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HAKEM KURULU

ELEKTRİKLİ OTOMOBİL SEGMENTİNDE TÜKETİCİ TALEBİNİ BELİRLEYEN DAVRANIŞLAR VE ELEKTRİKLİ ARAÇLAR İÇİN TÜKETİCİ TALEP TAHMİNİNİN MODELLENMESİ

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ÖZET

Küresel iklim değişikliği, dünya liderlerini kalıcı, sürdürülebilir enerji üretimi, enerjinin ekonomik tüketimi ve yenilenebilir enerji arayışına itmiştir. Ekonomik, sosyal ve çevresel sürdürülebilirliğe ulaşmak, enerjinin ekonomik olarak tüketilmesiyle mümkündür. Enerji yönetimi, ülke yönetiminin temelini oluşturur. Sürdürülebilir kalkınma hedefleri, ekonomik enerji politikasına odaklanmaktadır. Enerji, ülke refahında yaşam kalitesinin iyileştirilmesi, artan endüstriyel üretim, sağlık, temiz suya erişim, küresel iklim kriziyle mücadele ve tarımsal krizle mücadele için talep yönetimi gerektirir. Bu amaçla araştırmacılar, geleceğin enerji talebini karşılamak için enerji yönetimi, zaman serileri, regresyon ve ekonometri gibi geleneksel yöntemlerin yanı sıra bulanık mantık, genetik algoritma ve sinir ağları gibi yumuşak hesaplama tekniklerini de yaygın olarak kullanmaktadır. Destek vektör regresyonu, karınca kolonisi ve parçacık sürü optimizasyonu, enerji talep tahmini için benimsenen yeni tekniklerdir (Yılmaz Akdi, 2020). Bu çalışmanın amacı, iklim değişikliği nedeniyle ülkelerin karbon ayak izini en aza indireceği düşünülen ulaştırma sektöründe, elektrikli otomotiv sektörünün tüketici tarafından tercih edilme davranışını belirlemek ve tüketici talep tahminini belirleyen bir model ortaya koymaktır. Araştırma yöntemi nitel olup, talebi etkileyen faktörler, literatürde elektrikli araç talebini etkileyen faktörler üzerine çalışma yapmış araştırmacıların araştırmaları incelenerek ele alınmıştır.

Anahtar Kelimeler: Küresel İklim Değişikliği, Sürdürülebilirlik, Elektrikli Otomotiv Sektörü, Talep Tahminleri

BEHAVIORS DETERMINING CONSUMER DEMAND IN THE ELECTRIC CAR SEGMENT AND MODELING OF CONSUMER DEMAND FORECAST FOR ELECTRIC VEHICLES

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ABSTRACT

Global climate change has pushed world leaders to seek permanent, sustainable energy production, economical consumption of energy and renewable energy. Achieving economic, social and environmental sustainability is possible by consuming energy economically. Energy management forms the basis of country management. Sustainable development goals focus on economic energy policy. Energy requires demand management in order to improve the quality of life in the country's welfare, increasing industrial production, health, access to clean water, coping with the global climate crisis, and combating the agricultural crisis. For this purpose, researchers widely use soft computing techniques such as fuzzy logic, genetic algorithm and neural networks, as well as traditional methods such as energy management, time series to meet the energy demand of the future, regression and econometrics. Support vector regression, ant colony and particle swarm optimization are new techniques adopted for energy demand prediction (Yılmaz Akdi, 2020). The aim of this study is to determine the preference behaviour of the electric automotive sector by the consumer in the transportation sector, which is thought to minimize the carbon footprint of countries due to crucible climate change, and to reveal a model that determines consumer demand forecast.

The research method was qualitative, and the factors influencing demand were examined by reviewing the research of researchers who have studied the factors affecting electric vehicle demand in the literature.

Key Words: *Global Climate Change, Sustainable, Electric Automotive Sector, Demand Forecasts*

1. INTRODUCTION

The main reason influencing the demand for electric vehicles is not only the low cost of meeting the increasing energy demand due to global climate change, but also many cultural, economic, and psychological factors. Besides minimizing carbon footprint and fulfilling the requirements of the Paris Agreement and the Kyoto Protocol, psychological and social trends are driving individuals to use electric vehicles. Although electric vehicle owners are approached cautiously in many countries due to problems experienced by electric vehicle owners because of limited charging services and lengthy charging processes, their numbers are increasing every day worldwide and they are presented as an alternative in the fight against environmental pollution. This research employs a qualitative research method, specifically a literature review. The study investigates the history of electric vehicles and the main reasons influencing their demand. Demand forecasting is -included to academic research. Moral motives can cause individuals to exhibit the same behavior as rational motives. Despite efforts to reduce environmental pollution, and although the environmental impact of automobiles has been mitigated through technological innovations (e.g., more efficient engines, hybrid fuel systems, and fuel cell technology), various trends such as increasing car ownership and frequency of car use tend to negate this positive impact. Studies on forecasting in international trade and businesses focus on demand forecasts. It should be remembered that it is important in their forecasts for the estimates of economic indicators such as profit income, cost of future, continuity, inflation, inflation and state debt. Today, where technological progress has increased rapidly, estimates about the developments in technology have gained value. Predicting future events is called forecasting. This prediction can be made by mathematical analysis of previous data and sometimes by subjective methods. Estimation can be done by many methods. There is a separate method for estimating for each product. Sales made in previous years determine the sales rates of future years. There are very important contributions of demand forecasting for the business. These are:

1. Demand forecasting allows you to manage inventory management. It increases efficiency and reduces costs. It reduces waste, waste means lower costs and higher profits.
2. Demand forecasting provides production planning.
3. It improves supply chain management. A good demand forecast gives your team the method needed for the best supply chain.
4. It strengthens your financial position. Your ability to predict demand forecasts, cash flow, revenue and overall financial health also improves.

5. It provides greater awareness of risks and opportunities. It allows you to recognize risk earlier than other businesses.

Making predictions about future events is a science and an art. It is also a guess that experienced leaders guide qualitative forecasts. From a scientific perspective, using quantitative data, past and present information in various sectors and mathematical analysis. Making predictions with models is a scientific study. The forecasting technique in warehouse and stock, economy, finance, temperature, marketing and personnel planning increases the profits of businesses. Prediction is obtained in past time periods regarding a variable. It can be defined as determining what will happen to the data obtained in the future (Türksay, 1995) .

While the studies on electric vehicle battery demands in the international literature were investigated with the forecast model, historical traffic data and weather data were used. The forecast processes include a cluster analysis to classify traffic patterns, a relational analysis to determine the effective factors, and a decision tree model to create classification criteria. The charging demand of electric vehicles shows different charging load profiles on weekdays and weekends in summer and winter. In the forecast model, the charging demand of electric vehicles changes according to traffic data and weather data. Sustainability, particularly in the context of climate change and global warming, has made the efficient and effective use of scarce resources imperative. Sustainability is a key reason why the logistics sector, which is constantly exposed to carbon emissions, is opting for electric vehicles to improve the economy and ensure the survival of countries. The adoption of electric vehicles, considered a solution to improve transportation against carbon emissions leading to global climate change, has become widespread.

