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GAP ANALYSIS IN ECO CATEGORIES, ELECTRIC VEHICLE COMPARISON AND SOLUTIONS TO GLOBAL TRANSPORT CHALLENGES

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Resume

Nowadays, the world is facing many challenges that require a fast environmental and energy transition, but some obstacles have been found. A gap analysis has been made and the conclusion is that there are flaws in the eco categories distribution of different types of electric vehicles. A comparison is done and the conclusions are that hybrid electric vehicles (HEVs) and plugin hybrid electric vehicles (PHEVs) with smaller batteries are the most versatile, while the battery electric vehicles (BEVs) are good primarily for urban driving. The BEVs reduce the urban pollution, but the global ecological effects are rather controversial and their usage still has many limitations. A discussion of adequate options and solutions for the transport pollution and energy problems is presented. The ultimate goal is to provoke adjustments in government transportation policies towards appropriate solutions that solve today's pollution problems in better and more adequate way.

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1 Introduction

The world is on the brink of global climate changes, rising world conflicts, energy prices and many other complex problems that require urgent solutions. The transport is one of the biggest polluters and electric vehicles (EVs) are expected to be one of the main solutions. The problem is that some of them still have many drawbacks and for that reason they cannot become an immediate solution.

Nowadays, a lot of money are invested in development of the battery technology and breakthroughs are expected in that field, but the future is uncertain and the working solutions are expected to take years until applied in real life. At the same time the whole developed world wants to make the green technology transition now. This leads to a high demand of green technologies, but low initial supply. The supply of different car building materials is under question with the rising world conflicts and the broken supply chains. At the same time, all the prices are matter of supply and demand. The low supply and high demand automatically mean higher prices. The high prices make the green technologies less competitive

and stop their widespread use. This is especially true for lithium batteries that are built of rare components. Most of the lithium nowadays comes from Asia and this could be a problem because of the rising international tensions. All the mentioned problems could stop or slow down the EV wide adoption.

One of the solutions to these problems are expected to be the hybrid electric vehicles (HEVs), but they seem to be underestimated. An earlier investigation led to the conclusion that HEVs are the best transitional option from internal combustion engine vehicles (ICEVs) to battery electric vehicles (BEVs). They are greener than traditional ICEVs, especially for the city use and one of their benefits are the comparatively small batteries. The batteries are one of the most expensive components consisting BEVs and at the same time they have comparatively short calendar and cyclic lives. Their prices are still too high and they suffer from high flammability risks. Until the battery technologies develop or their prices fall enough, the HEVs are going to be the best transitional option. The expectations are the HEVs to be economically and ecologically viable at least in the next 10 years.

The problem is that many cities in the developed world started creating green zones for the BEVs and plugin hybrid electric vehicles (PHEVs) only. At the same time the HEVs are being put in the same eco category as the regular ICEVs. This is happening in Bulgaria too and it is a problem, since BEVs and PHEVs have many drawbacks yet and most of all, they are not affordable and economically viable, which means that only a few people will buy one. Most of their problems come from the big batteries and their drawbacks. The BEVs could be used for comparatively short trips only because of lack of charging stations and other deficiencies. For such short trips, usually, there are good public transportation systems and the owning of an expensive BEV is pointless. The BEVs may become widely spread if companies for shared use of BEVs are created. There are such companies for bicycles, electric bicycles and electric scooters.

The aim of this work was to analyze different types of vehicles and to find out how environmentally friendly and competitive HEVs are compared to them. The advantages of HEVs, compared to their corresponding traditional ICEVs, prove that they should not be treated in the same eco category with the same limitations. If the HEVs have access to all already created and future city green low emission zones, this will stimulate their widespread use and will help for the faster solution of the ecological problems. Various adequate solutions to the transport pollution problems are presented. The ultimate goal is to invoke adjustments to the government transportation policies towards appropriate solutions that solve the pollution problems of today in a better and more adequate way.

2 Methodology

The main types of vehicles and their main differences are presented for use in the following analysis. The HEVs are being underestimated nowadays and this problem is considered in more detail. An analysis concerning the HEVs pollution and competitiveness is done in comparison to other types of vehicles. It is based on real measurements and calculations done by other authors and on author's research and experiences. In this regard, the actual pollution of different Euro class ICEVs is presented. Their urban fuel consumption is compared to that of HEVs and it becomes clear that the vehicle consuming less fuel must be considered as more ecological and must fall in higher eco category. The results are backed up with studies investigating how different types of vehicles behave under different road conditions. Their conclusions are that, on average, the HEVs consume a lot less fuel than the corresponding ICEVs.

