Defining the Current Issues Preventing Natural Transition to Electric Vehicles (EVs)

Jakub Pernický[1]

[1]University of Economics in Bratislava, Faculty of International Relations,
Dolnozemská cesta 1, Bratislava, 852 35
Slovak Republic

jakub.pernicky@euba.sk

https://doi.org/10.53465/EDAMBA.2023.9788022551274.207-222

Abstract. This paper analysis the most important obstacles that are preventing more effective and faster transition to alternative means of transportation, while focusing on specific case of electric vehicles (EVs). As subject of transport emissions gains more attention, it is required to look for viable and economically and environmentally rational solutions towards transition to green road transport. First it evaluates, whether such transition is necessary and required, pointing out the current state of CO_2 emissions for which transport sector is responsible. Key issues preventing natural transition from internal combustion engine vehicles (ICEs) are then analyzed from consumer perspective. Paper evaluates and defines significance of each of the selected issues, reviews the most common assumptions and possible misconceptions. Several surveys data is analyzed and synthesized, providing a coherent answer applicable for most regions. Three key issues are defined and analyzed based on results, stating their relevance and solution possibility. The discussion then defines the current and future potential of EVs globally, as a potential successor of ICEs, based on information concluded, and provides summarized results of analyzed subject. Results points out to three major issues; range, price, and charging, while partially confirming their relevance, which is closely analyzed in individual parts of the paper. However, despite the fact, that the issues were confirmed to be still present, data proves a significant growth in demand for alternative transportation, specifically EVs. This trend could be expected to continue (even hasten) in short future due to gradual removal of given problems as perceived by consumers based on technological advance.

Keywords: Transport, Electric Vehicles, Technology, Climate Change.

JEL classification: *R 41, Q 56, O 33*

1 Introduction

Current modern transportation possibilities provide much more options for even a regular consumer, than means of transportation available in 20th century. Although some options, that are getting more popular these days were, from technological development point, available along with most common internal combustion engine vehicles (ICEs; or ICEVs) even before, their potential of effective transportation was very limited. As ICEs got more effective, affordable, and therefore very popular and easy to use, research in alternative transportation wasn't as necessary and was stagnating, since it appeared to be way too difficult and expensive.

Although the debates regarding human activity damaging nature were ongoing throughout the whole 20th century, the amount of attention they received was very limited until there were enough researchers pointing out to the same problem. By the end of the century, humanity started to strongly realize the impact of unlimited manufacture practices, transportation problems and other activities, which were producing massive emissions of greenhouse gases. This proves the later establishment of panels and conferences on various problems regarding climate change, which are to this day observing and organizing a regular meetups with representatives of countries from the whole world.

Many countries and organizations are calling for a more strict and faster global policy adaptation in the sphere of transportation, which proved to be a significant part of air pollution and emissions of greenhouse gasses. Out of whole transportation sector, road transport (including passenger vehicles such as cars, motorcycles, buses along with freight vehicles such as trucks) was responsible for almost 77% of CO_2 emissions, while nominal value from whole transport sector was totaling at 7,7 Gt of CO_2 in 2021 (for sub-sector distribution see Fig. 1.).[1] Globally speaking, road transport was responsible for 17% of all *(human-caused)* greenhouse gases ("GHG" or "hcGHG") emitted in 2019, placing it at the second place, after electricity/heat production sector, which was responsible for 32% of global GHG released. Looking solely at CO_2, it contributed with 22% share of global CO_2 emissions in the same year.[2]

This paper will focus on a potential of electric vehicles in combating a climate change and evaluate the most common obstacles that are preventing from a natural adaptation to less carbon demanding transport alternatives. The result will indicate whether electric vehicles are a viable and more importantly realistic alternative to current means of transport. Additionally, individual chapters will test the relevance of most common problems (of EVs) as perceived by consumers, in order to decide whether the concerns are justified.

[1] International Energy Agency – Jacob, T.: Transport - Sectoral overview, (2022)
[2] World Resources Institute – ClimateWatch: Historical GHG Emissions

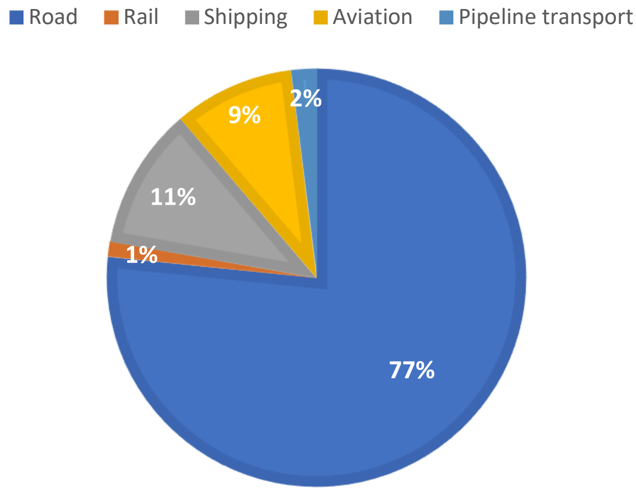

Fig. 1. Global CO2 emissions from transport by sub-sector (2021)

