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PROSPECTS OF ELECTRIC VEHICLE TECHNOLOGIES: A COMPREHENSIVE REVIEW

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Abstract. The development and renewal of the transport sector is a continuous and never-ending process. The technological revolution in the automotive industry has been discussed for a while. Vehicles with internal combustion engines, which are considered to be polluting, should be replaced by non-polluting or significantly less polluting ones. Recently, European countries are experiencing a major energy crisis. Both petroleum products and electricity are becoming more expensive, so vehicle consumers are increasingly asking the question, which is better: a vehicle with an internal combustion engine or an electric vehicle? This article examines the possibilities and perspectives of the development of electric vehicles in Lithuania, based on the best practices of other countries.
Keywords: electric vehicle, electric vehicle types, electric vehicle infrastructure

INTRODUCTION

Transport is one of the main sources of negative environmental impacts, contributing significantly to climate change. Vehicles are mentioned among the biggest sources of environmental pollution, and stricter environmental requirements to reduce air pollution are encouraging world manufacturers to invest in the production of more environmentally friendly electric vehicles (further EVs). State benefits and support for the purchase of EVs are growing the market of former in Lithuania as well. It must be understood that the evolution of EVs is quick and it will shape the future although it seems to be slow. The shift from internal combustion engine vehicles to electric is bringing benefits across the country. Manufacturers are tied to consumers – they try the consumers‘ requirements, and consumers are becoming more aware, become more and more careful about the environment. Electric vehicles will help to eliminate transport pollution: no one has probably come up with another option yet, so consumers appreciate it, technology is moving forward and, of course, technological evolution is accelerating the inevitable.

There is no doubt that driving an electric vehicle is modern and advanced. EVs are associated with the growing trend of clean technologies. Therefore, many countries have implemented new energy vehicles as alternatives to conventional vehicles to reduce the dependence on oil and air pollution caused by conventional vehicles (Sun et al, 2019). The so called oil tycoons are investing in green energy, the electric vehicle industry, solar panels, and etc. In 2022, due to the changed geopolitical situation, Europe experiences energy crisis, which may slow down the already accelerated production of electric vehicles and other new technology as well as infrastructure development. With the increasing use of EVs the efforts of European Union countries to increase renewable resources, reduce dependence on fossil fuels and environmental pollution. Each state must have a strategy to promote the increase in the number of electric cars and the development of electric car infrastructure. So the aim of the article: to present an analysis of electric vehicles operated in Lithuania and to examining the main prospects for the development of electric transport. The methos employed.

TYPES OF ELECTRIC VEHICLES

Electric Vehicles (EVs) are gaining momentum due to several factors, including the price reduction as well as the climate and environmental awareness (Sanguesa et.al, 2021). Currently, it is popular to classify electric cars into several types. Electric vehicles (fully or partially) are divided into four types: hybrid vehicles (HEVs), plug-in hybrids (PHEVs), extended-range hybrids (REVs) and pure electric vehicles (BEVs).

HEV – Hybrid Electric Vehicle. This type of vehicle has significantly better fuel economy than internal combustion engine vehicles, but the electric motor in this type of car basically performs only an auxiliary function. For this reason, many experts do not consider HEV vehicles to be electric ones. Currently, most of so called electric vehicles (that use an electric motor) in operation are HEV-typed.

PHEV – Plug-in Hybrid Electric Vehicle. This type of vehicle has both an electric and an internal combustion engine. Plug-in hybrids can travel a considerable distance on the electric motor alone. When using this vehicle in the city, the electric range can be completely sufficient for a day's driving needs. When the battery is discharged, the internal combustion engine starts working. "Parallel" mode is also possible, when the electric and internal combustion engines work at the same time. Unlike HEV cars, plug-in hybrids can be charged from the mains.

EREV – Extended Range Electric Vehicle. The main feature that distinguishes the REV-type electric vehicles from the PHEV is that in the REV"s internal combustion engine is not connected to the axles of the vehicle and is not the direct driving force of the car. The REV vehicle is always powered by an electric motor, and the internal combustion engine is only used to spin the electric motor's generator when the battery is discharged. Extended-trip hybrids have a greater range in electric mode than PHEVs.