A study on CO2 Emission Management Measurement Devices (CEMG) proposes an innovative theoretical model based on Task-Technology Fit, Technology Adoption, and Planned Behavior Theory to understand the key factors that can encourage electric vehicle adoption; a quantitative study conducted in a Southern European country showed that technological innovations inform consumers about emissions and influence their intention to adopt electric vehicles. Using CEMG devices in urban areas and integrating them with smart city algorithms will provide the necessary information to better manage the city's air quality and traffic. Collecting and presenting CO2 emission information to citizens in public spaces

Carbon dioxide (CO2) is the main greenhouse gas, and about one-fifth of it originates from road transport (Lamb, W.F.; et al. 2021).

2. LITERATURE REVIEW

Energy-saving behavior can lead to financial savings. Moral motives can conflict with rational motives. For example, in 2016 in Germany, the total cost of ownership of an electric car for the average household was higher than that of a car with an internal combustion engine (Plötz, Schneider, Globisch, and Dütschke, 2014). In the face of climate change, the two types of motives are not necessarily mutually exclusive (Stern, 2011) – for example, conserving natural resources, preventing economic crises, and engaging in energy-saving behavior are not conflicting motives. Previous research shows the importance of both rational and normative motives in the context of energy-related investment decisions in households. Numerous studies, focusing on rational adoption motives, highlight the importance of individuals' financial and technological evaluations of electric vehicles (see reviews Axsen and Sovacool, 2019; Biresselioglu et al., 2018; Li et al., 2017; Liao et al., 2017; Rezvani et al., 2015). Research that delves deeper into the role of norm-based motives is far less common (Kastner and Bobeth, 2018; Rezvani et al., 2018). These studies suggest that moral and social motives also play at least some role in this decision-making context. However, the extent to which different types of motives influence electric vehicle adoption and how these motives interact—whether they mutually reinforce or interfere with each other—remains unclear. In environmental psychology, there has been a long-standing debate about whether moral motivations are weakened by other motivations (e.g., rational motivations) in the context of behaviors requiring high financial costs and/or high amounts of effort (Diekmann and Preisendörfer, 1998).

Steg's (2005) study on different motivations for the adoption of electric vehicles has explored this issue in depth (Burghard and Dütschke, 2019; Noppers et al., 2014; Rezvani et al., 2018; Schuitema et al., 2013). These studies show that norm-oriented motives have a relatively equal impact on adoption intention as rational motives, and that the two types of motives are highly correlated. However, further research is needed to confirm these findings and further clarify the interaction between different types of motives. Action patterns related to the act of purchasing an electric vehicle are a particularly suitable approach for systematically investigating the importance and interaction of motives (Klöckner, 2015).

Wong et al., (1997) in their study examining scientific articles published between 1988 and 1995 on artificial neural networks applications through a survey; It has been determined that artificial neural networks applications are increasingly used in business activities. According to the research results; It has been stated that artificial neural networks quickly adapt to existing or developing new technologies, and innovations in artificial intelligence technologies and computer-based systems create new opportunities for the use of neural networks technology in business research. To date, the need to continue to invest in business models based on renewable energy sources is highly acknowledged by both practitioners and academics Augenstein K (2015), Manjon MJ, Merino A, Cairns I (2022) , Muñoz-Torres MJ, Fernández-Izquierdo MÁ, Rivera-Lirio JM, Escrig-Olmedo E (2019), Nußholz JL, Rasmussen FN, Milios L (2019) , Peralta A, Carrillo-Hermosilla J, Crecente F (2019) , Reinhardt R, Christodoulou I, Gassó-Domingo S, García BA (2019), Sarasini S, Linder M (2018) .

Electric vehicles are effective in reducing gas emissions and environmental problems as a solution-oriented alternative for reducing CO_2. The adoption of electric vehicles is widely accepted as a solution to reduce the environmental impact of transportation. Various technological, behavioral and economic factors are needed for its widespread adoption (Zuo, Z., Niu, Y., Li, J., Fu, H., & Zhou, M. 2024).

A study by Tiara Nur Anisah, Nadia, Kartinah, and Andika identified the roles of government incentives, consumer demand, and environmental concerns influencing the intention to purchase electric vehicles (EVs) in Indonesia. In a quantitative study using PLS-SEM analysis of a survey of 180 consumers, the results showed that financial incentives had a significant impact on intention to purchase (IT), driving actual purchase behavior (PB), while environmental concerns (EC) facilitated the transition from intention to actual purchase. Policymakers and industry stakeholders should leverage future research to monitor developments based on consumer behavior trends in the development of sustainable transportation strategies. Furthermore, cultural influences and technological innovation trends also appear to play an influential role in electric vehicle selection.

Electric cars can contribute to sustainability, but their adoption rate is not at the desired level in many countries. A study conducted by Bobeth and Ingo Kastner (2020), examined the motivations behind Germans choosing electric cars from an environmental psychology perspective. Table 1 shows the studies on identifying factors ınfluencing electric vehicle preferences (2015–2022).

Table 1: Study Findings Identifying Factors Influencing Electric Vehicle Preferences (2015–2022)

Author(s)	Year	
Ahmadi et al.	2015	Socio-economic factors
Helveston et al.	2015	Government subsidy support
Nichols, Kockelman & Reiter	2015	Air quality indices
Lebeau, Macharis & Van Mierlo	2016	Battery charging and charging infrastructure
Junguera et al.	2016	Consumers' charging time and vehicle price perceptions
Jansson et al.	2017	Consumers' self-awareness, interpersonal interaction, and attitudinal factors
She et al.	2017	Safety, reliability, and battery range
Huang & Qian	2018	Psychological consumer factors such as vehicle ownership status symbols and risk aversion
Abotalebi et al.	2019	Purchase price, financial incentives, and charging infrastructure
Carley et al.	2019	Technology
Chu et al.	2019	Minimized operational costs and user satisfaction
Featherman et al.	2021	Consumer perceived benefit and willingness to adopt new technologies
Chhikara	2021	R&D investments supported by financial and non-financial government benefits
Dong	2022	Transparent policies with high adaptability
Srivastava et al.	2022	Recommendations from government bodies
Almansour	2022	Sustainability perspective motivation
Plananska & Gamma	2022	Service charging commitments
Shakeel	2022	Cognitive consumer behavior related to solar energy adaptation
Ruoso & Ribeiro	2022	Socio-economic factors

Source: Adapted from Bryła, Chatterjee, and Ciabiada-Bryła (2023).

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The study found that new technological demands, public perception of them as trends, purchase price, and the difficulty of obtaining electric charging were among the reasons for limited adoption. The study focused on psychological factors influencing demand for electric vehicles, emphasizing the importance of rational motivations (moral and social norms). An online survey was conducted with 220 Germans who wanted to buy a new car. Three action models determining adoption intention were tested:

An adjusted technology acceptance model (TAM), an adjusted norm activation model (NAM), and an integrative model containing predictors from both models. The hypothesized models were analysed in detail using path analysis. The research results strongly suggest that moral and social motivations play a significant role in household investment decisions, and that expanding political support programs such as information and image campaigns is a way to more effectively promote the adoption of electric cars. The perceived benefit of technology is a rational motivation. If household members are informed about a technology at the beginning of its diffusion process, it can have a positive impact on their future choices.