With regard to rapid technological development in energy storage, increasing number of calls for green transformation of global economy, successful marketing strategies and other factors, one of the most viable alternatives at the beginning of 21st century to ICEVs turned out to be electric vehicles (EVs), specifically speaking battery electric vehicles (BEVs). A great example of efforts would be a recent policy adopted by European Union (EU) which states, that all new cars and vans registered in Europe will be "zero-emission" by 2035. To help reach this goal, intermediary step was also defined, stating that the new CO2 standards will also require average emissions of new cars to come down by 55% by 2030, and new vans by 50% by 2030. European Parliament and Council proposed and agreed to such policy with regard to policy of "Fit for 55".[3] Overall it is very clear, that the trend for support of EVs can be seen in most developed (but also developing) countries, looking at the incentives and subsidies of this sector. Most common way they are doing it (or have been), is by providing a large amount of financial subsidy to consumers, when they reach for electric vehicle instead of vehicle with combustion engine. The subsidies can occur also on the manufacturer side, when countries provide a subsidies to each sold EV, in order to boost sales but also attract investors.[4] This applies to all regions.[567] At the

[3] European Comission: Zero emission vehicles: first 'Fit for 55' deal will end the sale of new CO2 emitting cars in Europe by 2035, (2022)

[4] Reuters - Bernadette C. M., Fransiska N.: Indonesia to provide incentives to boost EV sales, attract investment, (2023)

[5] MHSR: MH SR zverejnilo podmienky poskytnutia dotácie na elektromobily, (2019)

[6] Reuters - Gleb S., Anastasia L., Darya K.: Russia plans to subsidise electric cars to spur demand, (2021)

same time, targeted year of full transformation of manufacturing processes by EU, for such a diverse consumer market consisting of 27 countries with different level of development, could appear to be quite bold. There are several questions that appear to remain unanswered before the whole sector transformation could occur, which seems to be taken by policy makers as "problem of the future and not present". Although currently the EVs still comprise rather small percentage of global fleet in comparison with ICEs (although the share in automobiles sales was drastically increasing for past 3 years, with 4% in 2020 to 14% in 2022[89]), the future where domination of EVs is present could bring several more issues.

2 Methodology

Given problematic is examined by analyzing most recent available statistical and empirical data. We use the official websites of manufacturers with statistical databases but also look at the empirical evidence provided by consumers. Key focus of the paper is to clarify the most common issues of electric vehicles from consumer perspective. With regard to that, our base question is, whether this mean of transportation at the current state, is viable alternative to current combustion engine vehicles and possible solution to large carbon footprint of passenger vehicles. A comparison of two is therefore made, to point out the differences and positive and negative attributes. Although more issues could be present, we focus on the most important ones, that are likely to have the biggest impact on consumers behavior. Additionally, consumer surveys from various sources and regions are processed, by analyzing each individual results, to determine the key issues preventing from increase in demand for such vehicles. After determining the most common individual problems by observing the overlap in results in analyzed surveys, we can define their presence for most regions and consequently test their relevance. Relevance is tested by comparison with statistical and empirical evidence as well as most recent literature focusing on batteries and effectivity of EVs for each individual problem mentioned. The discussion then synthesizes information, define the current state, and evaluates the potential solutions.

3 Defining the key issues from consumers perspective

To better understand the key issues as perceived by consumers, we analyze the surveys held by several agencies conducted in different regions (to minimize the potential deviation effect caused by different economic development stages) and

---

[7] Reuters - Philip B.: Factbox: How U.S. electric vehicle subsidy rules impact Europe (2023)

[8] CNBC - Anmar F.: Electric car sales surged by 55% last year to surpass 10 million, and China led the way: IEA, (2023)

[9] International Energy Agency - Leonardo P.: Electric Vehicles, (2022)

synthesize them into a coherent data. By doing so, it is then possible to examine the perceived issues and state their relevance.

Although most surveys point out an increase in interest towards buying electric vehicles (which is also proven by previously stated statistic of increasing share of EVs in car sales), this does not mean, that the final consumption curve would be parallel in growth. Currently, on average at least 50% surveyed individuals do consider buying an electric vehicle as their upcoming purchase of automobile, which could be considered a trend for most developed countries. A positive exception here, appears to be a China, where 87% asked considered purchase or already purchased electric vehicle.[10] The statistics also suggest the difference, between the priority issues discouraging consumers from buying an electric vehicle, based on country economic development stage. We can expect that stage of economic development would influence the priorities of consumers, which is partially also shown in results of the surveys, leading to a fact, that price could potentially be perceived as more important issue in countries with lower average income. Up to 78% respondents from USA stated that they would not prefer an electric vehicle because of the shorter driving range than with the gas-powered one. Since range is directly obtained from recharging, 73% finds it difficult to plan or look for charging stations.[11] Globally speaking, consumers are the most concerned about range (54%), cost (51%) and charging possibilities (43%).

Based on these results, we can clearly state that there are three key issues of electric vehicles, from which other smaller ones are derived, that are preventing the increase of demand for such transportation; consumers are skeptical about the range, which they consider insufficient; initial purchase costs are noticeably higher even in similar or same vehicle categories, making them less affordable and attractive to lower and even middle-income part of population; "refueling" or recharging takes more time, is less available and needs to be planed. It is important to notice, that all the issues are in comparison with ICEVs, which are widely available and dominating since the beginning of 20th century.

3.1 Battery

Among the most common concerns, battery replacement was also very often mentioned.

