16].

The Netherlands has set the goal that all new cars sold by 2030 would be emission-free and is putting incentive programs into place to achieve this goal. These incentives are based on exemptions from taxes like value-added, road and registration taxes. The government also started an information, communication and innovation program. 10,000 charging station initiatives were initiated in 2009 through the government financial support program, through towns and businesses, in order to address the charging network and range problem, which is the major concern for EVs. This makes it the top nation in Europe for public charging stations in 2018 [17-18].

Beginning in 2009, China began to promote the purchase of electric vehicles by offering price support and tax benefits for their widespread adoption [19]. These incentive schemes were gradually sustained until 2022. Four key categories of national incentives have been used to promote the adoption of EVs: EV manufacturing, EV purchasing, EV consumption and EV infrastructure [20]. The "Energy Saving and Electric Vehicles" plan has resulted in the implementation of policy measures, including financial assistance for EV buyers, promotion of the construction of charging stations, education regarding the technological and performance characteristics of EVs and parking spots specifically designated for EVs [21].

India is one of the nations that is leading the EV vehicle adoption. In 2015 and 2019, a nationwide program for EV mass production and adoption was introduced. With these initiatives, it is hoped to develop a domestic EV ecosystem and install EV charging stations along major motorways [22]. EV use has surged as a result of the impact of the Ukraine-Russia crisis and government initiatives to promote rigorous emission standards, tax policies and incentives. But the lack of infrastructure and charging stations is the biggest obstacle to the adoption of EVs. In addition, there is a requirement for the creation of advanced billing management systems, qualified human resources and standards for technology utilization. It might be argued that solving these issues will give the nation new chances [23].

### III. IMPORTANCE OF AWARENESS IN EV ADAPTATION

Historical data on EV market share and 28 nations accounting for more than 96% of global EV sales volume show that EV use has grown quickly in China, Sweden, Germany, the Netherlands and France, as well as in New Zealand, Italy, Switzerland and Greece. It is reportedly slow. The adoption of incentives and infrastructure development plans has been successful in nations with high EV adaptation [24]. A conceptual analysis between technology, business and perceptual factors of EV adoption was conducted in the research that was done on data from thirty countries between 2011 and 2020: charging infrastructure and vehicle range were positively affected, while battery cost and electricity prices were negatively affected [25]. High EV costs are one obstacle to EV adoption, followed by a lack of charging infrastructure. The usage of EVs can be facilitated by the availability of electrical infrastructure and the growth of public and private charging stations. For the purchase of EVs, tax and financial advantages can be available. To build infrastructure for social adaptation and to comprehend the use of technology, however, it would be advantageous to offer outreach programs and skill centers to the general population [26].

To investigate the factors that influence the adoption of EVs, surveys and analyses are conducted. Thus, it is possible to comprehend how implemented incentives and policies can be renewed. According to a 2011 survey conducted in China to determine the level of awareness regarding alternative fuel vehicles such as EVs, most consumers are aware that EVs use alternative fuels and are environmentally friendly, but lack sufficient knowledge regarding the performance, maintenance cost and charging interval of EVs. In order to promote the growth of the EV industry, Zhang et al. [27] have been determined that consumers' awareness of EVs must be increased.

We investigated the current visibility levels of public EV charging infrastructure in Canada and the statistical significance of the relationship between consumer awareness of public charging infrastructure and interest in purchasing EVs. As a result of the sample and binary logistic regression analysis, it was determined that public charger awareness is not a significant factor in EV use and it was suggested that policymakers focus on public charging, home charging, vehicle subsidies and other financial supports [28].

In the study conducted in China and Korea, behavioral and psychological aspects of EV user satisfaction were examined. It has been observed that the primary EV preferences in China are based on environmental considerations, whereas in Korea, the factors are minimal cost and government support. It comes out that EV users should support policies that reduce operating costs and increase charging convenience [29].

Incentives for EVs might not produce the desired socioeconomic outcomes. Using mixed-effect regression in France, policy recommendations for the automotive industry, charging operators and local authorities were evaluated by analyzing socio-demographic, technical and economic factors influencing the adoption of electric vehicles [30]. Infrastructures for charging stations and electricity grids may be the most significant deterrents to the growth of EV use. A balance must be maintained between incentives and

infrastructure instruments. In a case study conducted using the dynamic game approach between EV charging stations and EV support policies, it was determined that the EV incentive program could not be supported by sufficient infrastructure [31]. In a similar study, an exploratory policy analysis with a multi-agent-based modeling approach was used to conclude that the adoption of electric vehicles (EVs) in European countries depends on three primary factors: social interaction, charging infrastructure availability and energy price [13].

#### IV. SITUATION IN TURKEY AND RECOMMENDATIONS FOR THE EV MARKET

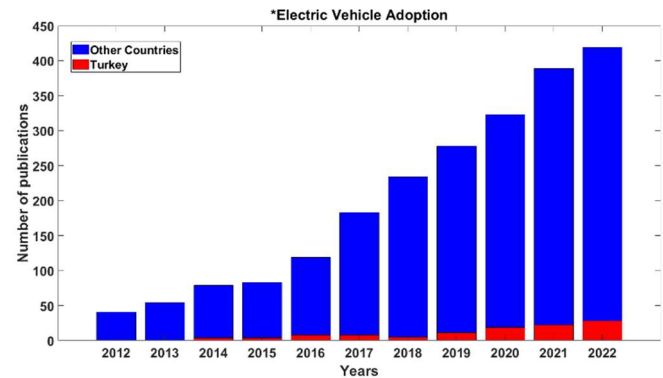
Turkey possesses a robust and dynamic automobile market. In the last decade, the typical number of automobile and light commercial vehicle sales has been around 800,000 [32]. There were 2,849 electric vehicles in 2021 and 8,210 in 2022 [33]. Domestic automobile production in the Turkish automotive sector began in 2018 with the establishment of EV by TOGG and production and sales began in 2022. For TOGG, Turkey's domestic and national vehicle, developed by Turkey's Automobile Enterprise Group, to make a good entry into the sector and ensure its permanence, technology that can compete with rival imported goods must be developed and protected. It is considered that TOGG has the potential to become an important player in the electric vehicle sector if consumer ethnocentrism is used as a positive motivation in marketing and supported by legal regulations and economic incentives [34].

