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DAILY ELECTRICITY DEMAND ASSESSMENT ON THE EXAMPLE OF THE TURKISH ROAD TRANSPORT SYSTEM – A CASE STUDY OF THE DEVELOPMENT OF ELECTROMOBILITY ON HIGHWAYS

Ocena dobowego zapotrzebowania na energię elektryczną na przykładzie tureckiego systemu transportu drogowego – studium przypadku rozwoju elektromobilności na autostradach

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Abstract: The aim of this study is to investigate how the daily electricity demand from road transport related to the implementation of an electric road system on the eight roads with the highest traffic flow connecting the seven largest cities in Turkey varies according to time and location. Intercity highway route O-7, O-5, O-21, D715, D687, E96, and E87 in Western Turkey was used as a case study. The daily electricity demand on the eight roads working on the full electrification of the existing traffic flow can be increased by 3.7% in the case of the reference point. However, if all roads in Turkey are converted to an electric road system and all land vehicles use this system, the corresponding peak power increase will be 100%. The daily electricity demand along the roads is derived from the available measuring points for the daily road traffic volumes. The study also compares the CO_2 reduction potentials and energy demands of the electrified road system with the use of fossil fuels to achieve the same transportation volume. The results show that an electric road system application on eight Turkish roads with considerable traffic flow can reduce 18.8 million tons of CO_2 emissions from the road transport sector. The research can find practical application in assessing the validity of developing a strategy for the development of electromobility on highways in Turkey.

Keywords: electromobility, electricity consumption, traffic measurements, CO_2 emission.

Streszczenie: Celem tego artykułu jest zbadanie, w jaki sposób dobowe zapotrzebowanie na energię elektryczną w transporcie drogowym związane z wdrożeniem elektrycznego systemu drogowego na ośmiu drogach o największym natężeniu ruchu, łączących siedem największych miast w Turcji, zmienia się w zależności od czasu i lokalizacji. Jako studium przypadku wykorzystano autostradę międzymiastową O-7, O-5, O-21, E96 i E87 w zachodniej Turcji. Dobowe zapotrzebowanie na energię elektryczną na ośmiu drogach pracujących nad pełną elektryfikacją istniejącego ruchu może w przypadku punktu odniesienia wzrosnąć o 3,7%. Jeśli jednak wszystkie drogi w Turcji zostaną przekształcone w elektryczny system drogowy i wszystkie pojazdy lądowe będą korzystać z tego systemu, odpowiedni wzrost mocy szczytowej wyniesie 100%. Dobowe zapotrzebowanie na energię elektryczną wzdłuż dróg pochodzi z dostępnych punktów pomiarowych dobowego natężenia ruchu drogowego. Badanie porównuje również potencjały redukcji CO_2 i zapotrzebowanie energetyczne zelektryfikowanego systemu drogowego z wykorzystaniem paliw kopalnych w celu osiągnięcia tej samej wielkości transportu. Wyniki pokazują, że zastosowanie elektrycznego systemu drogowego na ośmiu tureckich drogach o znacznym natężeniu ruchu może zmniejszyć emisję CO_2 o 18,8 mln ton z sektora transportu drogowego. Badania mogą znaleźć praktyczne zastosowanie w ocenie zasadności opracowania strategii rozwoju elektromobilności na autostradach w Turcji.

Słowa kluczowe: elektromobilność, zużycie energii elektrycznej, pomiary ruchu, emisja CO_2.

Introduction

Observations of the market reality indicate that in recent years energy production in the world has started to be transformed into a more sustainable system for a society less dependent on fossil fuels. Especially with the oil crisis that emerged in the 1970s, energy supply security is reflected in the economic policies implemented by the countries. Afterwards, with the increasing awareness on environmental pollution, renewable energy sources started to take their place in the energy equation. Countries with high energy dependency have started to work to increase the use and potential of renewable energy resources to overcome this problem (Ediger, 2018; Mittlefehld, 2018; Economidou et al., 2020). Europe's decommissioning of nuclear power and their investment in renewable energy, on the other hand, have not proved to be the development that has reduced fossil dependence on electricity generation (Karakosta et al.2013; Wise and Stoilov, 2021; Devogelaer and Gusbin, 2009) In 2016, 96% of the global transportation industry uses oil, and the industry produced 7.3 billion metric tons of carbon dioxide (CO_2) emissions in 2020 (Distribution, 2021). In addition, while reducing CO_2 and greenhouse gas emissions, the transport sector which is the primary source of air pollution in cities, accounts for about a quarter of Europe's greenhouse gas emissions (European, 2019). The US aims an economy-wide target for the US to reduce its net greenhouse gas emissions by 50-52% by 2030 from 2005 levels, creating a carbon pollution-free power sector by 2035 (Hannis, 2021). Turkey had set forth its greenhouse gas reduction targets before the UN Climate Change 21st Conference of the Paris in 2015 (Gundogmus, 2021). Countries that have ratified the Paris Agreement must fulfill their commitments to limit global temperature rise to 1.5°C and to zero greenhouse gas emissions by 2050. Turkey has made a commitment to reduce its emission increase by 21% by 2030, within the framework of its national contribution statement submitted to the UN Secretariat in 2015 (Gundogmus, 2021). With the aim of contributing to the fight against global climate change and the developments in clean energy technologies, the capacity of renewable energy resources in Turkey has increased significantly in recent years. Renewable power plants accounted for 97% of the electricity generation capacity commissioned in Turkey in 2021, and renewable energy accounts for 53.7% of the total installed power (Kaya and Gulsen, 2021).