Battery is very closely related to the final cost and driving range of the electric vehicles. Even though some safety concerns may apply in this matter as well, there seems to be lack of consensus of a higher danger, than in the case of ICEs.

Issue with batteries has its roots in the manufacture process and potential for energy storage. EVs in their current form use batteries which main material is lithium, (along with Cobalt and other materials such as manganese and high-grade nickel) which makes the manufacture of modern batteries still rather exhausting for resources and labor. This, naturally, influence the final cost perceived by consumers. Although active research is being conducted in effort to find a more abundant material

[10] OC&C: Hitting the brakes (2022)

[11] Emily R.: Electric Vehicle (EV) Statistics: Are Electric Cars the Future?, (2023)

substitution, currently, Li-ion (Lithium-ion) type of cells proved to be the most resilient and long lasting. Specifically speaking there is an effort to develop new batteries using two abundant, cheaper materials — sodium and sulfur.[12]

Long-lasting concern, that is still largely unsolved although improved in past decades, with every energy storage device is the natural loss of energy storage potential (ESP or "capacity") during its usage. Li-ion batteries implemented in EVs are no exception to such effect which is clearly and empirically observable by every consumer during their driving, charging, and discharging stages. Limited lifespan is stated after excessive testing by manufacturers, usually in number of cycles (amount of full discharge and charge) that they may go through before decreasing to a certain percentage level of their initial capacity. Loss of ESP is directly connected to the loss of effective driving range; therefore, a replacement is needed when range decreases to unsatisfactory level (which is usually considered to be 80% of initial). The performance (meaning top speed, acceleration) of vehicle may also be affected slightly with descending ESP. In comparison to ICEs, where loss of range during the lifespan of vehicle does not occur (or is insignificant), this could be perceived as a huge disadvantage.

The simplicity of EVs, which two key components that keeps them driving are electric motor and battery, makes the overall maintenance effective and in a way also cheap. EV's batteries (and motors), in most cases, require very little maintenance before their lifespan is reached, while vehicles with ICE requires a rather regular service checkups and replacement of key parts (which costs are not neglectable) after a given number of driven kilometers is reached. Additionally, the drivetrain in an ICE vehicle contains more than 2,000 moving parts typically, whereas the drivetrain in an EV contains around 20 parts[13]. Although their range is not affected, some statistics prove, that the cost to keep operating ICE vehicles, could reach the cost of a battery replacement for EV after several years of usage.[14] It is important to state, that this statement would need a further examination of operating costs of ICEs and EVs, and currently only serves as an indication of possible misconception.

Most EV batteries have an 8–10-year warranty or a 160,000 km drive limit.[15][16] Research labs already report up to 2,000 EFC (equivalent full cycles). Historical data from Tesla shows capacity degradation of about 5% after 80,000 km. With 2,000 cycles at 250 km each, an EV battery would be potentially good for 500,000 km (with gradual range decrease that would be still acceptable).[17] This could suggest, that the concern of replacing the batterie after a few years might not be justified.

[12] Nick C., Paul L.: EV battery makers race to develop cheaper cell materials, skirting China, 2022

[13] Forbes - Tom R.: Seven Reasons Why The Internal Combustion Engine Is A Dead Man Walking, (2018)

[14] Wolfgang R.: ADAC Pannenstatistik 2023: Wie zuverlässig sind Elektroautos? (2023)

[15] Tesla: New Vehicle Limited Warranty

[16] Volkswagen: Electric car high voltage battery warranty

[17] Battery University: BU-1003a: Battery Aging in an Electric Vehicle (EV), (2019)

Other issues that can be seen from a consumer perspective are also a temperature sensitiveness (with lower temperatures, the effectiveness of lithium-ion batteries reduces, resulting in loss of range)[18] and from environmental point of view, there could be a concern about the possibility of recycling of used batteries[19], which is still limited. Batteries also add a lot of weight to the vehicles, meaning that in general EVs are heavier and ICEs. Although this improve the stability and safety, since the center of gravity is very low to the ground, possible negative impact could be observed in faster infrastructure wear and tear.[20]

3.2 Range and charging

To this day, insufficient range seems to be the most crucial obstacle preventing from natural adaptation of electric vehicles. This subject is still very important in demand for EVs, as consumers are afraid of "flexibility" of the vehicle, meaning that it will not be reliable for a longer distance. Therefore, we will compare the average range of ICE vehicles and EV while analyzing, how much range is actually needed for average user.

Range of electric vehicles is very variable, going from as little as 125 km[21] up to 835 km per charge.[22] It is measured in Europe by a harmonized test procedure WLTP (Worldwide Harmonised Light Vehicle Test Procedure) which measures the real range of an electric car travelling at an average speed of 46.5 km/h in approximately 23 degrees Celsius temperature, from a 100% to 0% state of charge.[23] This obviously brings challenges, as the test procedure at 23 degrees and without auxiliary consumers such as the air conditioning system leads to idealized measured values. Although the certified WLTP range is not always achievable in real life, it does help to compare between different car makers and models. The "worldwide" part in WLTP might not be very accurate, as other regions apply different measuring practices, such as EPA in United States, or CLTC in China, which in a way, makes the EV range definition somehow non-harmonized and confusing when comparing the vehicles manufactured globally. Short review of real-life statistics proved, that the EPA is the most realistic one, followed by WLTP and then CLTC, which states the most optimistic values. Analyzing the EV database[24], we can state, that in most cases, the real-life achievable range is about 20% lower, then the one provided by manufacturer (in WLTP), while an additional result pointed to higher differences between real life and WLTP at higher range.