In the research conducted by Birdal, the effect of the number of electric vehicles on annual electricity consumption was examined using machine learning methods. Gradient Boosting, K-Nearest Neighbors, Extra Trees Regressor, Bayesian Ridge, and Flexible Network models were applied, and the models were evaluated with metrics such as MME (Mean Absolute Error), ROSM (Root Mean Square Error), and R^2 (Coefficient of Determination). According to the results obtained, the most successful model was the K-Nearest Neighbor Regressor. In the research conducted by Birdal, the effect of the number of electric vehicles on annual electricity consumption was examined using machine learning methods. Using data from 2004-2022, Gradient Boosting Method, K-Nearest Neighbor Algorithm, Extra Trees, Bayesian Ridge and Flexible Network models were applied for electricity consumption estimation. The models were evaluated with metrics such as MME (Mean Absolute Error), ROSS (Root Mean Square Error) and R^2 (Coefficient of Determination). According to the results obtained, the most successful model was the K-Nearest Neighbor Regressor. The K-Nearest Neighbor Algorithm model achieved the highest accuracy with a KNC = 17,186, KNC = 21,003, and R^2 = 0.81. The Stepwise Increment and Extra Trees models produced KNC values of 24,283 and 22,965, respectively. The Bayesian Ridge model showed insufficient performance with an R^2 score of -0.04, meaning the model could not successfully learn the relationships in the dataset. The Flexible Network model showed a moderate level of success with KNC = 33,064 and R^2 = 0.52.

In their study, Abdellatief et al. (2024) attempted to forecast car sales for Egypt's largest automobile manufacturing company. The independent variables were unit sales price, inflation rate, per capita income, fuel price, and previous sales. The study utilized ANN, adaptive neuro-fuzzy inference system (ANFIS), and multiple linear regression. The results showed that the ANN method yielded better results compared to other methods.

In Ak Kayış's (2023) study, the aim was to forecast demand for an automotive company. For the analysis, exponential smoothing, seasonal decomposition, ARIMA, random forest, ANN, support vector regression, and sequential minimal optimization regression methods were used. The study concluded that the random forest method showed the best performance (p 36).

Han, Sönmez, Avcı, Aladağ (2022) aimed to estimate the number of new car sales in Turkey using the ANN method and Holt Winters' method, an exponential smoothing technique. The independent variables of the study are the exchange rate, consumer confidence index, gross domestic product, and real sector confidence index; the dependent variable is the number of car sales. Using monthly data from 2015-2020, they attempted to estimate new car sales for the years 2019-2020. As a result of the study, it was determined that the ANN method gave more accurate results than Holt Winters' method.

Akyıldız (2004) stated that demand forecasting can be used by customers in the future. He says that it is an activity that requires determining the quantity and amount of goods or services that will be needed, and that it ensures that both marketing, production and logistics functions are carried out effectively. In addition, demand forecasts are to marketing in determining demands, promotional strategies and sales force size; production planning; He stated that it ensures increased efficiency by providing guidance to logistics on where and in what quantities the products should be stored and to which regions they should be transported according to the demand structure. If a long-term trend in demand is expected, a longer-term forecast is necessary. Demand values for some products decrease or increase depending on the seasons. In such cases, seasonal fluctuations in demand (Sevgi & Şahin, 2017).

Demand forecasts are generally made over four periods. These periods are as follows: (Tekin, 1996). Very short-term forecasts: There may be daily and weekly forecasts. They can be done for the purpose of spare parts control, stock control, re-ordering, and preparation of work schedules. Short-term forecasts, forecasts ranging from 1 week to 6 months. Medium-term forecasts, forecasts made for periods ranging from 6 months to 5 years. Long-term forecasts, these are forecasts made for a period of 5 years or longer.

3. DEMAND FORECASTING METHODS

Demand Forecasting Methods can be examined in 3 main groups: qualitative, quantitative and artificial intelligence-based forecasting methods.

Qualitative prediction is made based on subjective opinions. We can make quantitative methods with mathematical operations. Predictions about complex structures are made with artificial intelligence methods.

a.Qualitative Demand Forecasting Methods

Also called “subjective” or “criterion decision-based” techniques, use primarily human capacity to make predictions and generalizations. In qualitative forecasting, an individual makes a personal guess. This method of prediction is not used in scientific methods.

b. Quantitative Methods: Make mathematical predictions about the future using past data.

Calculations are made through transactions. To make predictions in quantitative techniques, past information must be obtainable and mathematically measurable.

c.Artificial Intelligence Based Methods

The ability to store uncertain information in computer memory with computers and robots enables predictions to be made with artificial intelligence, it is possible.

D. Measuring Demand Forecast Accuracy

No matter what method is used, there is no 100% accurate prediction. It is necessary to accept a certain error rate from the beginning. There are many criteria to evaluate the effectiveness of the forecasting method available. The accuracy of the forecast method is measured by analyzing the forecast errors. Prediction error is the difference between the true observed value and the predicted value.

We can list the generally used forecasting methods as follows (Akar & Uğurlu, 2005)

1. Time series analysis,

2. End user model,

3. Estimation with average increase percentages,

4. Econometric models,

5. Regression analysis,

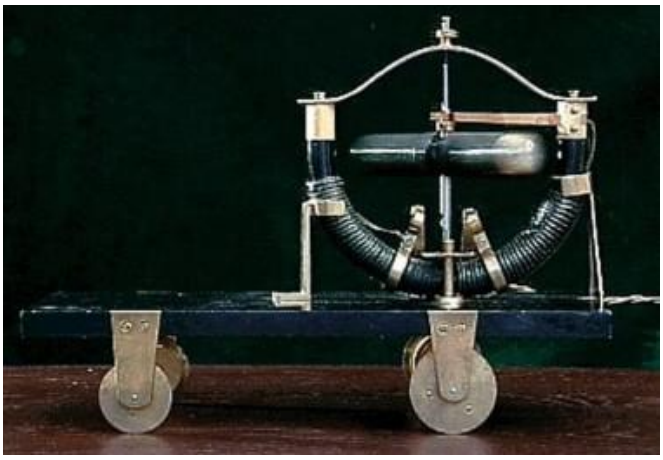
6. Artificial neural networks (ANN) (Bahar, 2019),

When making electric car charger estimates, weather and traffic road estimates should be considered. In the research conducted by, South Korea's historical traffic data and weather data were used in electric car demand estimates. It includes a cluster analysis to classify traffic patterns, relational analysis to determine effective factors, and a decision tree for classification criteria while making the estimate.

4. ELECTRIC CAR

The history of electrical cars was started with electrical machines. In 1827 the Hungarian Benedictine monk Ányos Jedlik built the first rudimentary but working d.c. electrical machine. After one year Jedlik drived a simple small-scaled car model (see Fig. 1, Guarnieri, '2012).