In order to succeed in achieving a fossil fuel-independent vehicle fleet and reduced greenhouse gas emissions, a radical transformation of the transport sector is required (Mutter, 2021).

With the growing share of renewable electricity generation, electric vehicles can significantly reduce the CO_2 emissions from the transportation sector have been broadly discussed in the literature (Bellocchi et al., 2018; Hill et al., 2019; Gryparis et al.,2020) For Turkey to completely eliminate greenhouse gas emissions by 2045 at the latest, it is necessary to reduce emissions from domestic traffic (excluding aviation) by at least 70% by 2030. For passenger vehicles and other light vehicles, 100% battery electric vehicles (BEV) or plug-in hybrid electric vehicles (PHEV) are possible solutions. Due to the extensive charging infrastructure and the increasing capacity of the batteries such solutions should also be possible for short-distance distribution traffic. For heavy long-distance traffic, the batteries would be so large and heavy that continuous charging appears to be more efficient (Coban et.al, 2022). Since the production and recycling of batteries on a large scale is a challenge and also energy- and resource-intensive (Porzo and Scown, 2021), it can be an advantage in terms of supply if part of the vehicle traffic can be driven by a continuous supply of electricity. Electric roads appear to be a potentially interesting solution for electrifying parts of road traffic (Coban et al., 2022). The analyzes made so far of the socio-economic profitability of electric roads refer to smaller sections and do not take into account the system effects that will prove to be decisive for the electric roads' opportunities to more significantly contribute to fossil-free vehicle traffic. Part of a composite solution can be electric roads that supply vehicles with electricity, for both propulsion and charging, while driving. With electric roads, cars can have smaller batteries than at present but still drive long distances; thus, the vehicle cost reduces by battery size. Electric buses in city traffic do not have to stop and charge at stations (Coban et. al., 2022, Alwesabi et al., 2021). In addition, electric roads enable the electrification of heavy long-distance freight transport, for which battery capacity can otherwise be a challenge. Electric roads transfer energy directly to electric vehicles while the vehicles are moving. The energy can be used to propel or charge the vehicles' batteries.

Road electrification may impose some constraints on the electricity grid depending on the extent, how, and when vehicles are charged. Therefore, it is also necessary to investigate which electricity networks to link to which electricity roads regarding the current capacity shortages in certain regions of the country. In these analyzes, it shall be assumed that the electricity networks that are to supply electricity roads with electricity are not subject to a concession, which is the permit required for the maintenance of high-voltage power lines.

Estimates from some studies show that total electricity consumption in Turkey in 2040 could rise to 315 TWh compared to the current 290 TWh (Temizer, 2021). The expected increase of around 25 TWh is partly due to the number of electric vehicles in Turkey is expected to reach 2.8 million in 2040 and electricity-intensive industries (Girisen et al., 2021). The demands for transmission capacity in the transmission grid are increasing, in conjunction with the construction of more renewable energy. Increasing electricity use in big cities causes regional grid owners to be insufficient in the electricity grid and have to demand electricity from other regions, which puts more strain on the main grid (Turkish, 2020). The Turkish power grid provides good security of supply when power outages are estimated at between 1 and 1.5 per output and per year. This corresponds to a power outage of 1 to 2 hours per customer during a year, no different from weather events. 90% of these power outages occur on local networks and 10% on regional networks. In recent years, several studies have been published describing the impacts and demand patterns of EVs on the electrical system.

However, there are few studies (Wänlund and Wänlund, 2021; Grahn, 2014; Stamati and Bauer, 2013; Taljegard et al., 2017) in the literature investigating the possible impact of ERSs (electric road systems) on peak power demand and the demand profiles of an ERS. The authors of (Wänlund and Wänlund, 2021) investigated the power requirement for the transformer stations in Sweden and the authors found that the power required to meet the electric road of the future is expected to range between 300 and 900 kW per kilometer during the busiest hours of the day. In another study (Grahm, 2014), the authors found that assuming 50% of the vehicle fleet consists of electric vehicles, charging vehicles will increase peak load in Sweden by approximately 1-2 GW. Another study (Stamati and Bauer, 2013) investigated the possibilities of meeting electricity demand with renewable resources for an electric highway in the Netherlands. Another study (Taljegard et al., 2017) showed that an ERS load profile of vehicles on all main highways in Norway will raise hourly peak power demand by around 7%. They also showed that assuming both heavy and light vehicles are electrified, heavy vehicles accounted for about 50% of the increase in peak power demand. There is a lack of studies investigating the energy demand from an electrified road system and analyzing how it will affect the grid and the potential CO_2 savings for road transport.