---

[18] Yazan A., Clara S., José R. S.: Effects of ambient temperature and trip characteristics on the energy consumption of an electric vehicle, (2022)

[19] Mengyuan Ch., et. al.: Recycling End-of-Life Electric Vehicle Lithium-Ion Batteries (2019)

[20] Mark P.: Electric Vehicles and The Impact On Infrastructure, (2022)

[21] Electric Vehicle Database: Mini Cooper SE

[22] Lucid: An absolute triumph of efficiency, Lucid Air achieves 520 miles of range, (2021)

[23] Electrive: How WLTP range is really calculated, (2022)

[24] Electric Vehicle Database (https://ev-database.org/)

The 5 best-selling electric vehicles in 2022[25] were Tesla Model Y (455 km WLTP)[26], BYD Song Plus (380 km WLTP)[27], Tesla Model 3 (491 km WLTP)[28], Wuling Hong Guang MINI EV (approx. 210 km WLTP)[29], BYD Qin Plus (approx. 365 km WLTP)[30]. Let's than assume, based on statistic provided, that currently, 400 km range is acceptable by consumers, when deciding between the increased price and range, as range is also directly correlated with battery, which we already stated is the crucial part of final price. Therefore, simple principle applies here; the longer the range, the higher the price, which is applicable in all situations, considering all other attributes of the vehicle stay unchanged.

With ICE vehicles, the range hasn't been for a long time a discussed matter, as the wide availability of refuel stations makes it rather non-important part of decision-making during purchase of such vehicle. Nevertheless, a median for a range on a full tank of passenger gasoline vehicles was at the 648 km for 2021 models, while maximal range peaked at 1,231 km. With EV, median stood at 377 km (EPA) while maximum mileage available was 652 km (EPA), meaning that the maximum range available barely reached the median of gasoline vehicles.[31]

A study held in 2010, which analyzed 500 vehicles patterns throughout the year revealed, that the limited-range EVs can in fact meet the needs of a significant proportion of drivers. It found that 9% of the vehicles observed, never exceeded 160 km in one day, and 21% never exceeded 241 km in one day. Importantly, this study was held in United States, which "car culture" is much more benevolent and accepting of a regular long-distance travel; we assume, that people are more in acceptance with working further from residence and are willing to travel longer distances by car (between states or for holiday) then in Europe. Therefore, this could imply, that in Europe, range of electric vehicles should be even less concerning.

Additionally, the study proved, that for drivers who would be willing to make adaptations on a few days a year, the suitable population is larger. If they are willing to make adaptations on 2 days a year, the same 160 km range EV would meet the needs of 17% of drivers, and if they are willing to do adaptation six times a year, limited-range vehicles would work for 32% of drivers.[32]

---

[25] Žiga L.: Global Electric Car Sales and Electric Vehicle Statistics (Q1 2023), (2023)

[26] Tesla.com

[27] Pedro L.: BYD Song Plus EV is the affordable alternative to the Tesla Model Y (2021)

[28] Tesla.com

[29] Qian J.: Wuling Mini EV Has Sold 1 million Units. Price Starts At 4,400 USD, (2023)

[30] Jed J. I.: BYD Qin PLUS EV 2023 Champion Edition with a range of 610km starts at 129,000 yuan ($18,893), (2023)

[31] Mark K.: US: Median Range Of 2021 Gasoline Vehicles Is 72% Higher Than BEVs, (2022)

[32] Nathaniel S. P. – et. al.: Electric vehicles: How much range is required for a day's driving?, (2011)

Although the range o 400 km might seem way too low in comparison with ICE, the future infrastructure expansion of charging stations and technological advance that would minimize the time required to recharge vehicle, would make this attribute omissible. Therefore, the “insufficient range” could be rather easily preventable in the future, by increasing the investments to charging stations infrastructure and efficiency. For house owners, this issue is not as significant, as for people living in areas, where house living is not available or less popular due to higher costs, and people have less or no options to recharge their vehicle at their residence.

More recent survey pointed out that, on average for US consumers, a charge time of 30 minutes and a range of 514 km from a single charge represent the 'tipping points' to achieve mainstream EV adoption.[33] Available statistics from European union (EU), following average distance travelled by person per day in 13 countries also pointed out, that just 12,4 km is driven daily by person on average, while drivers in Germany had the largest distance traveled (19 km/day) and drivers in Greece traveled the least (5.6 km/day).[34] Considering these distances, it is clear, that currently provided range of electric vehicles would most likely be sufficient for large part of EU population.

3.3 Price

Based on empirical data, price of electric vehicles does define the difference between buying or not buying the car for most consumers. In development of initial costs, we can observe a price reduction, due to the possibility of a wide selection of lower category models and decreasing costs of batteries.[35][36] At the same time, based on a survey data it appears that the price point still hasn’t reached a tipping point, where the EVs negatively perceived range would be overlooked for an affordability and savings during the operation.