Fig. 1 The Electric Car Model Built By Á. Jedlik İn 1828



Source: (Sabonnadière J.-C., 2009)

Another small-scale electric cell supplied electrical was built in 1835 by Sibrandus Stratingh, (Guarnieri, '2012). Small scale electric car model developed by S. Stratingh in 1835 (H. Scheer, 2007). Scotsman Robert Anderson is the inventor of the first full-scale electricity driven carriage. His prototype was built sometime from 1832 to 1839 in Aberdeen It used primary cells (non-rechargeable batteries) to generate electrical power and had a maximum speed of 12 km/h. Scotsman, Robert Davidson, also of Aberdeen, developed the first electric locomotive in 1837. In 1851 Charles Grafton Page, a senior examiner for the U.S. Patent (Văscan , 2022). After the failures of Peugeot/Citroen in electric cars in the 1990s and Audi's Duo in 1997, Toyota in the hybrid electric engine in the 2000s, the California Air Resources

Board experimented in the electric or hybrid electric vehicle market. hybrid-electric engines are new in the automotive industry. Manufacturers who want to offer innovative supply in response to consumer demands have gained momentum and are focusing on R&D studies to prepare for the discovery of innovations that will give them an advantage over their competitors.

Studies on the production of electrolyte and cathode materials have begun, and at least 100 new gigafactory facilities have begun to be built in automotive production regions in Asia, Europe and North America. It is thought that even these studies do not have sufficient battery factory capacity to meet the demand for electric cars and trucks.

Demand production growth for lithium-ion batteries is leading to the emergence of startup EV battery suppliers such as Northvolt, Farasis, SVOLT, as well as major battery cell suppliers such as LG Chem, SK Innovation, CALT and Panasonic in the supply chain. OEMs such as Volkswagen Group, General Motors, Stellantis and Ford are placing increasing demands on lithium mining and gigafactory operations with Tesla and Panasonic joint venture lithium battery production models. (Daniel Harrison, 2021)

Electric road vehicles are a promising strategy to reduce CO2 emissions and air pollutants (Stephanie Heitel, 2020). According to the Automotive Sectoral Outlook report prepared by KPMG Turkey, the global automotive market in 2022 reached 2021 numbers with 66.2 million new vehicle registrations, due to the increase in sales in the last quarter of the year. While approximately 85 million motor vehicles were produced in the world in 2022, the number of motor vehicles sold was 81.6 million. In the European region, new passenger vehicle registrations decreased by 10.4 percent on an annual basis in 2022. Problems in semiconductor supply and the ongoing Russia-Ukraine war came to the fore among the factors effective in this development. Passenger vehicle production in the European Union increased by 7.1 percent in 2022 compared to the previous year. On the other hand, the decrease in production in Russia and Ukraine by 67.4 percent and 79.7 percent, respectively, in the same period caused production across Europe to decrease by 1.6 percent on an annual basis in 2022 (KPMG, 2023).

Potential estimates of consumers for electric A-segment cars by years, consumer demands according to economic, social and political events are estimated with a discrete choice model by classifying the basic characteristics of the automotive, and consumer evaluations of the product are estimated using the estimated coefficients. Separate coefficients can be estimated for everyone from the sorted individual data prepared for this purpose in the doctrine.

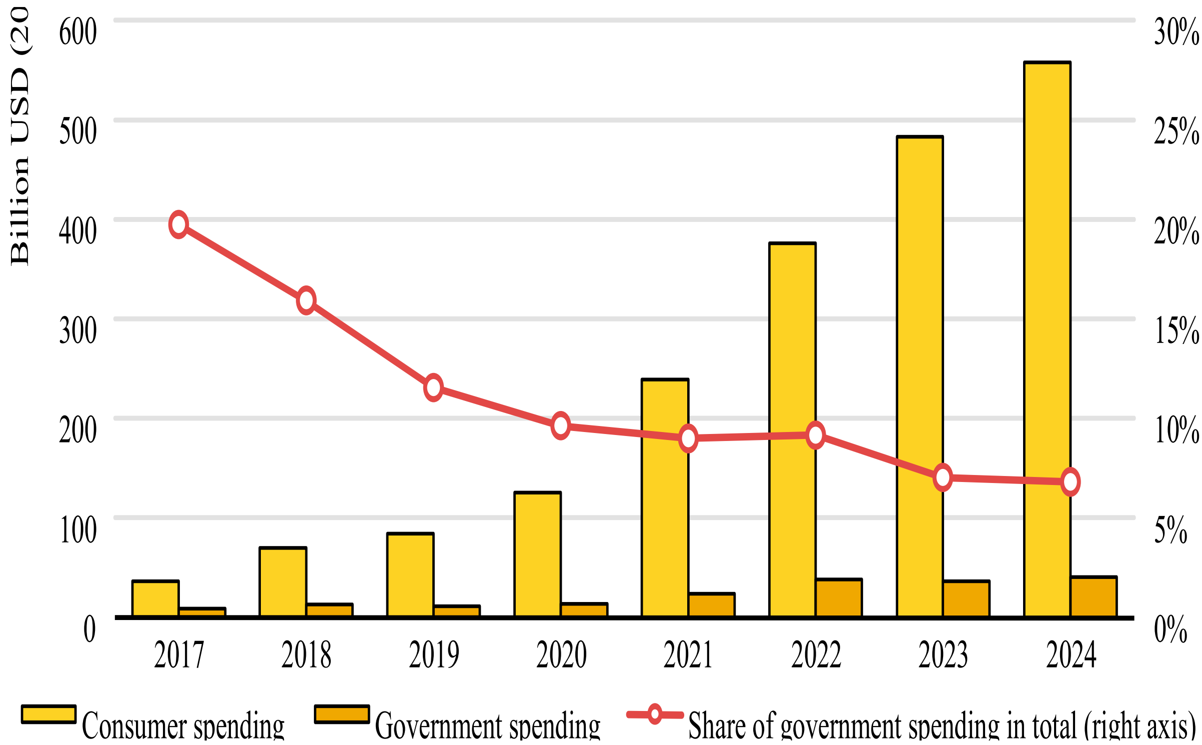
The automotive market capacity utilization rate in Turkey increased by 7 percent compared to 2021, with the support of the base effect in 2022, reaching 70%. According to the report, which states that the effects of the global chip crisis, Covid 19 epidemic and the Russia-Ukraine war continue in the automotive industry, the demand for production made it difficult to meet. In Turkey, 1.3 million vehicles were produced, and 827 thousand vehicles were sold in 2022. In 2021, 1.2 million vehicles were produced, and 773 thousand vehicles were sold. In Turkey, 970 thousand vehicles were exported in 2022, while 454 thousand were imported.

In 2023, automotive exports increased by 15% in Dollar terms and 16% in Euro terms. In 2023, total automotive exports will reach 17.7 billion dollars, and automobile exports increased by 20%, reaching 5.4 billion dollars. In euro terms, automobile exports increased by 16% and reached 4.9 billion euros. According to 2023 year-end estimates, total automotive exports are estimated to be 34 billion dollars.

The pandemic, which spread in China and affected the whole world, has changed the demands in the automotive industry, as in all sectors, supply problems, chip crisis, digitalization, the emergence of new markets, automation in production processes, artificial intelligence technology, internet of things, innovative smart mobility alternatives, increased competition, The compelling driving force of the demands for the automotive industry working with renewable energy sources has caused the automotive industry to enter a process of change and transformation.