Electric roads are a potentially interesting solution for electrifying parts of heavy road traffic. The study presents a way to estimate to reveal the impact on CO_2 emissions and the daily electricity demand assessment of vehicles including heavy vehicles that can use electrified roads. The subject of the research was to obtain the energy consumption of electrified roads. This study extends the existing research in (Coban et al., 2022) which different concepts for electric road technology have also been tested in Turkey. However, there has been a lack of an assessment of the socio-economic profitability of electric roads in a larger perspective, where system effects are taken into account. This study presents a calculation of the electricity demand in longer distances along the Turkish road network. The calculations have been limited to the highways between Turkey's 7 metropolitan areas. To the best of our knowledge, this article is the first in which the issues related to electric roads' electricity demand and the first case study was discussed.

The key contribution of this study is a pioneering analysis based on an expert method used, among others, automotive experts, to which only a small number of researchers have access. We study the electricity demand of seven electric road scenarios and answer mainly three questions.

1. How analyze methodologically the effect of electricity consumption on electric roads?
2. What is the effect of reducing CO_2 emissions in the electrification of the road network?
3. If reducing dependency on fossil fuels can be achieved, which part of the road network should be electrified first to achieve as high profitability as possible?

This method has been enriched with additional factor ignored by many experts, concerning heavy vehicles. Briefly, this article brings a new look to the existing literature in the following areas: (I) electricity demand modeling, (II) effect on emission reductions of CO_2, (III) transport infrastructure, (IV) development plans and domestic electromobility market.

The article is organized as follows. Chapter 2 explains assumptions and input data. Chapter 3 a detailed description of the research approach. Chapter 4 describes the results of experimental research along with their interpretation. Chapter 5 presents the final conclusions of the research, indicating their limitations, practical application and future directions of research in this field.

2. Assumptions and input data

In this research, it is evaluated that electric roads can contribute to facilitating freight transport and reducing greenhouse gas emissions in the national freight transport strategy. Therefore, a long-term plan should be developed for the construction and expansion of electrified roads. Therefore, this study analyzes the effects, CO_2 mitigation potentials, and electricity demand of the 7 biggest city electric road routes at the system level.

In addition, it is thought that in the freight transportation strategy, priority should be given to important freight routes such as the routes between Istanbul, Bursa, Izmir, Ankara, Konya, and Antalya and connections to important ports. The analyzes for electric roads so far refer to smaller segments and do not take into account network and system impacts that could be decisive for electrified roads' opportunities to contribute more significantly to fossil-free vehicular traffic.

In order to calculate the effect of the energy that the electric roads will consume on the system, it is necessary to make estimations about which vehicle kilometer will be applied on the electric roads, depending on which part of the network is electrified. Electric road scenario for 7 big cities established:

- A network of 224 km (total of both directions) O-7 between Istanbul and Kocaeli,
- European road (O-7), 714 km long Kocaeli and Ankara (in both directions),
- The road (O-21, D715, D687) between Ankara, Konya, and Antalya,
- A medium-sized network of (E87) between Antalya and Izmir,
- An extensive network of the national road (E96) between Izmir and Ankara,

individual urban areas. Between Bursa and Istanbul, there are large logistics centers, suburbs of the region, and 2 international airports. Total length 2985 km (in one direction).

This study will not examine the type of various electric road systems, although separate results were obtained for light vehicles, buses, and heavy trucks. Detailed information about the types of electrified roads and their applications can be obtained from (Coban et al., 2022; The General; 2021).

3. Materials and Methods

3.1. Road traffic data

Data for traffic flows were retrieved from the Turkish Transport Administration's database, where various measurements in the form of sample measurements, annual average daily traffic, and average speeds were available (The General, 2021). From the traffic flow map in the database, annual average daily traffic could be manually recorded at each entrance and exit along the route, which resulted in 197 measuring points in both directions. Figure 1 shows the daily road traffic data points on highway O-7.

To obtain the diurnal variation over the chosen section, 16 measurement stations were used along the