Observing the US car market, analyzing all sales of passenger vehicles in 2023 and separating it into two categories – EVs and ICEVs, on average, new electric vehicles initial purchase cost was 20% higher, than with ICE vehicles.[37]

Somehow surprising fact that occurred in one of the survey was, that most people would be willing to accept a slightly higher price of the electric vehicle of the same quality and category as ICE vehicle, meaning that they would be willing to pay more for EVs over ICEs.[38] This may be due to several assumptions of consumers (which based on information provided in this paper are mostly correct); first, EVs are cheaper

---

[33] PRNewswire - WAYNE, N.J.: New Castrol Study Reveals 'Tipping Points' To Drive Mainstream Electric Vehicle Adoption in The US (2020)

[34] Eurostat: Passenger mobility statistics, (2021)

[35] International Energy Agency: Trends in electric light-duty vehicles, (2023)

[36] U.S. Department of Energy's Vehicle Technologies Office: Electric Vehicle Battery Pack Costs in 2022 Are Nearly 90% Lower than in 2008, according to DOE Estimates, (2023)

[37] Cox Automotive: New-Vehicle Transaction Prices Trend Downward as Incentives Rise, (2023)

[38] Electric Vehicle Council: Consumer Attitudes Survey 2021, (2021)

to drive, since the source of energy is not petrol or diesel, but electric energy which is expected to be significantly cheaper (energy crises are an exception), due to easier production. The availability could also be considered an advantage if we include a slow charging residential power along with the dedicated fast charging stations to recharge possibilities. Also, with advancing technology of photovoltaics, many households are capable of self-production of electric energy, which can be then transferred to the electric vehicle for "free" (initial cost of solar panels energy production system applies here); secondly, the expected maintenance costs are much lower with EVs than with ICEs, due to the simpler construction; lastly, the assumption that EVs are an environmental friendly alternative to the ICEVs could be observed in the responses and considered a general opinion. Given that, outwardly and during a basic usage, the average consumer does not observe any negative impact on the environment while driving the electric vehicle, the assumption is very natural. Unfortunately, the negative environmental impact of EVs is present, and is not insignificant.

Statistics provided by IEA, which compare the whole life cycle of EVs and ICEs, suggests that the emissions (that include all the emissions related to manufacture and operating of the vehicle) of EVs are at the level of 20 $tCO_{2(e)}$ on average per life cycle. In comparison to the ICEs, which add nearly 42 tons of $CO_{2(e)}$ to the atmosphere during their life cycle, EVs are more than 50% less carbon intensive towards environment (fig. 2).[39] Although this is a positive trend towards the global carbon neutrality, there still needs to be significant adjustments to manufacturing, recycling, and energy production processes, until the electric vehicles could be considered truly carbon neutral and environmentally harmless.

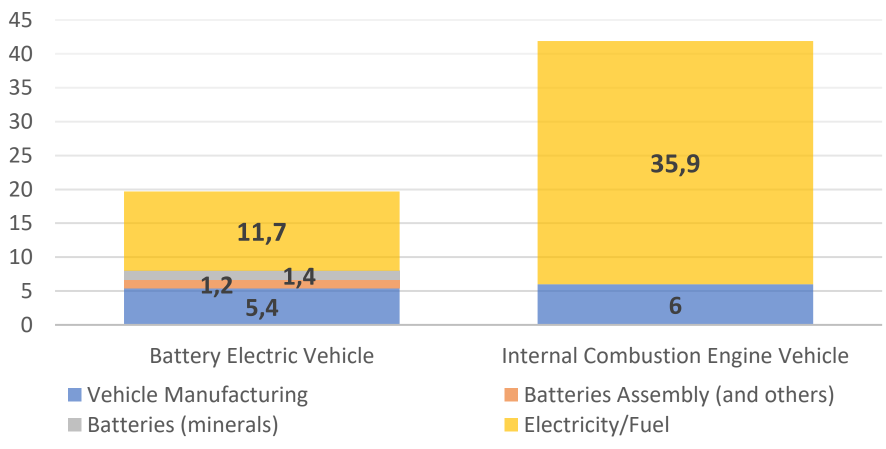

Fig. 2. Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle (in tCO_2e per vehicle lifetime)

[39] International Energy Agency: Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle (2022)

The results are also clear on financial subsidies. In each case, subsidies provided by local governments prove to significantly increase an interest towards electric vehicles. Although this attempt to support the faster transformation of transport sector is feasible in small-scale, which we are currently still experiencing, with increasing demand and manufacturers on market, natural demand with no subsidies would be required for a mass-scale transition.

4 Discussion and Conclusion

The increasing interest and demand for electric vehicles is undoubtedly a trend of 21st century. Although significant issues preventing natural transition are still present, we stated that their relevance is slowly decreasing.