In the report (2022), which also includes the 23rd Global Automotive Executives Survey published by KPMG, a research firm, executives say that they will make higher profits in the next 5 years compared to 53% in 2021. It is stated that they see macroeconomic developments such as smart automation and digitalization, autonomous vehicles, IoT (internet of things) supported parts, great demand, finding qualified human resources, raw material supply, high inflation as important risk factors. However, regarding profitable growth in the long term, 83 percent of sector managers state that high profits will be achieved in the sector in the next five years. Since the 2000s, hybrid electric vehicles have been an important research topic in the R&D studies of the automotive industry. Competition in the automobile market that runs on electric motors, which are offered instead of internal combustion engines that have been on the market for more than 100 years, is increasing day by day. Meeting the demand, innovative engines are a solution to global warming with renewable energy. It is requested to be. Hybrid electric motors have now been sold 1.5 million times worldwide. As electric car sales have grown over the past decade, government spending per vehicle, in the form of purchase subsidies and tax incentives, has steadily declined – a trend that accelerated in 2022 as subsidies were phased out. In 2024, government spending accounted for less than 7% of total spending on electric cars globally, compared to 20% in 2017. In absolute terms, annual government spending on electric cars has hovered around the USD 38 billion mark since 2022. At the same time, total consumer spending on electric cars globally has grown continuously to reach USD 560 billion in 2024. Chart 1 shows global consumer and government spending on electric cars, 2017-2024.

Chart 1: Global Consumer And Government Spending On Electric Cars, 2017-2024



Sources: IEA analysis based on EV Volumes and national policy documents. https://iea.blob.core.windows.net/assets/7ea38b60-3033-42a6-9589-71134f4229f4/GlobalEVOutlook2025.pdf

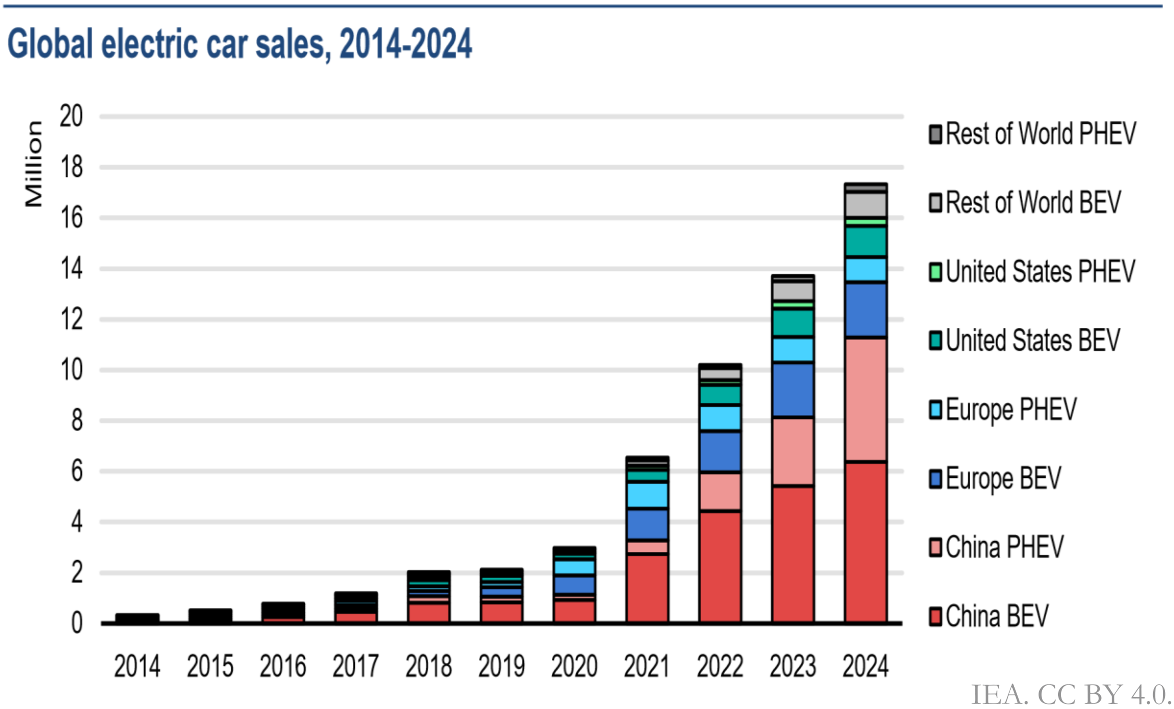
In 2023, digitalization, sustainability, autonomous vehicles, mobility as a service, and increased demand for electric vehicles are expected in the sector. Technology companies plan to manage long-term profitability, renewable energy, digitalization and sustainability trends in the global sector and customer demands in the automotive sector. The demand for new cars depends on the structure of the car fleet, i.e. scrapped and exported cars, the development of population, any further increase in income/GDP, andregional car density (M, Sparka, & Friedrich, 2013).

The Electric Vehicle Demand Forecast 2024 Report, prepared by the Electric Vehicle Initiative (EVI), examines global electric vehicle forecast statistics and policy measures by investigating trends in the adoption of electric vehicles, the factors determining them, the demand for their batteries, charging infrastructure, policy developments and industry strategies, the affordability of electric vehicles, the production and trade of their batteries, and new trends in the market until 2030.

The high cost of renewable energy sources, the difficulty in storing energy and the limited renewable energy infrastructure prevent the widespread use of renewable energy in the world. The increasing awareness of global warming and environmental issues, and the developments in energy production and transmission technologies, it is expected that the demand for renewable energy sources will increase further in the coming years. In 2024, global electric vehicle sales exceeded 17 million, reaching a market share of over 20%. Even the 3.5 million additional electric vehicles sold in 2024 surpassed the total number of electric vehicles sold worldwide in 2020.

In 2024, global electric vehicle sales exceeded 17 million, reaching a market share of over 20%. Even the 3.5 million additional electric vehicles sold in 2024 surpassed the total number of electric vehicles sold worldwide in 2020. China maintained its lead; In 2024, electric vehicles accounted for almost half of all car sales. Over 11 million electric vehicles were sold in China last year, exceeding global sales just two years prior. As a result of continued strong growth, one in every 10 cars on Chinese roads is now electric. In Europe, sales slowed in 2024 due to reduced subsidy programs and other supportive policies, but the share of electric vehicles remained around 20% as stronger sales in some countries offset lower sales in others. According to the report, electric vehicle sales in the United States increased by approximately 10% year-on-year. In Asia and Latin America, electric vehicle sales increased by over 60% in 2024. Sales shares rose in Thailand and Vietnam. In Brazil, electric vehicle sales more than doubled in 2024, reaching 125,000. Sales also more than doubled in Africa, with increased sales in Egypt and Morocco fueling demand. Relatively affordable electric vehicle imports from China accounted for 75% of the market share. China, Europe, and emerging economies are leading the growth in electric vehicle sales. Global electric vehicle sales are expected to exceed 20 million by 2025, representing more than a quarter of all cars sold worldwide. China's incentives for replacing older vehicles have lowered electric vehicle prices, and this decline is projected to reach 60% of car sales in the country by 2025. The introduction of emission standards by the European Union and the United Kingdom has also boosted zero-emission vehicle sales by 2025. In Europe, a 25% share of electric vehicle sales is projected for 2025 to meet the emission reduction target. The goal is to reach 40% of electric vehicle sales by 2030 https://www.iea.org/reports/global-ev-outlook-2025/executive-summary. Significantly, outside of these three major markets, there was a record increase in sales of nearly 40% to reach 1.3 million, closing in on the United States' sales of 1.6 million electric cars.