BEV – Battery Electric Vehicle. A fully-electric vehicle is powered exclusively by an electric motor. For this purpose, the battery capacity of this type of vehicle the highest. Because BEVs do not use fossil fuels at all, BEVs offer the highest environmental benefits and fuel economy of any type of electric vehicle.

The operation diagrams of the power units of these electric vehicles are presented in Figure 1.

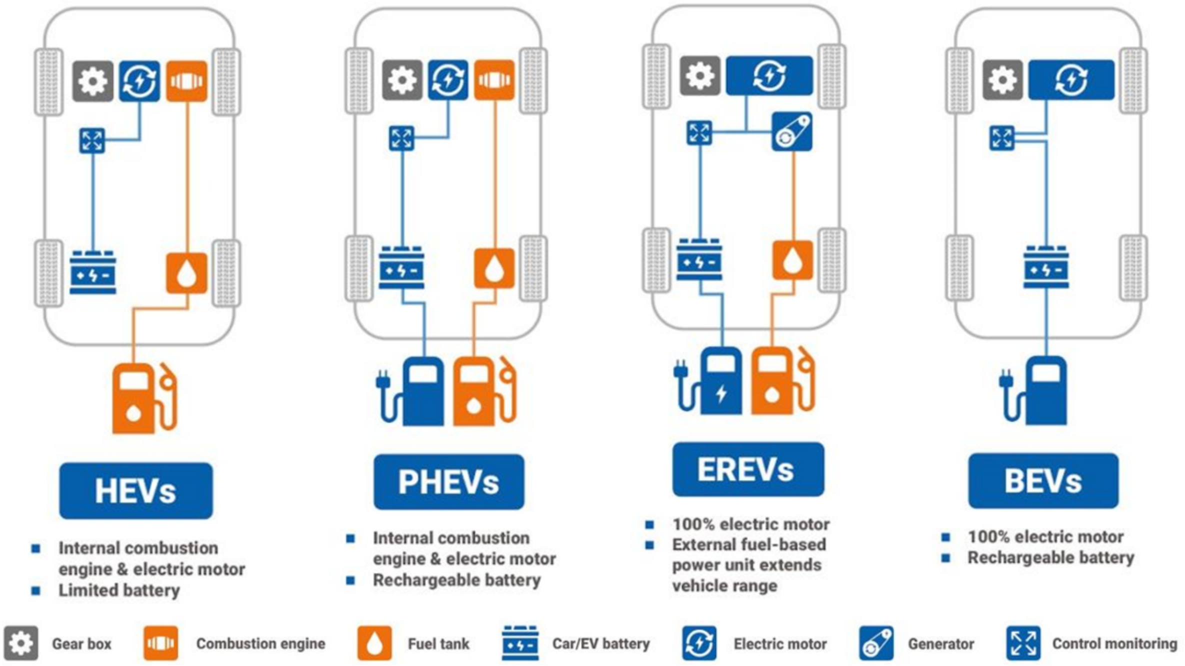

Figure 1. **Different types of electric and hybrid vehicles (Larnie et al., 2013)**

After examining the types of electric vehicles, it can be concluded that the electric technology vehicles currently produced and on the market can meet the needs of various users. Different electric vehicles could meet the needs of the vast majority of drivers in terms of range and driving characteristics and the road infrastructure required for electric vehicles. That is, the user has a choice for both city trips and country trips.

ELECTRIC VEHICLE BENEFITS AND CONSIDERATIONS

The transition from VDV vehicles to electric generate brings benefits across the country. This section explores at the areas where electric vehicles provide benefits.

Economic benefits due to lower carbon dioxide (CO_2) emissions – depending on the type, electric vehicles either do not emit CO_2 at all, or emit significantly less compared to CEs (Combustion engine) vehicles. In this way, the country receives economic benefits due to cleaner air, lower population diseases and the possibility to sell unused CO_2 emission allowances (or less need to "import" emission allowances). In this way, the country receives economic benefits due to cleaner air, lower population diseases and the possibility to sell unused CO_2 emission allowances (or less need to "import" emission allowances). However, it must be noted that when despite the fact electric vehicles come to the lower CO_2 emissions, it should be taken into account that the electricity generation process can emit large amounts of CO_2 into the environment, depending on the type of generation. Thus, the overall CO_2 emissions savings depend on the country-specific distribution of electricity production by fuel sources. Other point to stress is that electric motors reduce dependence on oil – compared to combustion, the electric ones do not use (or use significantly less) fossil fuel for driving. This means less fossil fuel consumption across the country. This is extremely relevant for countries dependent on oil imports, since in the long term, electric vehicles can significantly contribute to the achievement of energy independence.