In regard to range, which was one of the most expressed concerns with EVs, a great improvement could be observed, which is expected to continue. Deriving from presented status, we can define several scenarios which would need to fulfill in order to remove the “range” as a concerning attribute of electric vehicles as perceived by consumers; first the technology of batteries would need to advance in such a way, that storage of energy would be more efficient per mass, less demanding for materials and labor and easily recyclable; effectivity of electric motor and other energy demanding parts in EVs would need to increase in order to consume less energy and use it more efficiently, thirdly, the charging stations network would need to be significantly improved and easily accessible in all regions and for all EVs (standardization of charging connectors would also improve the accessibility and reduce the building cost of charging stations), additionally charging stations would need to prove to be sustainable and reliable; lastly, the amount of time to recharge the vehicle, either at residence or charging station, would need to decrease to a comparable level of a time required to refill the tank of ICE vehicle. Making EV battery a removable module is also a possibility, which is being tested by some manufacturers in China and which would allow a establishment of battery replacement stations. Such stations would have a higher potential of time saving during the swap (i.e., recharge) of the battery. Positive fact remains, that statistical data shows, that these scenarios are likely to happen in following decades concurrently. One of the less implemented options among the manufacturers, trying to increase the range of electric vehicle, is also photovoltaics (PVs). Although the efficiency of current solar panels is not at the level, where such a small potential area of placement on passenger vehicle, would make enough of a difference to the range to justify the increase in cost, some manufacturers are indeed trying to implement them in their electric vehicles.[40][41] As mentioned, the issue is that the average passenger car does not provide enough of a physical space, for solar panels to be placed on, resulting in a very limited potential of electricity production from sun. Although the size of vehicles and locations of usage differs, an

[40] Sono Motors official website (https://sonomotors.com/)
[41] Lightyear One official website (https://lightyear.one/)

example provided by one of the studies analyzing the efficiency of solar panels installed on specific electric vehicle showed, that the amount of energy, which given EV can receive per day to recharge the battery on a July day (which measured the maximum), allow to travel additional 7.98 km (EPA). On the contrary, the lowest measured amount during winter, in January, added only 1.55 km (EPA).[42] Electric vehicles consume a large amount of energy in a short time, which is also one of the reasons, why photovoltaics in its current form is unable to produce enough energy to make vehicle completely independent from grid charging. It is also very common to store vehicles outside of sun to avoid overheating of cabin or damage to the external or internal parts[43], which significantly reduces the potential of PV.

The efficiency of electric motor used in most electric vehicles is already at very high energy efficiency (90%)[44], meaning that the improvement in energy consumption is unlikely. Therefore, the issue of PVs usage in electric vehicles could be addressed in three ways; first, as larger vehicles provide more area for a placement, the potential of solar panels installment increases for trucks with trailers, buses, camper vans as well as other electric vehicles such as ships, where larger area could be used for solar energy production. This means, that PVs even in its current form, could be viable addition for such vehicles. Secondly, energy efficiency of solar panels would need to increase more significantly and thirdly, which is directly connected with efficiency, the costs would need to decrease to the level where the instalment of solar panels would not increase a final price of EV significantly. Technological advance that would result in an increased efficiency of PV could eventually lead to a fully sustainable electric vehicle that would be able to travel *indefinitely* without an external charging (i.e., charging from grid/external energy production device). This prediction can already be observed in a specific case of solar ships.[45] However, in current stage, it is hard to predict, whether the efficiency of solar panels in future could increase to the level, which would make them a regular addition to average sized passenger electric vehicles.

The issue of price might seem to be concerning and relevant at the time, but also follows a positive trend of decline. One of the supporting facts, that makes EV cheaper is, that they are always compared to the prices of ICE vehicles (rationally, as there is no other relevant substitution), which have been increasing in last decade. Some predictions assume, that EV prices could match that of ICE, in the same category and expected level of features, by the end of 2023.

Nevertheless, it is without a doubt that electric vehicles are still notably more expensive than cars with internal combustion engine. Key part, that is the most responsible for current EV prices, are batteries which makes up to approximately 30% of the final costs with most EVs. With regard to that, the expected replacement after

[42] Diahovchenko I.- Petrichenko L. – Borzenkov I. – Kolcun M.: Application of photovoltaic panels in electric vehicles to enhance the range (2022)

[43] Sunawar A. - Garniwa I. - Hudaya C.: The characteristics of heat inside a parked car as energy source for thermoelectric generators (2019)

[44] Renault Group: The energy efficiency of an electric car motor (2021)

[45] Silent Yachts official website (https://silent-yachts.com)

8-10 years puts EV batteries in even more negative position. Additionally, in case of collision and even the slightest damage to the battery, the electric vehicle would be considered not suitable for driving and will require the change of the whole battery pack.[46] Issue of battery pack damage is currently getting more attention, and could most likely be avoided in future, by splitting the battery pack into several easily repairable modules, which would then require the replacement of only the parts (modules), that were damaged during the collision. The replacement would then be connected to the remaining undamaged battery modules, which would significantly reduce the overall costs of repair.

On the other hand, the fact that batteries account for a large share of the initial price of EVs indicate, that other parts implemented in such cars are not as cost demanding as parts in ICE vehicles. Therefore, if technology allows an improvement in manufacture of battery systems and extraction of lithium (or other materials, such as sodium), making them significantly cheaper, while manufacturing processes of ICEs stays unchanged, the prices of EVs could be much lower compared to ICE vehicles in the future.

Although the electromobility has a still long way before replacing the currently dominating internal combustion engine vehicles, the statistics prove that they are in fact their largest competitor and possible successor. While issues from various areas, such as range, price, charging, energy availability and environmental footprint are still present, the demand is noticing significant increase in past decade and would most likely continue in this trend in following years.