An analysis of different scientific research is done that consider the emissions of different types of vehicles based on road conditions, speed, charging conditions and different levels of carbon generated by the grid. The

results clearly show how different vehicles behave in different cases. The conclusions are that the HEVs and PHEVs are the most versatile, while the BEVs are good primarily for urban driving.

Investigations concerning the current BEVs ecological effects on global and local urban levels are presented. The conclusions are that they reduce the urban pollution, but the global ecological effects are rather controversial. Their pollution might be even higher than that of ICEVs for extra-urban high-speed driving.

Everything that is economically viable is easily spread widely. This is important because people decide what vehicle to buy. In this regard, the competitiveness of the various vehicles is compared. The conclusion is that the HEVs and PHEVs with smaller batteries are the economically viable and competitive option now and their usage must be stimulated now. The finding of the right vehicle for the timely reduction of transport pollution is important, however, there are and other effective measures that can be applied now. Different adequate solutions to the rising transport pollution and energy problems are presented in a structured way in relation to each other.

The aim of the research is to provoke adjustments in government transportation policies towards appropriate solutions that solve today's pollution problems in better, safer and more adequate ways, which will accelerate the green transition.

3 Main features of different types of vehicles

Nowadays there are five main types of vehicles:

- Internal combustion engine vehicles - they run entirely on oil fuel engines and have high fuel consumption and pollution, especially in cities.
- Hybrid electric vehicles - they have a petrol engine and an electric motor and run mostly on fuel, but regenerate energy in comparatively small battery. The batteries could be NiMH or Li-Ion ones and are usually with 1.3 kWh capacities. They are a lot more fuel efficient and cleaner especially in city environments than ICEVs.
- Plugin hybrid electric vehicles - these are practically HEVs with bigger batteries. The batteries are Li-Ion and are usually with about 8 kWh capacities. In comparison to HEVs, they could be charged from the grid and have higher run per battery charge. It could be fairly stated that with good design, tailored to current battery technology drawbacks, the PHEVs could combine the advantages of HEVs and BEVs and could become the most favored transitional option to more ecological transport.
- Battery electric vehicles - they have only an electric motor and run entirely on electricity stored in a big battery. Their batteries currently are Li-Ion and usually are with capacities over 20 kWh. For

example, usually different Tesla models are with battery capacities from 75 to 100 kWh.

- Fuel cell electric vehicles - they run on hydrogen. They are not included in this analysis because our experience points out that they are still with poor competitiveness and this technology is not expected to improve much in the near future.

4 Imperfections analysis of eco categories

In 2020, the Bulgarian government changed the regulation No. H-32 for periodic examinations of the technical health of road vehicles. According to this ordinance, five ecological groups for passenger vehicles are created. The government intends to use these ecological groups for car limitations in certain green city areas. These vehicle division groups have been applied from the summer of 2021. Their aim seems to be good, however, in reality, this regulation equates HEVs with ICEVs and this is completely wrong from ecological point of view. According to it, HEVs are regular ICEVs and only PHEVs, BEVs and fuel cell electric vehicles are considered to be ecological vehicles. This incorrect classification leads to many pitfalls which are expected to hinder the expected ecological effects.

It seems that in Europe the ecology restrictions are mostly done based on the registered CO₂ emissions of the vehicles, but it is unclear if they take under consideration that the actual urban values are 30 - 50 % lower for the HEVs than for corresponding ICEVs. A study concludes that the current policies in the EU and Germany are not making use of the full environmental potential of EVs and therefore regulatory gaps have been identified. It was shown that existing policies do not differentiate sufficiently between different EVs.

While the regulatory focus on exhaust pipe emissions might be reasonable for the era of combustion vehicles, regulation risks with this current scope to turn a blind eye to the real-world carbon emissions of EVs and therefore undermine climate mitigation efforts [1].

The HEVs and ICEVs are very different technologies and their distinctions stand out especially when driving in an urban environment, where these groups should apply. At the same time, today, the HEVs are the more competitive vehicles compared to PHEVs and BEVs due to some of their distinctive advantages. Most of these advantages are due to the smaller batteries and the problems of current battery technologies. There are expectations for many of these problems to be solved soon, but they are not solved yet. There are already some promising laboratory results in this regard, but nothing has been proven in real-life tests yet and very often the real-life conditions and results are very different.