Balancing of electric grids is one more benefit worthy to mention. On the one hand, the high prevalence of EV means an additional load on the country's electric grids, but at the same time, EV also mean new opportunities for efficient management of electric grids. The majority of EV charging is likely to occur at night, when there is a demand for electricity decreases (especially if a large share of the country's electricity generation comes from renewable resources such as wind power). Thus, EV can help to ensure a more even curve of daily electricity consumption, especially if smart grid technology is implemented, which would allow regulate of the charging time of EV's optimally and to take electricity from the EV back to the grid during times of high grid load. In this way, the use of EV can help to avoid additional investment in power grid capacity. Opportunity to get into the EV industry is still in its infancy. This provides an opportunity to develop an industry and create the EV value chain even for countries that had historically no automotive production experience.

ASSESSMENT OF THE EV DEVELOPMENT IN LITHUANIA

Renewable energy projects are rapidly developing in Lithuania. The country is one of the leaders in the development of renewable energy throughout the European Union. EV's still make up a small part of all passenger cars sold in Lithuania, but their popularity is growing. 230 thousand EV and 60 thousand charging accesses for charging power of which will reach about 1000 MW - all this is planned to be available in Lithuania as early as 2030. Lithuania is one of the leading countries in Europe in terms of the number of registered vehicles per thousand inhabitants. It should be emphasized that this information distorts the real situation of the fleet: in the absence of effective vehicle taxes in Lithuania, a significant part of vehicles are unused cars. The high vehicle taxes applied in other EU countries allow to reduce the risk of providing inaccurate data: fleet data reflect the vehicles in use. Thus, Lithuania does not occupy a leading position when evaluating the fleet of vehicles in use. Comparing the total number of cars with internal combustion engines to electric vehicles, Lithuania in the context of European countries looks like a lagging country in terms of the development of EV's. This chapter presents an analysis of the fleet of EV's in Lithuania: the dynamics and development is illustrated by the graph presented in Figure 2.

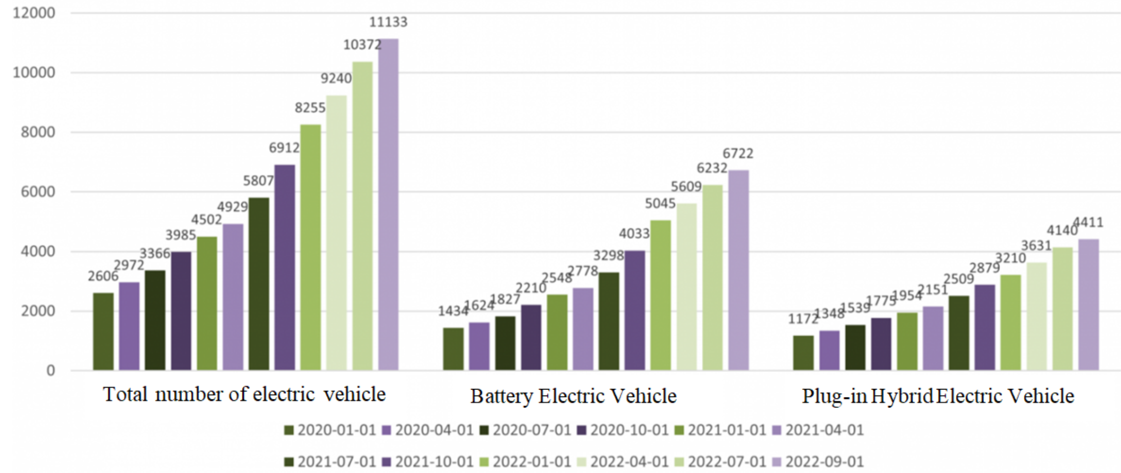

Figure 2. **Changes in the number of electric vehicles in classes M1 and N1 between 2020 and 2022. Class M1 vehicle for the carriage of passengers with a maximum of 8 seats for passengers and 1 seat for the driver (passenger car). Class N1a vehicle for the carriage of goods with a total mass not exceeding 3,5 t (lorry)** (https://sumin.lrv.lt/lt/kita-veikla/kita-veikla/pletra-ir-inovacijos/elektromobiliu-skaicius-lietuvoje)