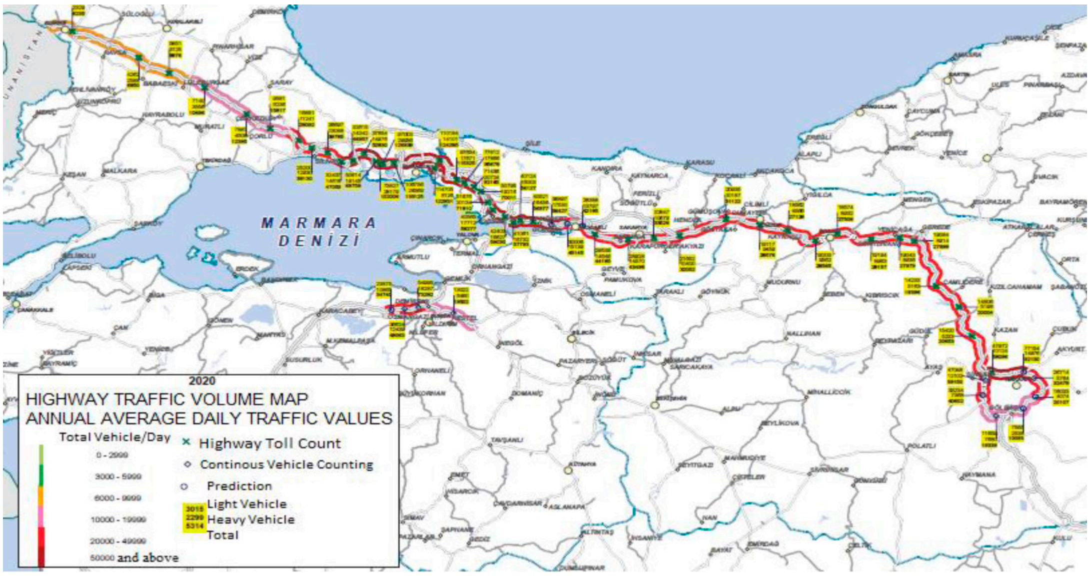

Fig. 1. The road daily traffic data-points on highway O-7

Source: The General Directorate of Highways, "Traffic and Transportation Information 2020," 2022. https://www.kgm.gov.tr/SiteCollectionDocuments/KGMdocuments/Istatistikler/TrafikveUlasimBilgileri/20TrafikUlasimBilgileri.pdf%0A

The O-21 between Konya and Ankara has varying surroundings and traffic flows. Between Konya and Antalya, the section is characterized by rural areas and section which was assumed to represent how the flow varied during a day (The General, 2021). These data were available for the year 2020 and contained data on the traffic flow each day. To obtain the variation of the traffic flow, the only measuring point along the route was used as registered measurements for the entire year. Figure 2 shows the total traffic volume map for light and heavy vehicles in 2020. In this study, the variation in traffic flow over the weekdays assumed that the number of vehicles during the weekend is about a quarter of the number of vehicles during a weekday. most part, the road has speed limits of 110 to 120 km/h, while there are lower speed limits on the stretch closest to the city center. Heavy trucks are largely limited by the specific speed limits for the vehicle type, except for the nearest city center where the speed limit is sometimes down to 70 km/h. The roads chosen in this study are highways. Other inter-city roads and vehicle traffic are not taken into account.

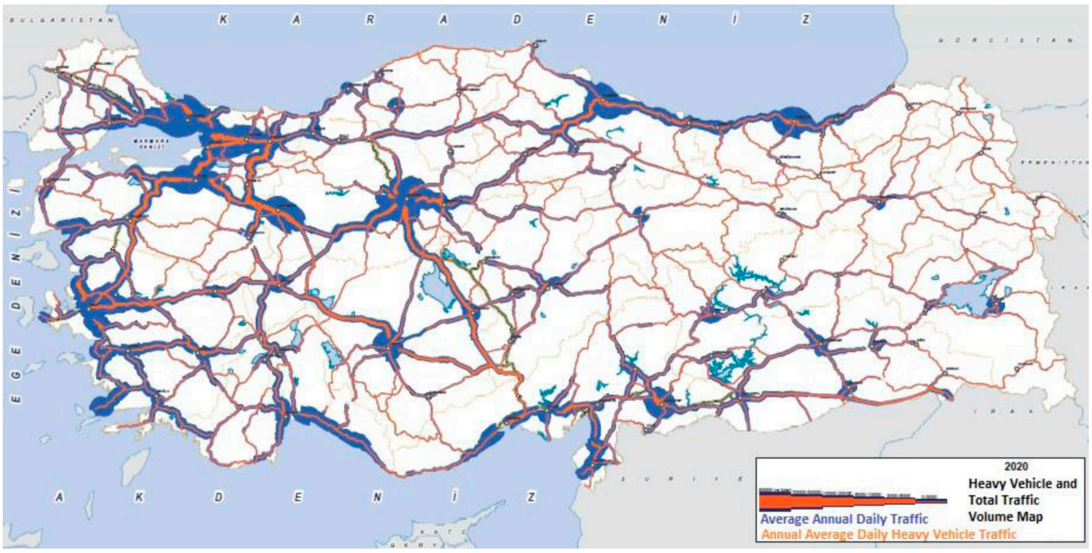

Fig. 2. Turkey's total traffic volume map in 2020

Source: The General Directorate of Highways, "Traffic and Transportation Information 2020," 2022. https://www.kgm.gov.tr/SiteCollectionDocuments/KGMdocuments/Istatistikler/TrafikveUlasimBilgileri/20TrafikUlasimBilgileri.pdf%0A.

The types of vehicles that are included in average daily traffic are light and heavy vehicles, respectively, where heavy vehicles consist of heavy trucks and buses. All kinds of vehicles registered abroad are also included. The distribution between heavy trucks and buses of the total number of heavy vehicles is summarized in Table 1. Since there is no electrified road in Turkey yet, Sweden's CO_2 emissions and electricity consumption are presented. These data were used in Turkish analyzes and were assumed to be valid for Turkey since the geographical conditions of the two countries are similar.