Chart 2: Global Electric Car Sales Between 2014-2024 Years

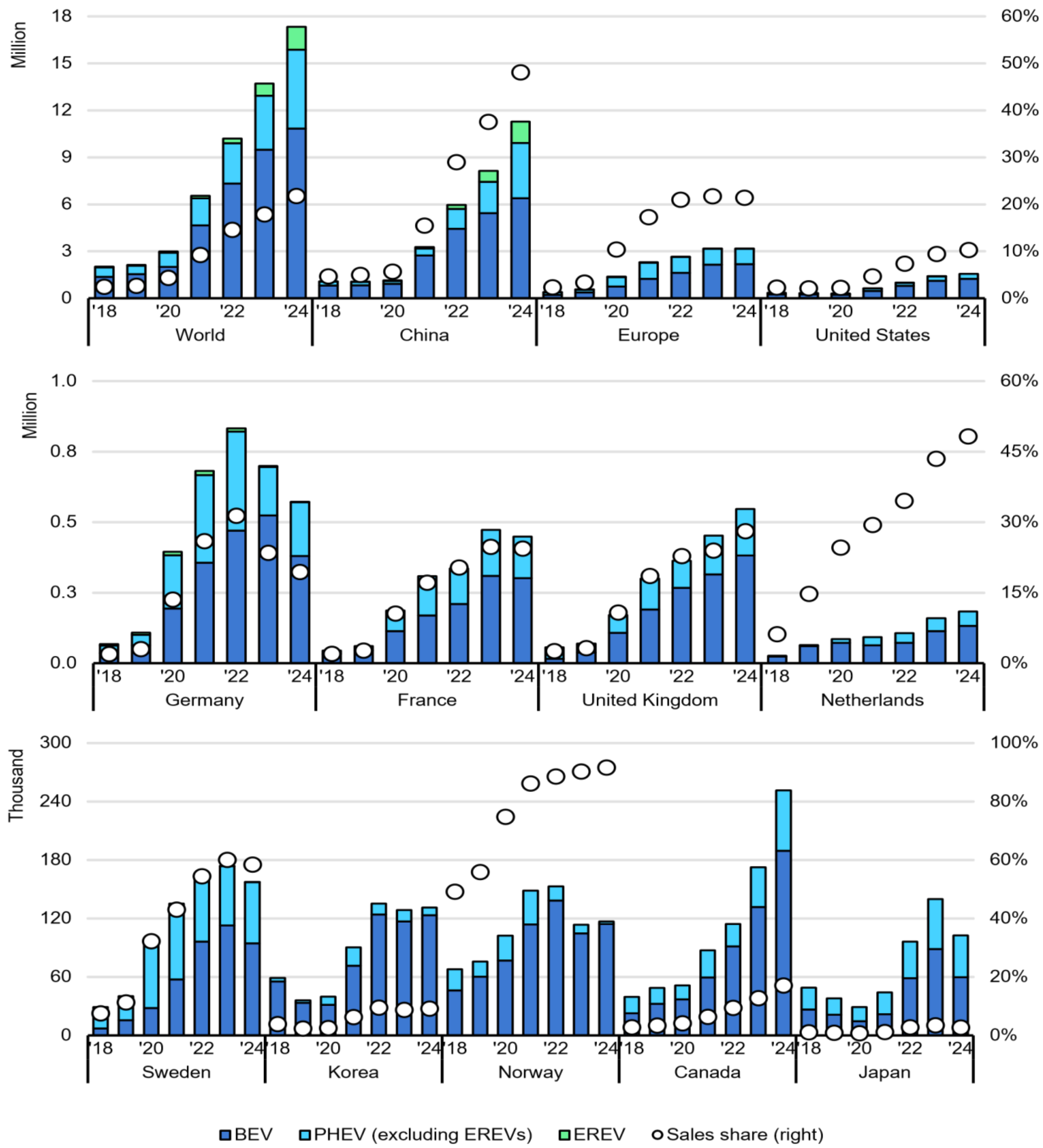


Sources: IEA analysis based on country submissions and data from the European Automobile Manufacturers Association (ACEA), European Alternative Fuels Observatory (EAFO), EV Volumes and Marklines.

Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid vehicle. Includes new passenger cars only.

A modification to the US Clean Vehicle Tax Credit at the start of 2024 enabled buyers to receive an instant discount (up to USD 7 500 for a new electric car and USD 4 000 for a used electric car) at the point of sale, which may have served to entice interested buyers. However, not all electric cars were eligible for the credit: in 2024 about 20 electric models (not accounting for different trim levels) out of a total 110 were eligible, which translated to over half of US electric car sales. The real share that benefitted from the tax credit may be even higher. In 2023, provisions were introduced on leased electric cars to reclassify them as commercial vehicles, thereby making them eligible for the tax credit without having to meet requirements on local manufacturing. As a result, by 2024, nearly half of all EVs sold were leased, more than double the share seen 3 years earlier. In addition to the federal tax credit, in 2024, 27 states offered additional incentives, rebates and exemptions promoting electric car adoption.

Chart 3: Electric Car Registrations And Sales Share İn Selected Countries And Regions, 2018-2024



Sources: IEA analysis based on country submissions and data from ACEA, EAFO, EV Volumes and Marklines.

Sources: BEV = battery electric vehicle; PHEV = plug-in hybrid vehicle, EREV = extended-range electric vehicle.