5 Environmental and costs comparison of different vehicles

The research led to the conclusion that most ICEVs, no matter if they are new or old, burn 30 % to 50 % more fuel in urban driving than in extra urban driving. This is valid for regular cars since for the more powerful models the urban fuel consumptions could be a lot more than 50 %. The difference between new and well-maintained older cars is that the new models are licensed for higher eco category which should mean that they emit less poisonous gases and CO₂ for certain amount of burned fuel. Real-life measurements of different vehicle emissions, done with Emissions Detecting and Reporting (EDAR) system, prove that in most cases the higher emission categories lead to lower release of some

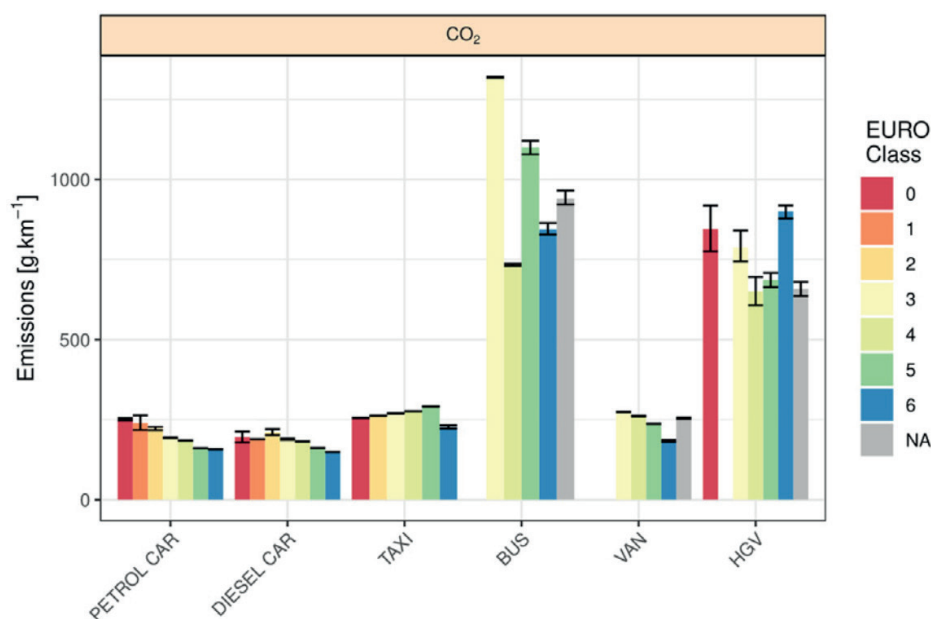


Figure 1 Average CO₂ emissions from ICEV vehicles observed during the EDAR campaigns [2]

Table 1 Characteristics of the considered powertrains [4]

Powertrain	Body type	Engine capacity, cm ³	Battery capacity, kWh	Maximum power, kW	Weight, kg
ICE	Sedan	1,798	-	103 (Petrol Engine)	1,315
HEV	Sedan	1,798	1.3	90 (System)	1,410
PHEV	Hatchback	1,798	8.8	90 (System)	1,540
BEV	SUV	-	44.5	105 (Electric motor)	1,532

of the measured gases, but not all the emitted gases are measured and the difference for some of the pollutants is not high between different Euro standards [2-3]. For example, the difference of the emitted NO_x gases should be 5 times if Euro 3 and Euro 6 emission standards are compared, but the real-life measurements show about 3 times difference. The particulate matter difference should be 10 times and the real-life measurements show about 10 %. The real-life CO₂ difference is about 10 - 20 %, Figure 1.

In comparison, most HEVs almost always burn the same amount of fuel in urban as well as in extra-urban driving. This is because every time the vehicle slows down or stops, energy is being regenerated and stored in the battery, which is being used after that. On average, the HEVs ability to regenerate energy is their major advantage over corresponding ICEVs. Due to this advantage the HEVs consume a lot less fuel in city environments than corresponding ICEVs and this cannot be changed even with major internal combustion engine (ICE) developments, because the HEVs also possess an ICE. Almost every innovation in ICE exhaust treatment systems or alternative fuel systems could be applied to HEVs, as well. If the ICEs develop further, this will improve the HEVs ecology too. If under certain rare conditions the ICEVs perform better, then for them, the driver should have the option to drive the vehicle as regular ICEV. This possibility could be created if a scientific analysis proves it to be economically viable. The research points out that modern HEVs perform better than modern ICEVs in most of the scenarios. If they do not, in certain special cases, it is a matter of better automatic or driver control.

This practically means that each HEV consumes 30 to 50 % less fuel than the corresponding ICEV models and this automatically means 30 to 50 % lower release of CO₂ and other poisonous gases in the city environment. The conclusion is that the fuel economy of a vehicle is more important for determining the eco category used for the low emission zone limitations. It could be fairly stated that HEVs are 30 to 50 % less polluting in city environments than the corresponding ICEVs from the same emission standard. Even the first HEVs, created by Toyota and licensed for Euro 2, seem to be competitive to corresponding modern Euro 6 vehicles for urban environments, but in Bulgaria they will fall into the 2nd ecological group and most likely will be restricted at some point. The real-life measurements

of regular Euro 2 vehicles show about 30 % difference in CO₂ emissions, 4 - 5 times difference in NO_x and about the same PM emissions which could be even with lower values compared to Euro 6 ones [2-3]. This means that Euro 2 HEVs are supposed to have only about 2.5 - 3.5 times higher NO_x emissions because they consume 30 - 50 % less fuel in urban environments. At the same time, they are expected to have 30 - 50 % lower PM emissions and about 0 - 20 % lower CO₂ emissions. If we consider that the NO_x gases are considered the more toxic then they could be accused to be a little more polluting than a corresponding regular Euro 6 vehicle, but the difference for urban environments does not seem to be a lot.