A speed vector was created based on the speed limits that apply to vehicles along the route. For the

3.2. Method description

In this study, the method is based on 16 different daily road traffic data points on the investigated roads. It has been chosen from the available 12-hour data point to represent the daily average traffic, as shown in Table 2. The daily vehicle numbers profile values used in this study were taken from the report of (Ma et al.,2012; Turkish, 2021) which was measured by daily traffic data points.

In this study, the method is based on 16 different daily road traffic data points on the investigated roads. It has been chosen from the available 12-hour data point to represent the daily average traffic, as shown

Tab. 1. The breakdown of the vehicles.

	Share of the vehicle fleet	CO_2 emissions ($g\ CO_2$/vehicle/km)	Electricity consumption on ERS (kWh/vehicle/km)
Passenger cars	54.3%	167	0.16
Pick-ups, Minibuses	18.3%	181	0.36
Heavy Trucks	3.6%	963	2.24
Buses	0.9%	678	1.29
Others (motorcycle, tractor, etc.)	22.9%	NA	NA

Source: The General Directorate of Highways, "Traffic and Transportation Information 2020," 2022. https://www.kgm.gov.tr/SiteCollectionDocuments/KGMdocuments/Istatistikler/TrafikveUlasimBilgileri/20TrafikUlasimBilgileri.pdf%0A.

in Table 2. The daily vehicle numbers profile values used in this study were taken from the report of (Ma et al.,2012; Turkish, 2021) which was measured by daily traffic data points.

3.3. Vehicle data

For calculations of CO_2 reduction and electricity demand potential using an electric road system, heavy vehicles are divided into buses and heavy trucks,

Tab. 2. Average daily traffic flow of this study

Name of the road		Heavy vehicles	Light vehicles	Length (km)
R1	Istanbul – Kocaeli	20,134	51,676	112
R2	Kocaeli – Ankara	10,187	20,935	357
R3	Ankara – Konya	6,274	12,206	271
R4	Konya – Antalya	1,072	5,177	303
R5	Antalya – Izmir	1,589	5,759	461
R6	Izmir – Bursa	5,747	11,653	345
R7	Bursa – Istanbul	7,639	14,482	153
R8	Izmir – Ankara	5,186	9,199	590

Source: The General Directorate of Highways, "Traffic and Transportation Information 2020," 2022. https://www.kgm.gov.tr/SiteCollectionDocuments/KGMdocuments/Istatistikler/TrafikveUlasimBilgileri/20TrafikUlasimBilgileri.pdf%0A.

The entire main road network of Turkey has a length of 16,250 km and there are 21,479 traffic flow measurement points.

Average daily traffic data for the Turkish road network is provided by the Turkish General Directorate of Highways administration (The General, 2022). The chosen road network accounts for nearly half of Turkey's total yearly traffic. For the different average daily traffic intervals shown in Table 1, the traffic profiles can be applied to each of the 18 road sections of the entire country road network. Figure 3 shows the road network investigated in this study which connects 7 big cities.

and light vehicles are divided into passenger cars, minibuses, and light trucks. CO_2 emissions for various vehicle classifications and their respective shares in the Turkish vehicle fleet are obtained from the Turkish Statistical Institute. The electricity consumption per kilometer and CO_2 emission factors of vehicles using electric road systems are shown in Table 2. The average electrical consumption of ERS-equipped vehicles is taken from (Jelica et al.,2018) in the current literature. When the distance covered by vehicles in 2018 is analyzed according to the fuel types of vehicles; 47.8% of the total vehicle kilometer was made by