References

1. Anmar F.: Electric car sales surged by 55% last year to surpass 10 million, and China led the way: IEA, In: CNBC, (2023), https://www.cnbc.com/2023/04/26/electric-car-sales-surged-by-55percent-in-2022-to-hit-over-10-million-iea.html, last accessed: 2023/4/25
2. Battery University: BU-1003a: Battery Aging in an Electric Vehicle (EV), (2019), https://batteryuniversity.com/article/bu-1003a-battery-aging-in-an-electric-vehicle-ev, last accessed: 2023/4/25
3. Bernadette, Ch. M., Fransiska, N.: Indonesia to provide incentives to boost EV sales, attract investment, In: Reuters, (2023), https://www.reuters.com/technology/indonesia-provide-incentives-ev-sales-starting-march-20-official-2023-03-06/, last accessed: 2023/4/25
4. Carey N. – Lienert P. – Mcfarlane S.: Scratched EV battery? Your insurer may have to junk the whole car (2023), In: Reuters, https://www.reuters.com/business/autos-transportation/scratched-ev-battery-your-insurer-may-have-junk-whole-car-2023-03-20/, last accessed: 2023/6/21
5. Cox Automotive: New-Vehicle Transaction Prices Trend Downward as Incentives Rise, (2023), https://www.coxautoinc.com/market-insights/kbb-atp-february-2023/, last accessed: 2023/4/25

[46] Carey N. – Lienert P. – Mcfarlane S.: Scratched EV battery? Your insurer may have to junk the whole car (2023)

6. Diahovchenko I.- Petrichenko L. – Borzenkov I. – Kolcun M.: Application of photovoltaic panels in electric vehicles to enhance the range (2022), In: Heliyon, ISSN 2405-8440, https://www.sciencedirect.com/science/article/pii/S2405844022037136
7. Electric Vehicle Database: Mini Cooper SE, https://ev-database.org/car/1409/Mini-Cooper-SE, last accessed: 2023/4/25
8. Electrive: How WLTP range is really calculated, (2022), https://www.electrive.com /2022/05/23/how-wltp-range-is-really-calculated/, last accessed: 2023/4/25
9. Emily R.: Electric Vehicle (EV) Statistics: Are Electric Cars the Future? (2023), https://www.driveresearch.com/market-research-company-blog/are-electric-vehicles-the-future-survey-reveals-more-than-half-of-the-country-says-no/, last accessed: 2023/4/26
10. European Comission: Zero emission vehicles: first 'Fit for 55' deal will end the sale of new CO2 emitting cars in Europe by 2035, (October 2022), https://ec.europa.eu/commission /presscorner/detail/en/ip_22_6462, last accessed 2023/4/24
11. Eurostat: Passenger mobility statistics, (2021), https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Passenger_mobility_statistics#Distance_covered, last accessed: 2023/4/26
12. Gleb S., Anastasia L., Darya K.: Russia plans to subsidise electric cars to spur demand: Russia plans to subsidise electric cars to spur demand, In: Reuters, (2021), https://www.reuters.com/business/autos-transportation/russia-plans-subsidise-electric-cars-spur-demand-2021-08-04/, last accessed: 2023/4/25
13. International Energy Agency: Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle (2022), https://www.iea.org/data-and-statistics/charts/comparative-life-cycle-greenhouse-gas-emissions-of-a-mid-size-bev-and-ice-vehicle, last accessed: 2023/5/4
14. International Energy Agency: Trends in electric light-duty vehicles, (2023), https://www.iea.org/reports/global-ev-outlook-2023/trends-in-electric-light-duty-vehicles, last accessed: 2023/4/27
15. Jacob T., International Energy Agency: Transport - Sectoral overview, Paris, (2022), https://www.iea.org/ reports/transport, last accessed: 2023/4/24
16. Jed J. I.: BYD Qin PLUS EV 2023 Champion Edition with a range of 610km starts at 129,000 yuan ($18,893), (2023), https://www.gizmochina.com/2023/04/09/byd-qin-plus-ev-2023-champion-edition-range-610km/, last accessed: 2023/4/25
17. Leonardo P., International Energy Agency: Electric Vehicles, https://www.iea.org/ reports/electric-vehicles, last accessed: 2023/4/25
18. Lightyear One official website (https://lightyear.one/)
19. Lucid: An absolute triumph of efficiency, Lucid Air achieves 520 miles of range, (2021), https://www.lucidmotors.com/stories/lucid-air-achieves-520-miles-of-range, last accessed: 2023/4/25
20. Mark K.: US: Median Range Of 2021 Gasoline Vehicles Is 72% Higher Than BEVs, (2022), https://insideevs.com/news/561634/us-median-range-gasoline-bevs/, last accessed: 2023/4/25
21. Mark P.: Electric Vehicles and The Impact On Infrastructure, (2022), https://www.forbes.com/sites/forbestechcouncil/2022/12/29/electric-vehicles-and-the-impact-on-infrastructure/?sh=3e3d26821835, last accessed: 2023/4/25
22. Mengyuan Ch., et. al.: Recycling End-of-Life Electric Vehicle Lithium-Ion Batteries, (2019), Joule, ISSN 2542-4351
23. Ministry of Economy of the Slovak Republic: MH SR zverejnilo podmienky poskytnutia dotácie na elektromobily, (2019), https://www.mhsr.sk/aktuality/mh-sr-zverejnilo-podmienky-poskytnutia-dotacie-na-elektromobily, last accessed: 2023/4/25