Real-life measurements of the HEV and ICEV fuel consumptions, driven under different road conditions, show that the HEV has 49.3 % lower fuel consumption than the corresponding ICEV for the city driving and this result overlaps with our findings [4]. On average of all the route modes, the Well-to-Wheel CO₂ emissions of HEV and PHEV and the Well-to-Tank emissions of BEV, are about 65 %, 50 % and 35 % respectively, compared to the corresponding ICEV. For extra urban driving the HEV has 35.4 % lower fuel consumption for prevalingly flat road and 31.1 % for hilly roads [4]. The characteristics of the compared vehicles are presented in Table 1. Vehicles with such parameters are widely used nowadays.

This scientific research [4] is new and such achievements are normal for the HEVs built after 2009, especially for the models built after 2015. The results seem to be great, but another study concludes that BEVs consume significant energy for heating the interior and windscreens to prevent condensation in cold weather leading to an estimated reduction in range of approximately 28 % in some situations [5]. Our experience is the same, but it is noticed that in cold weather HEVs also consume more fuel. The problem for both is partially due to the at least initially cold battery, which has lower usable capacity. A scientific investigation concludes that for increasing the range of city electric vehicles it is better to focus on a systems, which can heat the batteries to the appropriate temperature when the battery has low internal resistance [6].

Another analysis concludes that the BEVs have the lowest emissions for city driving and the highest for the high speed highway driving, Figure 2. The PHEVs are with a little higher emissions from BEVs for city driving, but with twice smaller than those of the corresponding ICEVs. They have the lowest emissions for the high-

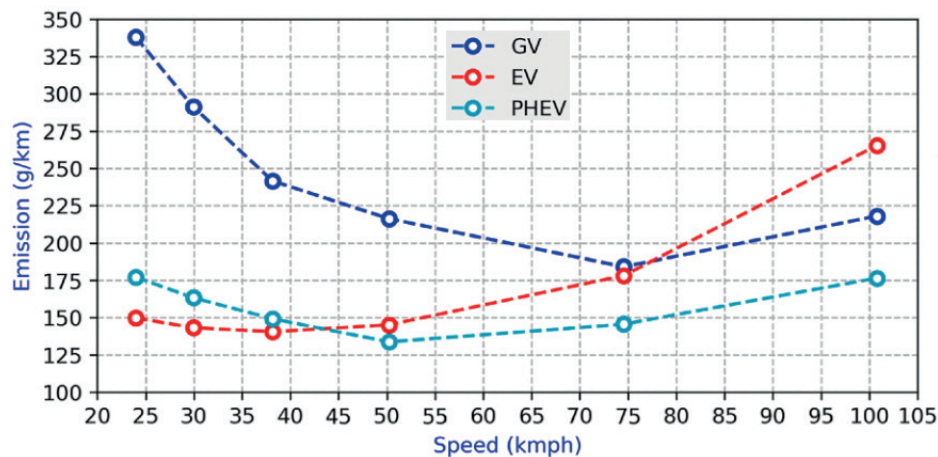


Figure 2 Emission versus speed plot of different vehicles for the Texas electricity generation mix [7]