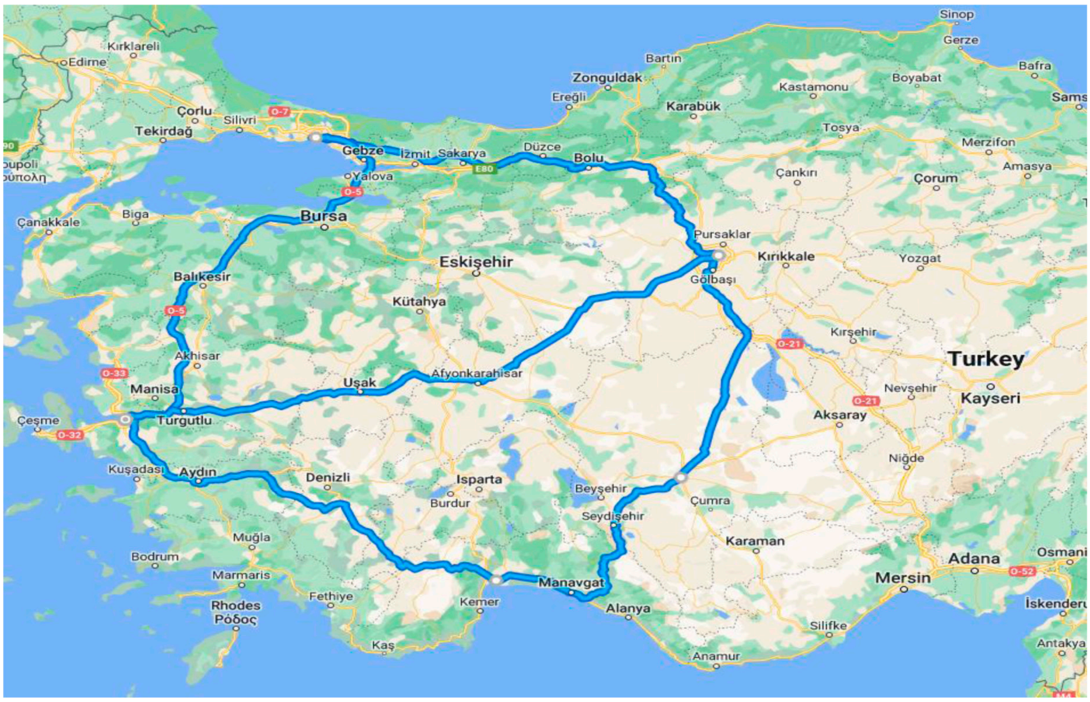

Fig. 3. The road network investigated in this study

Source: Google Maps.

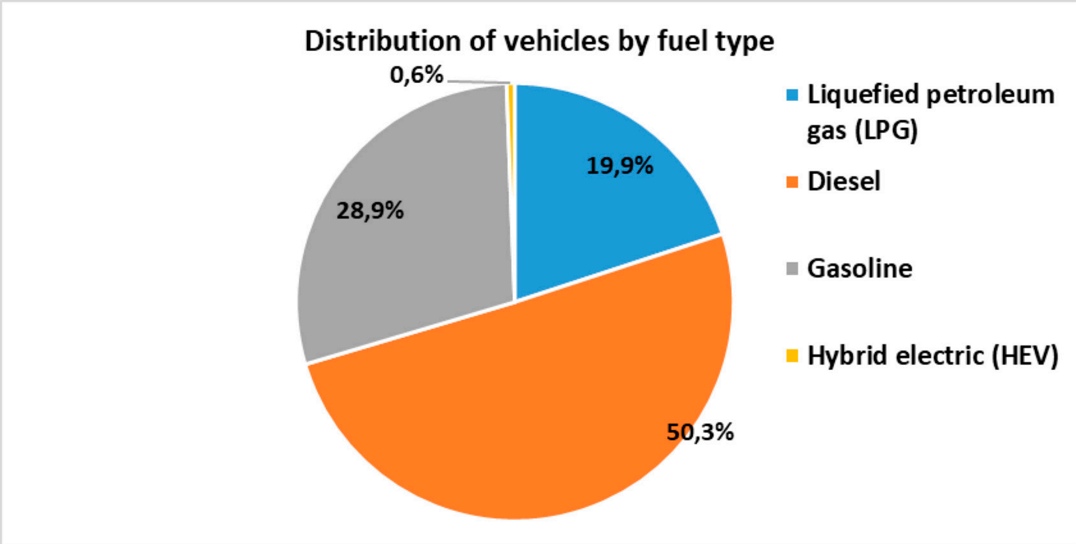

Fig. 4. Distribution of vehicles by fuel type in Turkey in 2021.

Source: own elaboration of the authors based on: Turkish (2021).

diesel, 33.4% by LPG, and 18.8% by gasoline-fueled cars. Figure 4 shows the distribution of vehicles by fuel type in Turkey for 2021 (Turkish, 2021). Considering the installed power of Turkey's electric power and the development of electric power generated from renewable sources, a completely carbon-free electric system is assumed by zero CO_2 emissions from electric vehicles. Moreover, no indirect emissions associated with electric vehicles such as those associated with battery or vehicle manufacturing are taken into account. Several studies have investigated emissions from the manufacture of electric vehicles (Nealer and Hendrickson, 2015), the use of electric vehicles (Ellingsen, 2017; Moro and Lonza, 2018) and the installation of electric road system infrastructure (Taljegard et al., 2020; Taijegard et al., 2017). These studies have shown that emissions from the production of an electric vehicle largely depend on the electricity source used to manufacture the batteries, and the use of electric vehicles makes the highest contribution to decarbonization (Ma et al.,2012; Kim et al., 2016). It is assumed that 100% of the vehicles using the roads (Figure 1) examined in this study use ERS. It is also assumed that the internal batteries of these vehicles will have the same state of charge as when the vehicle enters ERS and exits ERS.

4. Results and discussion

Figure 5 shows the electricity demand on a typical day when an electric road system is applied on the investigated roads. The electricity demand on an average day of the year is 34,914 MWh. Figure 5 shows daily electricity demand for electric road systems with 100% electric vehicle penetration.