24. Nathaniel S. P. – et. al.: Electric vehicles: How much range is required for a day's driving?, (2011) Transportation Research Part C: Emerging Technologies, ISSN 0968-090X
25. Nick C., Paul L.: EV battery makers race to develop cheaper cell materials, skirting China, (2022), https://www.reuters.com/business/autos-transportation/ev-battery-makers-race-develop-cheaper-cell-materials-skirting-china-2022-11-15/, last accessed: 2023/4/25
26. Pedro L.: BYD Song Plus EV is the affordable alternative to the Tesla Model Y (2021), https://pushevs.com/2021/05/17/byd-song-plus-ev-is-the-affordable-alternative-to-the-tesla-model-y/
27. Philip B.: Factbox: How U.S. electric vehicle subsidy rules impact Europe, In: Reuters, (2023), https://www.reuters.com/business/autos-transportation/how-us-electric-vehicle-subsidy-rules-impact-europe-2023-03-30/, last accessed: 2023/4/25
28. Qian J.: Wuling Mini EV Has Sold 1 million Units. Price Starts At 4,400 USD, (2023), https://carnewschina.com/2023/01/30/wuling-mini-ev-has-sold-1-million-units-price-starts-at-4400-usd/, last accessed: 2023/4/25
29. Renault Group: The energy efficiency of an electric car motor (2021), https://www.renaultgroup.com/en/news-on-air/news/the-energy-efficiency-of-an-electric-car-motor/, last accessed: 2023/6/26
30. Silent Yachts official website (https://silent-yachts.com), last accessed: 2023/6/28
31. Sono Motors official website (https://sonomotors.com/), last accessed: 2023/6/28
32. Sunawar A. - Garniwa I. - Hudaya C.: The characteristics of heat inside a parked car as energy source for thermoelectric generators (2019), In: Int J Energy Environ Eng 10, https://doi.org/10.1007/s40095-019-0311-2
33. Tesla: New Vehicle Limited Warranty, https://www.tesla.com/sites/default/files/downloads/Model_3_New_Vehicle_Limited_Warranty_NA_en.pdf, last accessed: 2023/6/22
34. Tom R.: Seven Reasons Why The Internal Combustion Engine Is A Dead Man Walking, In: Forbes, (2018), https://www.forbes.com/sites/sap/2018/09/06/seven-reasons-why-the-internal-combustion-engine-is-a-dead-man-walking-updated/?sh=3b9b9460603f, last accessed: 2023/4/25
35. U.S. Department of Energy's Vehicle Technologies Office: Electric Vehicle Battery Pack Costs in 2022 Are Nearly 90% Lower than in 2008, according to DOE Estimates, (2023), https://www.energy.gov/eere/vehicles/articles/fotw-1272-january-9-2023-electric-vehicle-battery-pack-costs-2022-are-nearly, last accessed: 2023/6/28
36. Volkswagen: Electric car high voltage battery warranty, https://www.volkswagen.co.uk/en/owners-and-services/my-car/important-information/warranties-and-insurance/warranties.html, last accessed: 2023/6/22
37. Wayne, N.J.: New Castrol Study Reveals 'Tipping Points' To Drive Mainstream Electric Vehicle Adoption In The US, In: PRNewswire (2020), https://www.prnewswire.com/news-releases/new-castrol-study-reveals-tipping-points-to-drive-mainstream-electric-vehicle-adoption-in-the-us-301117318.html, last accessed: 2023/4/25
38. Wolfgang R.: ADAC Pannenstatistik 2023: Wie zuverlässig sind Elektroautos? (2023), https://www.adac.de/rund-ums-fahrzeug/unfall-schaden-panne/adac-pannenstatistik/, last accessed: 2023/5/10
39. World Resources Institute – ClimateWatch: Historical GHG Emissions, https://www.climatewatchdata.org/ghg-emissions, last accessed 2023/4/25

40. Yazan A., Clara S., José R. S.: Effects of ambient temperature and trip characteristics on the energy consumption of an electric vehicle, (2022), Energy, Volume 238, ISSN 0360-5442
41. Žiga L.: Global Electric Car Sales and Electric Vehicle Statistics (Q1 2023), (2023), https://tridenstechnology.com/electric-car-sales-statistics/, last accessed: 2023/4/25

Surveys analyzed:

42. Electric Vehicle Council: Consumer Attitudes Survey 2021, (2021), https://electricvehiclecouncil.com.au/wp-content/uploads/2021/10/2021-EVC-carsales-Consumer-attitudes-survey-web.pdf, last accessed: 2023/4/28
43. Graeme B.: What's stopping Americans from buying electric cars?, (2020), https://today.yougov.com/topics/consumer/articles-reports/2020/10/23/whats-stopping-americans-buying-electric-cars, last accessed: 2023/4/28
44. Jeff S. B.: More Americans Would Buy an Electric Vehicle, and Some Consumers Would Use Low-Carbon Fuels, Survey Shows, (2022), https://www.consumerreports.org/cars/hybrids-evs/interest-in-electric-vehicles-and-low-carbon-fuels-survey-a8457332578/, last accessed: 2023/4/28
45. Joann M.: The world's car buyers are ready to go electric, (2022), https://www.axios.com/2022/05/23/electric-vehicles-consumer-interest, last accessed: 2023/4/29
46. OC&C: Hitting the brakes (2022), https://www.occstrategy.com/media/3297/occ-hitting-the-brakes_speedometer_singlepage_final.pdf, last accessed: 2023/4/29