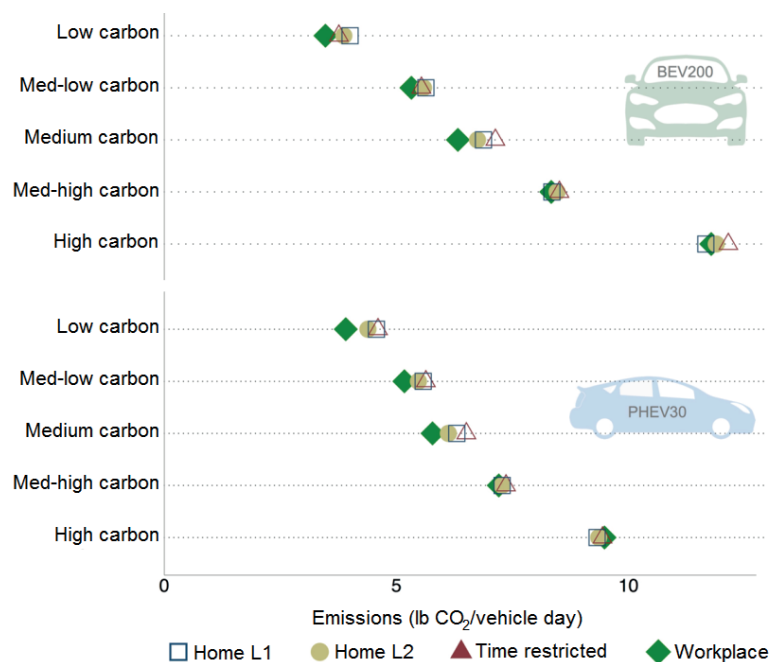


Figure 3 Total emissions per vehicle day by region, vehicle type and charging scenarios [8], BEV200 is a vehicle with 200 miles full charge range and PHEV30 is a vehicle with 30 miles full charge range

speed highway driving [7]. The energy for the BEVs charging comes mostly from conventional nonrenewable energy sources, which is the common case nowadays.

Another study concludes that the PHEVs have lower total emissions than ICEVs and yield lower total emissions than BEVs in four of the five grid types. The low-carbon grid is the only case in which BEVs have lower total emissions, Figure 3 [8]. The analysis is done for BEVs and PHEVs with different full charge electric ranges.

The studies [7-8] do not consider HEVs, but usually they have about the same or even better mixed fuel/energy consumption than the PHEVs, most likely due to their lower weight. If more kilometers are driven by electric power, then PHEVs perform better, but if they are driven entirely in hybrid or mixed mode, or if the percentage of electric kilometers part of the total is insignificant, then HEVs perform better. The HEVs

are better for prevailing long distance extra urban driving, while the PHEVs are better for prevailing short distance urban driving or close to city driving. The difference is that HEVs are with lower costs of usage because of the smaller batteries.

There is certain variation of the results of different studies, but the research led to the conclusion that most of them agree that on average HEVs and PHEVs are a lot cleaner and more fuel-efficient than the corresponding ICEVs. The difference varies depending on the road conditions, type of grid, charging scenarios, vehicle speed, vehicle types and others.

There is a certain level of disagreement between different studies, considering how clean the BEVs really are, but on average, it seems to prevail the opinion that they could be greener alternative to HEVs and PHEVs only for low-carbon grids. For low speeds in urban areas, they have a significant advantage, but for extra-

urban high-speed driving their advantage disappears. The problem is that usually the conclusions are based on a lot of calculations and approximations and it is difficult to properly take all factors into account. A study analyzes the CO₂ emissions in eight leading countries in relation to the stock of electric vehicles and concludes that, BEVs have an overall negative effect on CO₂ emissions, while they weakly and positively affect EVs [9]. Research concludes that the application of vehicles with an electric motor is ecologically justified only in cases of obtaining electricity in an environmentally friendly way and that in other cases there is no profit in an ecological sense. From an economic point of view, if there were no subsidies to manufacturers and buyers of electric cars, they would not be competitive with internal combustion engines now [10]. If we consider the fact that two corresponding vehicles need the same amount of energy to move, the ICEV will generate that energy through direct fuel combustion and the BEV will receive it from the grid. The conventional power plant also needs fuel to generate energy, but it can do that cleaner and with higher efficiency than an ICE. The problem is that this energy must be transported and there are transmission and conversion losses on the way to the final consumer. Then, it must be converted and stored in the BEV's battery and then converted again to power the electric motor. All the mentioned steps generate losses. Additionally, the battery production process is energy-intensive and dirty. The main difference is that the ICEV engines are constantly running and burning fuel, while the BEVs use energy only when needed and can regenerate some of it back. The conclusion is that the BEVs are cleaner than conventional ICEVs for lower speeds and even for predominantly high-carbon grids. For high speeds and predominantly high-carbon grids they might be more polluting even than the ICEVs.

The main sure disadvantage of the BEVs is that they are not economically viable. A contemporary study for Scotland concludes that if all diesel and petrol light-duty vehicles are replaced with BEVs, this will lead to a reduction in the total amount of carbon emissions by approximately 33.7 %, but the owners would spend about 75.7 % more money as initial costs compared to conventional cars. In the long term, electric vehicles are expected to save money to their owners, because of the considerably low price of electricity, with estimated savings of about 69.1 % per annum [5]. The ecological effect is possible only if the electricity is generated prevalingly from the renewable energy sources. The savings may not be real if the owner has to replace the battery at some point, because the new battery may cost as much as the new BEVs. The current battery shelf-lives are 15 years and the warranties are about 8 years. This means that the batteries will have to be replaced every 10-12 years and the owners most likely will have to draw away the vehicles and to buy new ones if the price of the battery replacement is about the same. Only a few can afford to buy a new vehicle

every 10-12 years and the old one drawing away will not have a good ecological effect. The BEVs receive energy from other sources and their lives are better to be extended to at least 25 years. Nowadays, the reasonable life expectancies of many vehicles are about 25 years. This limit is due to the contemporary chemicals used for winter road cleaning, that corrode all the metal parts of the cars. For that reason, at some point their maintenance becomes a burden. The conclusion is that, today, from the global point of view, BEVs cannot be cleaner alternatives compared to the other types of vehicles under consideration.