However, assuming a 15% and 20% decrease in electricity demand for both light and heavy vehicles on

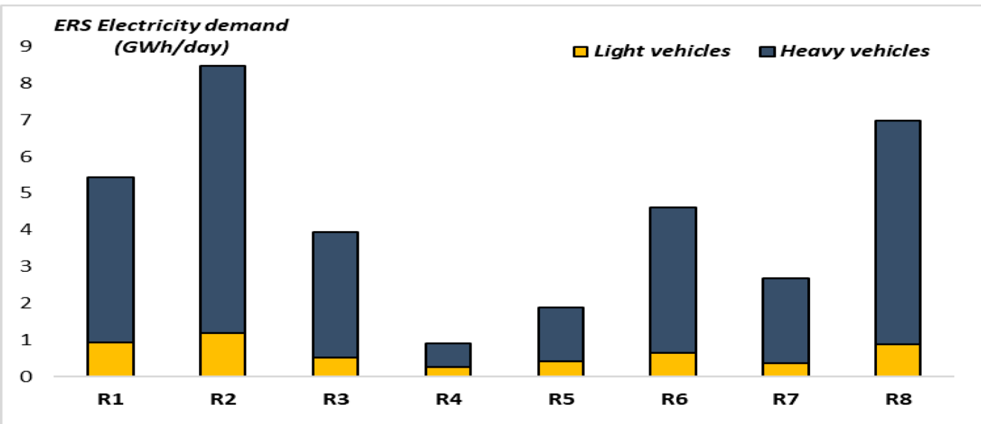

Fig. 5. The daily electricity demand for electric road systems with 100% electric vehicle penetration.

Source: own elaboration of the authors.

Saturday and Sunday, respectively, Figure 6 shows the daily electricity demand using an electric road system for an average week for the roads under the study.

According to the 2019 Turkish Statistical Institute (TSI) data, the average kilometers made by vehicles in a year; are 45,100 km of buses, 44,346 km of trucks, 24,636 km of minibusses, 16,562 km of pickup trucks, 13,325 km of cars, and 3,854 km of motorcycles. In Turkey, the annual electricity demand is 161 TWh when ERS is used for all vehicle kilometers driven on all roads, assuming ERS is used by all vehicles. Turkey's electricity generation in 2021 was 329 TWh, and the total installed power was 99.8TW.

Although it seems like a dream for now, implementation of ERS across the entire road network will therefore increase national electricity demand by nearly 100% while reducing annual fuel use to 0.

The coronavirus epidemic caused a significant fluctuation in the energy sector and consumption, roughly 28 billion liters of diesel and 3 billion liters of gasoline were consumed annually in Turkey. According to the EMRA report, 2,657,320 tons of fuel were used in Turkey in November 2021. While 282,953 tons of these fuels were gasoline, 2,257,000 tons was diesel.

According to the greenhouse gas emission inventory data of the TSI, in 2020, Turkey's total greenhouse gas emission is 523.9 Mtons of CO_2 equivalent (Turkish, 2020), and in 2017 84,659 kilotons of CO_2 equivalent of this is emissions caused by transportation (Ministry, 2020). According to TSI's 2017 greenhouse gas emission inventory data, 93% of CO_2 emissions originating from transportation originates from the road, 4.5% from the airway, 1.1% from the seaway, 0.5% from the railway and 0.9% from other modes of transport. If we look at the situation in the EU 28 countries, 25% of the total greenhouse gas emissions in the EU-28 in 2018 came from transportation (excluding international aviation and marine emissions) (Ministry,

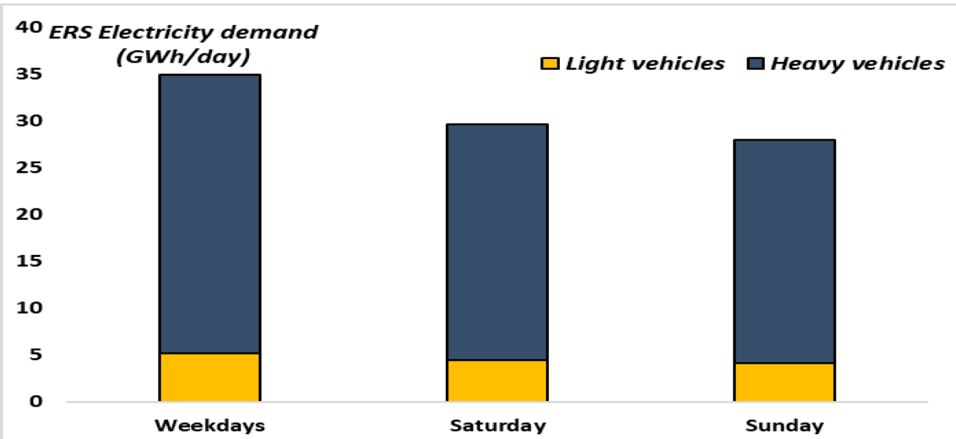

Fig. 6. Electricity demand for electric road systems for the Turkish road network shown in Fig. 1.

Source: own elaboration of the authors.