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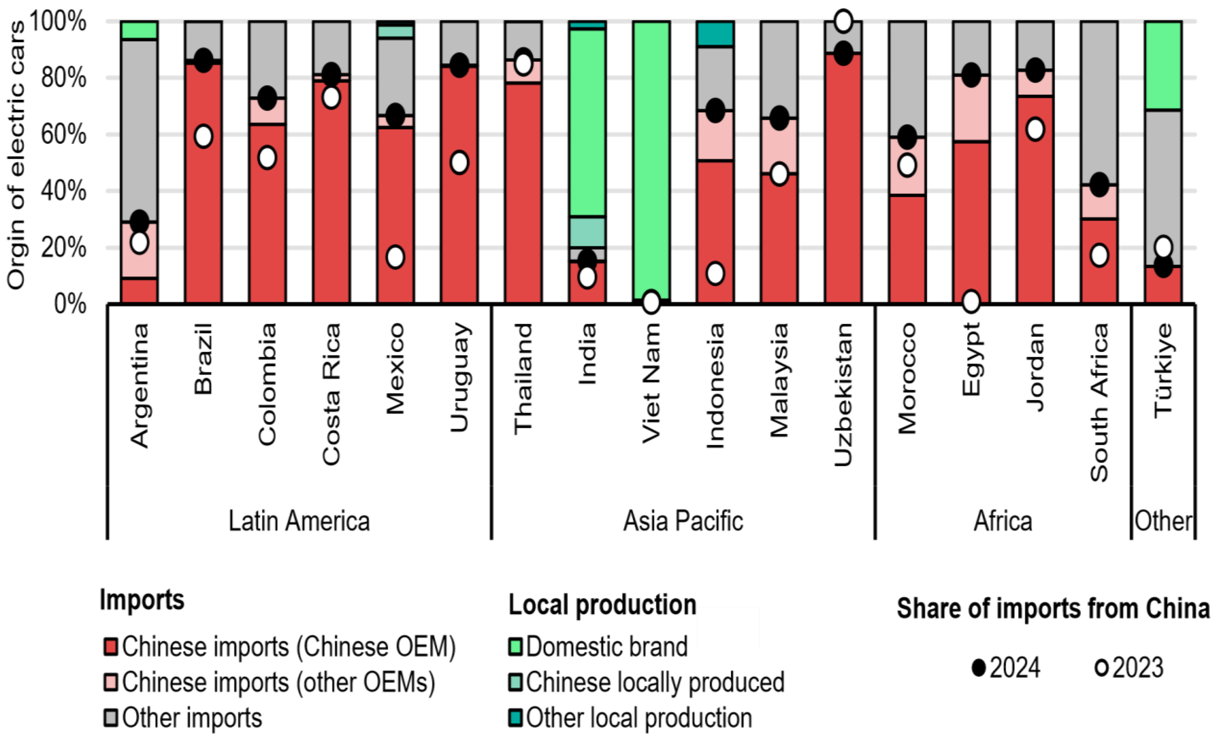
Türkiye continues to deploy the domestically produced Togg electric cars, increasing its total production by 50% year-on-year. The increase in domestic production and in imports resulted in the country reaching an electric sales share of 10% in 2024. In July 2024, the Turkish government announced a USD 5 billion package to boost its annual production to 1 million electric cars per year.

India's electric car market is predominantly supplied by Indian OEM Tata. In addition, at the end of 2023, Indian steelmaker JSW signed a joint venture with SAIC Motor, a Chinese OEM, to work together on car production under the name MG Motor. In 2024, the joint venture produced about half of its electric cars sold in India domestically, while the other half were imported from China. At the end of 2024, JSW also announced the launch of its own EV brand, and is in talks with partners such as BYD and Geely regarding collaboration on technology transfer.

Chart 4: Origin Of Electric Cars Sold İn Selected Markets, 2024, And Share Of Total İmports From China, 2023 And 2024



Sources: IEA analysis based on data from EV Volumes.

Notes: Chinese OEMs include BAIC, Geely-Volvo, GWM, GAC, BYD, Chery Automobile, JAC, Neta Auto, Seres Group, FAW, Changan, Dongfeng, Jiangling Motors, SAIC, Leap Motor, Xiaopeng, Aiways Automobile. The domestic brands are Tata Motors, Mahindra & Mahindra (India); Togg Inc. (Türkiye); VinFast (Viet Nam) and Tito (Argentina).

5. A SEGMENT AUTOMOTİVE

Vehicles are divided into segments according to their models and features. Classification of vehicles according to their designs is called segment. The segment of vehicles refers to their design and features. In general, vehicle segments in the world are as follows (Gnann, T, Seddig, & Schade, 2022):

Vehicle segments have different designs and features, as well as different price levels.

Compact: has large dimensions. It also offers the opportunity to carry more load with its large luggage capacity. Segments in vehicles are named such as a, b, c, d, e, f, g, m, j segment. Segment A Vehicles the subject of this article which has a maximum length of 3.7. with their size, they provide both ease of parking and ease of use in the city. According to IEA's Global Electric Vehicle Outlook report, more than 10 million electric cars were sold in the world in 2022, and sales increased by 35% in 2023, reaching 14 million. Cars will need at least 5 million barrels of oil per day in 2030. Cars are just the first wave; electric buses and trucks will soon follow. To date, most electric car sales are concentrated mainly in three markets: China is the first country where more than half of the world's electric cars are produced. The second and third largest markets are Europe and the United States., within the scope of the Fit for 55 targets published by the EU within the scope of combating climate change and green transformation targets, amending the legislation on emission performance standards of passenger and light commercial vehicles and effective on 25 April 2023. According to EU Regulation No. 2023/851 published in the Official Journal of the EU, it is aimed that all passenger and light commercial vehicles to be put into traffic in 2035 will be carbon emission-free. In this context, legislative studies on batteries, which have been determined by the European Commission as one of the priority product groups within the scope of the Circular Economy Action Plan, were initiated at an early stage before the Sustainable Product Initiative, and the legalization process of the draft Battery and Battery Waste Regulation, published on 10 December 2020, was completed and 28 months ago. It was published in the EU Official Journal in July 2023. According to the legislation, which imposes obligations regarding the entire life cycle of all types of batteries, including the electric vehicle battery used in automobiles, from design to waste; Sustainability and safety rules have been determined for batteries to be put on the EU market, and the use of harmful materials such as mercury and cadmium has been restricted. For electric vehicle batteries, carbon footprint declaration obligation has been introduced as of February 18, 2025, carbon footprint performance classification obligation has been introduced as of August 18, 2026, and compliance with the carbon upper limit has been introduced as of February 18, 2028. For this purpose, as of February 18, 2027, it is mandatory to carry a QR code and access to the digital battery passport will be provided. While on 18 August 2031, batteries within the scope of the legislation were required to contain a certain amount of recycled content in cobalt (16%), lithium (6%), nickel (6%) and lead (85%) raw materials, on 18 August 2036, these amounts were increased to cobalt (%). 26), lithium (12%), nickel (15%) and lead (85%). Batteries will need to carry a recycled content certificate. In waste management of batteries, the minimum collection target for portable batteries for the manufacturer/importer distributor supplying batteries to the EU market has been determined as 45% for 31 December 2023, 63% for 31 December 2027, and 73% for 31 December 2030. It will be mandatory for batteries to be removed and reinstalled by the end user. Material recovery targets and recycling efficiency targets have been determined according to battery contents in the legislation, and the material recovery target for lithium has been determined as 50% for 2027 and 80% for 2031. For lithium-containing batteries, the recycling efficiency target has been determined as 65% for the end of 2025 and 70% for the end of 2030. As of 18 August 2025, within the scope of the legislation, companies with an annual turnover of over 40 million Euros and offering primary batteries to the EU market are subject to a duty of care. Third countries that supply products to the EU market will be obliged to certify that the carbon footprint of the products, recycled material content and duty of care requirements regarding social conditions are met, and mandatory notification regarding raw material information will be introduced through conformity assessment bodies (Approved Bodies). Exporters who will supply electric vehicles and automotive batteries to the EU must ensure that the batteries to be used in the vehicles comply with the criteria to be met by the said Regulation. If exporters who have received a certificate of conformity from the organization that evaluates this conformity also have a CE certificate, it will be possible for the products to enter the EU market. For exporters to enter the EU market, batteries must meet sustainability and safety criteria (articles 6-10, 12) and labeling and information criteria (Part III); duty of care; They must have a CE certificate to meet the legislative requirements regarding extended producer responsibility and Digital Passport (Turkey, 2023).