From this analysis it could be concluded that the HEVs and PHEVs are the most versatile vehicles and they are good for urban as well as for extra urban driving. The BEVs are the best for the city driving only and the ICEVs are the worst. The main disadvantage of the HEVs is that they could have higher maintenance costs, if poorly designed, compared to corresponding ICEVs, but on average, the positive effect of lower fuel consumption outweighs. The BEVs have the lowest maintenance costs if the battery replacement at certain mileage or age is not considered. The final conclusion is that the HEVs deserve to be classified in a higher eco category than the corresponding ICEVs.

6 Analysis of the limitations of electric vehicles

Most of the limitations of electric vehicles come from their batteries. The current battery technology has many drawbacks. At the same time the battery is the single most carbon-emitting component of an EV, accounting for 31 - 46 % of the total EV manufacturing emissions [11]. The widely used lithium batteries have comparatively low calendar and cyclic lives. Luckily, it seems that the cyclic life could be improved significantly with a good cooling system design, but the real calendar life implications are unknown yet.

The high flammability of the lithium batteries is another major problem. The more the electric vehicles, the more fire incidents are expected to occur. There have been already many fire incidents with Tesla EVs during car crashes. At the same time, the major fire problems usually occur during the lithium battery charging processes, especially when they get older [12-13]. If we consider that charging is expected to be done more often at home, then apartment buildings and their inhabitants for example may be threatened with higher fire risks than the usual.

The current lack of many charging stations is another major problem which is expected to be solved in the recent years. Study concludes that the potential of the PHEVs to reduce emissions is highly linked to the availability of a charging point at home or at work for regular charging [14]. At the same time, electric vehicles suffer from the long charging times and comparatively short run per battery charge. These problems currently

limit their usage to certain areas around big cities. Another problem is that not many people living in cities need a car for just city use. Usually, there are good transportation systems in cities, which makes such an investment useless in many cases.

Scientific investigations suggest that the power grid and power plants may not be prepared for the upcoming electric loads due to the expected wide use of electric vehicles. Study for the Netherlands concluded that uncoordinated charging would increase national peak load by 7 % at 30 % penetration rate of EVs and household peak load by 54%, which may exceed the capacity of existing electricity distribution infrastructure. At 30 % penetration of EVs, off-peak charging would result in a 20 % higher, more stable base load and no additional peak load at the national level and up to 7 % higher peak load at the household level. Therefore, if the off-peak charging was successfully introduced, electric driving may not require additional generation capacity, even in case of 100% switch to electric vehicles [15].

A study of Scotland estimates that approximately 4 GWh per annum of additional electricity will be needed to compensate for such growth in electricity demand [5]. New power plant and electricity distribution infrastructure projects take years for development and all of this goes on the top of the rising global conflicts and energy prices.

The PHEVs and especially BEVs have high-capacity batteries which are too expensive. For that reason, their initial purchasing costs are higher than those of the corresponding ICEVs or even HEVs. The total costs of ownership is also higher. Such vehicles could be afforded only by richer people who are a lot lower percentage of the total human population.

Almost the whole world is moving towards greener technologies and this is expected to lead to very high demand for such and surely to at least initial insufficient supply. All the prices are driven from the laws of demand and supply. At least initially, the rising economic tensions and broken supply chains are expected to reinforce the trend leading to more expensive green technologies, including batteries. This is expected to make the EVs with bigger batteries even less competitive in the short term, but the HEVs with their small batteries are competitive now. The history shows that usually only economically viable products become widespread.

Nowadays, there is no proven and established economically viable technology for the lithium battery recycling. This leads to many ecological problems in the short term and could lead to high level of stored lithium battery garbage. The easy availability of raw materials used in manufacturing batteries at a lower costs as compared to the recycling costs is the prime factor to impede the battery recycling market growth, but it is expected to grow by 2030 anyway due to rising use of the EVs [16]. At the same time the HEVs have small batteries, which could be of the proven NiMH type,

which are also with very low flammability risk compared to the lithium ones.