In 2022, the legal regulation for EV charging services went into effect for the first time and with it came the issuance of EV charging operator licenses. In one year, there were 127 charging network license companies and the total number of charging points installed through this company exceeded 4,000. As a license requirement, the charging service regulation stipulates that at least 50 charging stations must be established in at least five distinct provinces. The goal is to increase the number of EV charging stations in this manner.

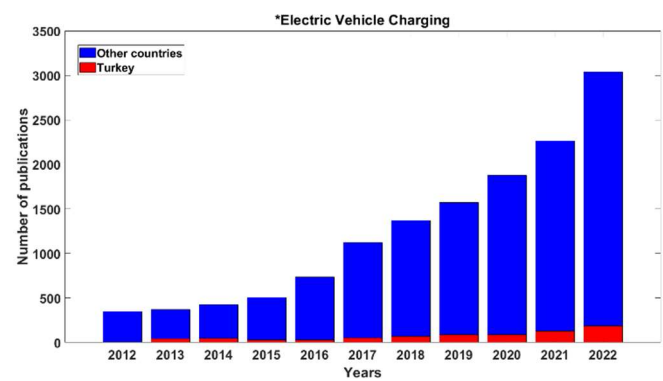
Since the implementation of EVs and EV charging stations in Turkey is still in its infancy, social awareness cannot be said to be sufficient. In a study involving nearly 300 participants, the variables of EV purchase intent, perceived price value and environmental concern were examined. In general, the desire to purchase EVs is strong and domestic EVs are preferred. However, since there is no utilization experience with EVs, no results have been obtained in terms of EV charging stations, technical infrastructure or incentives [35]. With the growth of the market and charging infrastructure, the impact of electric vehicles on power infrastructure is expected to increase. In this context, it has been explained that smart charging mechanisms will be crucial for capacity management and that precautions must be taken because regional distribution network problems may occur [36].

The adoption of electric vehicles (EVs), charging methods and technologies, charging infrastructures and other similar challenges are the subject of global studies and national analyses of proposed solutions. Using a database of journal citations, Fig. 1 presents the literature report on the adoption, charging and charging infrastructure of EVs in Turkey and other countries over the past decade. It is observed that there

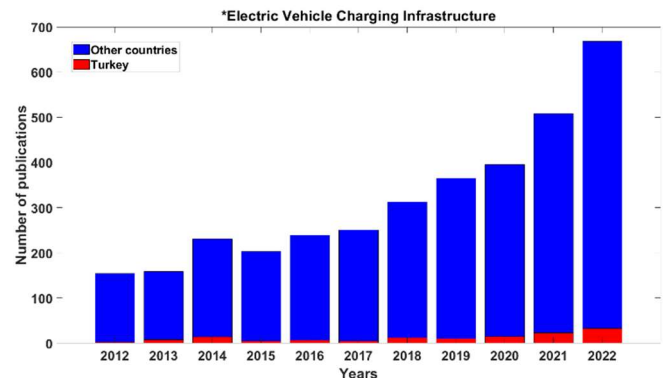
are a growing number of studies on three selected primary topics around the globe. In Turkey, on the other hand, it is possible to say that research in these three areas has begun within the last three years, dependent on the country's EV policies.



a.



b.



c.

Fig. 1 Published research articles during the last ten years: (a) EV adoption, (b) EV charging, (c) EV charging infrastructure.

In Turkey, the existence, awareness and social adaptation of EV use and EV charging stations are deemed insufficient. Considering countries like India, it can be said that developing an EV ecosystem by creating one's own vehicle is a beneficial policy. However, economic income and inadequate purchasing power may have mitigated the effect on EV adoption. However, with the introduction of EV vehicle technology and the development of charging stations, there is a need to train the human resources of the EV field to supply the sector with labor. At each service level, skill training and academic training can be developed for this purpose.

With the academic research to be conducted in the field, it will be possible to determine the factors influencing the intent, attitude and behavior of the Turkish populace regarding the purchase of electric vehicles. Using marketing communication tools that consider source-related variables (attention, understanding, persuasion and retention), message-related variables, buyer-related variables and environment-related variables, it is possible to increase the adoption rate of environmentally friendly electric vehicles.

When examining countries with advanced EV adaptation, government policies and support are the most decisive factor. All incentives used in other nations to encourage the publication of EVs may be harmonized for Turkey. There should be public education campaigns regarding EV charging stations and charging specifications. Primarily provincial and district central administrations, city planning sub-works and social responsibility projects can be executed for this purpose.

Nationally, action programs should be planned to increase the use of EVs over the medium and long term and essential legal arrangements should be made. With the deferral of regulations, it is anticipated that progress will slow down. Forecasting studies that can account for dynamic and changing conditions may be advantageous to conduct surveys to determine how programs will be accepted by society and to ensure that EV support policies and infrastructure requirements are compatible.

It is not difficult to anticipate that the automotive market will switch entirely to EVs over time and that cities, countries and even the entire planet will become interconnected and interdependent smart grid structures. To achieve this transformation in a manner that serves the good of societies, scientific, economic and political collaborations are required to make a holistic effort to prepare society for this transformation while maintaining rapid technological advancements.

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