6. ELECTRİC VEHİCLES İN TURKEY

To popularize electric vehicles in Turkey, the state imposes a special consumption tax starting from -10% depending on engine power. A 75% discount is applied to the annual motor vehicle tax. The number of electric vehicles in Turkey reached 247 in 2019, 1,623 in 2020, and 3,587 in 2021. The Ministry of Industry and Technology in Turkey plans the demand forecast for electric vehicles in 3 different ways: low, medium and high. The first forecast is in 2025;

- First estimate. In the high scenario, annual electric vehicle sales will be 180 thousand units and total electric vehicle stock will be 400 thousand units,
- Second estimate: In the medium scenario, annual electric vehicle sales will be 120 thousand units and total electric vehicle stock will be 270 thousand units,
- Third forecast: In the low scenario, annual electric vehicle sales are predicted to be 65 thousand units, and the total electric vehicle stock will be 160 thousand units.
- By 2030;-first estimate: In the high scenario, annual electric vehicle sales will be 580 thousand units, and the total electric vehicle stock will be 2.5 million units,
- Second estimate: In the medium scenario, annual electric vehicle sales will be 420 thousand units and total electric vehicle stock will be 1.6 million units,
- Third forecast: In the low scenario, annual electric vehicle sales are predicted to be 200 thousand units, and the total electric vehicle stock will be 880 thousand units. According to the forecast of the Ministry of Industry and Technology, more than 1,600,000 electric vehicles will be in traffic in 2030.

7. CONCLUTIONS

Global climate change necessitates measures worldwide. Agreements prepared by international organizations to achieve sustainability goals present challenges for every country in international trade. Taxes related to carbon footprint impose a financial burden on producers, increasing costs. Wars fought to gain access to increasingly scarce energy resources have made the efficient use of energy imperative. The number of electric vehicles is increasing daily in China, and as the demand for electric vehicles increases in the context of energy transformation, the nature of these demands and the number of academic studies determining these demands are also increasing. The results of these studies have revealed that the factors determining demand forecasts for the electric automotive sector are not only economic variables. Social, psychological, technological, and political factors also shape the trends and demands for the electric automotive industry. This qualitative research, based on a literature review, has revealed that the demand for electric vehicles has a multi-dimensional structure. In other words, it's not just the legal obligation to reduce carbon footprint and economic reasons that shape demand; global and regional technological developments are shaping demand forecasts.

Research findings show that the factors determining the increase in electric vehicle demand are awareness, environmental responsibility, legal regulations aimed at reducing carbon emissions, government incentives, technological developments (especially the decrease in battery costs and increased range), the prevalence of charging infrastructure, and consumers' moral and normative motivations. Studies, particularly in recent years, show that rational economic motivations and normative and moral motivations are not mutually exclusive; on the contrary, they strengthen demand formation together. This situation reveals that it is essential to consider behavioural factors in electric vehicle demand forecasting.

On a global platform, China, the European Union, and the United States are the countries that lead the electric vehicle economy. One of the reasons for the decrease in the demand for electric vehicles in Europe is the scarcity of chargers and the long waiting time for charging. It is estimated that more than 30 thousand open charging sockets will be needed in Turkey in 2025. It is estimated that at least 1 charging socket will be needed for every 10 vehicles. In 2030, this number is determined as 160 thousand. At least 50 thousand fast charging sockets need to be installed in Turkey by 2030.

This research examines the factors determining demand forecasts for the electric automotive industry in global markets. Using a qualitative research methodology, this study highlights the influences of consumer behaviours, sustainability, and technological transformation on electric vehicle (EV) demand. Factors influencing electric vehicle demand are not limited to economic factors and the legal obligation to reduce carbon footprint. Economic, technological, psychological, social, and political factors influence household demand for electric vehicles. Electric vehicle demand forecasts are affected by price, income, and cost, as well as cultural and traditional variables. Social responsibilities, social norms, environmental responsibility, reputation, and status, along with moral and symbolic motivations, also play a role. Demand forecasting studies in the electric automotive sector vary according to behavioural and psychological variables. Advanced technology has resulted in reduced battery costs, extended driving range, and improved charging efficiency. The continuous development of battery technology is increasing consumer demand.

For electric vehicles to become widespread, policymakers need to prioritize not only financial incentives but also information campaigns, interventions, and long-term infrastructure planning based on social norms. Automotive manufacturers need to develop their technologies according to consumer expectations and the demands of supply chain actors. Product strategies regarding sustainability, technological innovations, and the total ownership experience need to be developed in an economical and accessible way. The affordability of charging, the increasing number of charging centers, and improved accessibility and reliability have also contributed to increased demand. The suitability of infrastructure for electric charging, the construction of smart cities, the connection of GPS systems to electric charging systems, infrastructure preparation, consumer confidence and adoption intentions, and coordinated public sector advertising of electric vehicles – all have shaped government policies, incentive mechanisms, regulatory frameworks, and demand trajectories at the macro level thanks to increased private sector investment strategies and government incentives. In the European Union, China, and the United States, widespread adoption efforts related to electric vehicles, legal regulations, sustainability-focused regulations, emission reduction targets, and carbon pricing mechanisms are increasingly focused on increasing the number of electric vehicles. Evidence obtained from our examination of the literature shows that some European markets are experiencing problems with electric vehicles due to insufficient infrastructure support and low government subsidies. All preparations made without the necessary infrastructure slow down the electric vehicle forecast. Long-term policies should allocate funds from the national budget for infrastructure. China's infrastructure acceleration efforts serve as an example for the whole world. To sustain market growth, there is a growing use of hybrid forecasting approaches that combine AI-based technological innovations such as machine learning algorithms, econometric models, artificial neural networks, and vector regression, as found in literature studies. Research that scientifically examines behavioural dynamics and nonlinear relationships in markets to combat uncertainty is needed. Integrated models incorporating infrastructure variables, psychological, behavioural, sociological, and economic indicators, technological learning curves, and consumer behavioural factors that influence future demand forecasts for electric vehicles need to be examined from a policy and management perspective. For the widespread adoption of electric vehicles, policymakers should prioritize not only financial incentives but also information campaigns based on social norms, interventions, and long-term infrastructure planning. Automotive manufacturers should develop their technologies according to consumer expectations and the demands of supply chain actors. Sustainability, technological innovations, and product strategies related to the total ownership experience should be developed in an economical and accessible way. With sustainability goals in mind, A-segment electric vehicles offer strategic contributions to urban mobility solutions, considering their affordability, efficiency, and compatibility. When we review research on electric vehicle demand forecasting, we see that demand estimates can vary due to psychological factors, economics, status, desire to win, productivity, and government support. Future research may change year by year as technology advances. The electric vehicle manufacturing sector should be developed by considering every research study, and demands should be considered. Despite the contributions of empirical research, this study has some limitations. As a qualitative literature-based analysis, empirical estimates or country-specific econometric results are not available in the literature. Future research should integrate cultural, institutional, and regional factors with advanced forecasting models, and comparative cross-country analyses using mixed methods approaches to accelerate the transition to electric mobility to prevent future climate crises.

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