All the mentioned problems are going to stop or considerably slow down the greener more ecological transport initiatives. It is necessary that the obstacles standing on the way of the widespread use of HEVs to be eliminated. They are the cleaner and more competitive transitional vehicle which will support a greener transport system, at least for the next 10 years. Their purchasing and usage must be stimulated until better, the real-life proven and economically viable technology appears. The conclusions are confirmed by study, estimating that only about 30 % of the worldwide passenger vehicle fleet will be the EVs in 2032. However, results also display vast differences between countries, which can particularly be attributed to divergences in governmental support [17].

7 Discussion of options and solutions for the transport pollution

All the suggested solutions are product of the experiences and many investigations done during the years.

The main problems of the EVs are the expensive batteries, which have comparatively low calendar and cyclic lives and the limited run per battery charge. The battery problem is expected to be solved in the up-coming years because a lot of money are invested for the development of battery technology. There are already breakthroughs in the field. The NMC532 lithium battery cell has been projected to have 100 years of lifetime for 20 °C work temperature [18]. The real lifetime is expected to be lower, but this is amazing achievement considering that the current lithium battery technology allows 15 years of calendar lifetime. It will take time for this technology to be applied and tested in real life.

A proper initial solution could be the PHEVs with big enough batteries for certain run entirely in electric power for city usage. Our experience points out that 20 - 40 km run is enough for most of the small and medium size cities, but different configurable options could be created for different cities, based on investigations. The idea is the battery to be with comparatively low capacity for the lower driving costs but with enough capacity for the daily needed electric city driving. Such a car would be versatile and economically viable and will help a lot for the timely ecological problem solution. Current HEVs are with very small batteries, about 1.3 kWh, which is enough for only about 5 km run and they cannot be charged from the grid. The PHEVs are usually with larger batteries than necessary. Often, they have batteries with about 8 kWh capacities. We suggest that in most cases the PHEVs with battery capacities of about 4 - 5 kWh are enough. This will allow for comparatively lower total ownership costs and for greener inter city transportation.



Figure 4 The Sion - the car that charges itself [19]

The problems with the overcharged power grids and insufficient or conventional power generation could be partially overcome by integration of photovoltaic systems on the outside of the car bodies. The company Sono Group N.V. have already created such vehicle. They have seamlessly integrated 456 half photovoltaic cells into the body of the car, that can add 112 km, on average and up to 245 km per week, of driving range to the car's battery, through the power of the sun, Figure 4. This creates full self-sufficiency on short distances [19].

Certain recent developments in internal combustion engines could also become a solution, but every new development takes time to be applied in practice. For example, a team from the University of New South Wales has retrofitted single-cylinder diesel engine to run on 90 % hydrogen which led to 85.9 % CO₂ reduction and 13.3 % indicated mean effective pressure/efficiency increase [20]. The main problem with hydrogen is that it is highly explosive and it could harm many in the case of a road incident. Our view is that hydrogen can be used as alternative fuel only when the production technology has developed sufficiently to allow efficient real-time production in the vehicle. Moving vehicles with hydrogen tanks are practically moving explosives.

The fuel and energy consumptions of all types of electric vehicles could be improved by better utilization of inertia. The previous research led to the conclusion that from 6 to 15% improvement of the run per battery charge is possible. This could be achieved with comparatively simple change of the vehicle control. It is suggested the gas pedal to be used only for acceleration and the stop pedal to be used only for two levels of regeneration and stopping with the brake pads. When neither one of the pedals is pressed the vehicle should move in automatic neutral gear. This will allow the driver unintentionally to better use the vehicle inertia because only the driver knows what is going to happen next on the road.

The governments should invest in a green and convenient public transport systems, which are often cheaper than the private vehicles for city use. A study analyzes the synergy and co-benefits of reducing the CO₂ and air pollutant emissions by using electric private cars, taxis and buses in Shanghai. The results

show that electric buses provide the highest co-benefits. Thus, replacing traditional fuel vehicles with electric buses can simultaneously reduce air pollution and CO₂ emissions [21]. The public transport systems from smaller settlements to the near big cities should also be improved. They are rather poor in Bulgaria. The proper solutions are electric trains, trams, buses and trolleybuses. The battery technology is expected to offer lithium batteries with very high cyclic lives soon.

The smart traffic light control based on current traffic measurements and the creation of green light waves could also help a lot. In this regard the tendency the speed limits in urban areas to be lowered should be discontinued. The too low speed limits are bad for ecology because all the vehicle types use more energy for their movement. Speed limits of 30 to 60 km/h are a good balance between safety and vehicle economy. A study concludes that CO₂ emissions are minimum at 75 km/h for the ICEVs, at 38 km/h for the BEVs and at 50 km/h for PHEVs [7]. Better maximum speed control should be applied for the higher urban transport safety instead of lower speed limits.