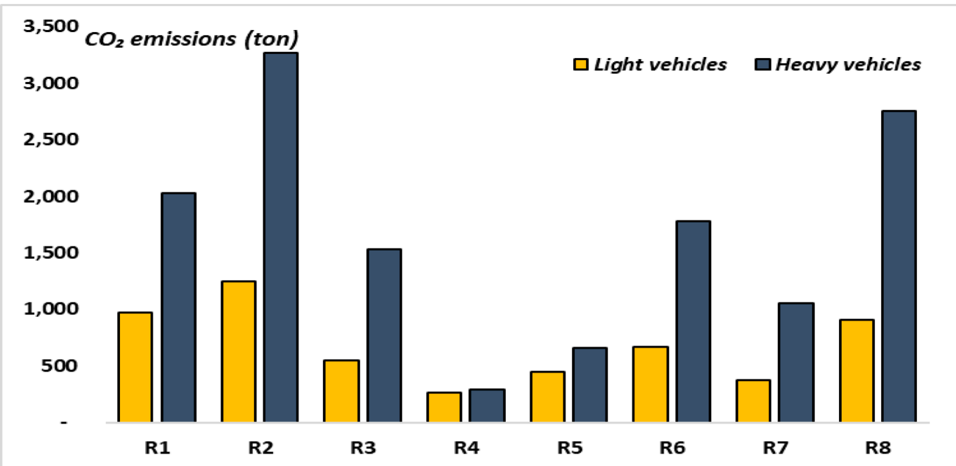

Fig. 7. CO_2 reduction potentials with 100% electric vehicle penetration for the road network section under study.

Source: own elaboration of the authors.

2020). By implementing an ERS on all roads under the assumptions of 100% vehicle connectivity to the ERS and electricity demand meets from only a renewable electricity system, in 2022 Turkey will reduce national CO_2 emissions from the transportation sector from 89.54 Mtons CO_2/year to 0 emissions which is 17% of total CO_2 emissions. Figure 7 shows CO_2 reduction potentials with 100% electric vehicle penetration for the road network section under study.

5. Conclusions

The electrification of the road transport sector is a very important element in creating a zero-emission transport system, and the development of sustainable transport and environmental protection are one of the priorities of the transport policy of a country such as Turkey. The current process of developing electromobility in Turkey is focused mainly on urban centers. It should be assumed that along with the development of vehicle charging infrastructure, a decrease in technology prices, or an increase in public interest in electric vehicles, this process will become more dynamic. On this basis, the authors predict that in the near future one of the key challenges will be the problem of electrification of highways, and thus solving the issues related to the daily energy demand and consumption.

This research has shown that an ERS application on the eight roads with the highest traffic flow in Turkey will increase the daily electricity demand by 3.73%. Implementing an ERS in the same eight routes would involve 12,744 GWh per year consumption and increase the annual electricity demand in Turkey by 3.8%. However, in the case of electrification of the entire road transport or even a significant part of it, the increase in energy demand will be even greater. Currently, transport accounts for approximately 25% of total energy consumption, so a similar increase is likely to occur with mass electrification. In addition, the implementation of these eight electric roads will reduce CO_2 emissions caused by road transport in Turkey by 0.022%. The CO_2 savings results from the introduction of ERS obtained in this study assume that electricity generation consists of only renewable sources. Among the roads examined, O-7 between Kocaeli and Ankara, although it is not the longest road, it has the highest number of vehicle kilometers, and thus it has the highest electricity consumption and the greatest potential for CO_2 reduction. The O-7 between Istanbul and Kocaeli has the highest vehicle density and thus the second-highest electricity demand and the second-highest energy savings and CO_2 reduction potential per kilometer of electrified road. According to the results, electrification of O-7 will provide the highest electrification effect in terms of economic efficiency, while electrification of E96 will provide the highest overall electrification effect.

This is the first study to analyze the daily electricity demand impact of the implementation of Turkey's electrified roads. This type of research has its limitations. From the research point of view, it is important to underline that the connection of the electric road to the power grid is based on local and regional conditions in the surrounding power grid. Initially, suitable transformer stations should be selected according to some requirements regarding location, capacity, and the number of transformers. For different scenarios, it should be examined whether the electrical path of the substations can meet the power requirement. To determine this, the usable capacity in the substations has been produced and the voltage drops in the supply lines, and the grid power ratio should be calculated. Voltage drop and network ratio should be controlled according to electrical quality limits. The profitability and effect of an expansion of electric roads appear to be relatively robust even with assumptions about large variations in future electricity and diesel prices. The expansion of electric roads should also include interruptions in the supply of electricity and intermittent operation of electricity, which means that hybrid trucks must be equipped with a battery with a minimum range of about 70 km (Coban et al, 2022), invariably ensuring the highest socio-economic profitability regardless of CO_2 valuation.

Summarizing the analyzes presented by the authors regarding the assessment of the daily demand for electricity on the example of the Turkish road transport system, they do not fully exhaust the essence of the issue, but are only an attempt to signal the complexity of the analyzed issues regarding the essence of the connections related to the development of electromobility on highways, CO_2 reduction and energy demand. These issues will certainly be the subject of further analyzes and research in order to assess the legitimacy of implementing solutions based on the idea of electromobility in relation to road transport in Turkey.

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