In USA often there is a permission for right turn on red traffic light, which helps in some cases for easing congestions.

Safe bicycle and electric scooter transport networks should also be developed in cities, as well as between them. In Ruse city such has been created recently and it seems that more and more people are using bicycles or scooters. Such bicycle road networks should also be created from the smaller settlements to the big cities, because almost all the people living there travel daily for work. If there are safe and good road conditions many will start using greener and better for their health transport means.

Another option are the affordable short period rentals of electric bicycles, electric scooters as well as electric cars for the city or close to city use. Study concludes that 13 % of the daily car trips, corresponding to 2 % of the car kilometers in Germany, are suitable for replacement. At the same time, the E-scooters are estimated to have twice lower greenhouse gas emissions than EVs for their lifetime [22]. Mass uptake

of e-bikes could make a significant early contribution to transport carbon reduction, particularly in areas where conventional walking and cycling do not fit journey patterns and bus provision is relatively expensive [23]. Research concludes that electric bicycles are the finest development in our ever congested world and provide an easy solution to daily commute woes. They save a lot of fuel and keep the environment clean, but also help people develop good health with little pedal exercise [24].

The extra urban riding speed limits of electric bicycles and scooters should be 50 km/h, the same as that of mopeds. The problem is that 40 km/h can be maintained with a high quality road bicycle on an even road for a long period of time; 50 km/h are also easy to achieve, but for short periods of time. This is the reason why mopeds are limited to 50 km/h. If such speeds could be achieved easy with regular bicycles and they are not dangerous then they should be possible for extra-urban driving and they will stimulate the wide spread use of the greener two-wheeled vehicles. The 25 km/h speed limit is good for city uses on bike lanes, but if the electric bicycles must share the road with cars, then the city speed limits of the automobiles (maximum 50 km/h) should apply in these cases because riding with speeds close to those of the other vehicles is safer.

The high ownership price of electric vehicles and the other problems related to batteries could be overcome with affordable shared use of rented EVs. In such cases the price will also be shared. The batteries will not be allowed to get older and their live cycles will be better used because the vehicles will be constantly used by someone. The prices for all ownership taxes will also be shared. In this case, the maintenance costs could also be lower. Better electricity rates can also be negotiated by the rental company. This would also solve the problem with the home charging of the flammable lithium batteries. This will lower the usage costs of the shared EVs and is expected to make them cheaper for driving compared to the expenses related to ownership.

All the measures are expected to have a strong ecological effect.

8 Conclusions

The HEVs and PHEVs with smaller batteries are the only economically viable solutions of the transport pollution problems today and their usage should be stimulated instead of limited. They can help for the solution of the rising ecological problems and those related to rising energy prices now. This is not expected to change in the next 10 years although there are some new breakthroughs in the battery technology.

Today, the BEVs are not economically viable and possess many drawbacks, mainly due to their big batteries. They will become cleaner and viable alternative only when the energy production shifts to predominantly renewable sources, when enough energy

could be produced and distributed, when longer lasting batteries are designed and when a good charging network is created. Due to the rising world conflicts and tensions, it is expected energy prices to rise and energy production processes temporarily to regress towards conventional energy sources. This means that in the near future the BEVs may not become neither affordable nor cleaner solution. Their only advantage today is that they could lower the local air and noise pollution in urban areas. A study concludes that from the local point of view the electric vehicles can contribute to reduction of CO concentration in densely populated areas. However, from the global point of view, using the electric vehicles does not weigh in on slowing down the global warming [25].

The conclusion is that the HEVs, PHEVs and BEVs ownership and usage should be equally stimulated. Low emission city zones could be created, but HEVs, PHEVs and BEVs should have equal access to them, or a convenient green public transport system must be created together with the cheap enough short term BEV rental services. There are many solutions to the ecological and energy problems and all the decisions in this regard should be well balanced and should be based on what is possible and appropriate today.

Further country-based research is needed on the actual local pollution and competitiveness of the BEVs, depending on their energy mix. In terms of public transport, a local comparison of the pollution and competitiveness of electric trains, trams, buses and trolleybuses is also needed. There are still shortcomings in the control of electric vehicles and further research and improvements are needed in this regard. Battery technology is evolving rapidly and a continuous search for less flammable batteries with longer calendar and cycle lives is needed. For example, the Lithium Nickel Manganese Cobalt Oxide batteries are widely used in EVs today because of their high specific energy, but they are with higher flammability risks too. The Lithium Iron Phosphate batteries are with close characteristics, with a little lower specific energy, but with considerably lower flammability risks and for that reason they are the safer solution today. Considering the EVs, there are many issues that need to be explored for better solutions.

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Conflicts of interest

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