According to the date provided by state enterprise „Regitra“ 11,133 M1 and N1 class EVs were registered in Lithuania by September 1st, 2022. 6,722 of them were fully-electric (BEVs), 4,411 externally charged hybrid vehicles (PHEVs) and also 48634 M1 and N1 class hybrid vehicles (HEVs) (https://sumin.lrv.lt/lt/kita-veikla/kita-veikla/pletra-ir-inovacijos/elektromobiliu-skaicius-lietuvoje). Thus, a steady increase in electric vehicles is noticeable.

The supply of electric cars has recently been meeting the needs of consumers. In 2022 the number of registered fully - electric vehicles (BEVs) of the most popular (M1 and N1 class) is shown in Figure 3.

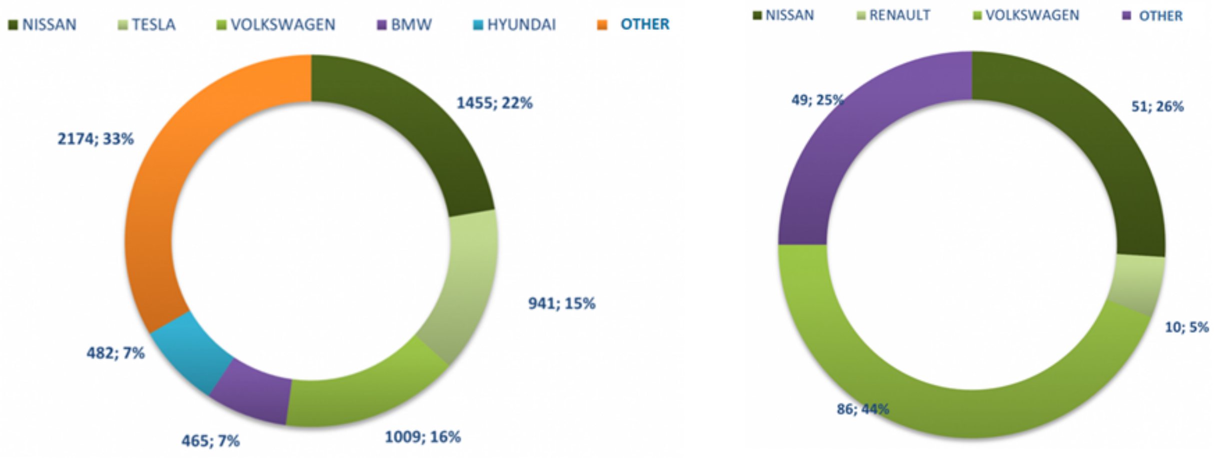

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Figure 3. **Models of electric vehicles registered in Lithuania during 2022: (a) M1 class, (b) N1 class** (https://sumin.lrv.lt/lt/kita-veikla/kita-veikla/pletra-ir-inovacijos/elektromobiliu-skaicius-lietuvoje)

Analysis of the number of different EV shows (Inci et. al 2021) various operating parameters that can influence the price of 1 km driven and the choice of consumers. Currently, up to 30 BEV and PHEV-type models can be counted on sale.

The following compares some of the most famous current models of EV mostly sold in Lithuania: Nissan Leaf, Mitsubishi i-Miev., Renault Fluence Z.E., Renault ZOE, Renault Kangoo Z.E., Tesla Roadster, Chevrolet Volt. Table 1 shows a comparison of the listed models according to their technical characteristics:

Table 1

Technical characteristics of electric car models (See Complex electric vehicles feasibility study on transport development)

Model	**Type**	**Maximum speed, km/h**	**Engine power, kW**	**Battery capacity, kWh**	**Distance traveled on a single charge, km**
Nissan Leaf	BEV (M1)	130	80	24	117 – 161
Mitsubishi i- Miev	BEV (M1)	130	47	16	100 – 160
Renault ZOE	BEV (M1)	135	65	22	130 – 210
Renault Kangoo Z.E.	BEV (N1)	130 (with limiter)	44	22	160
Renault Fluence Z.E.	BEV (M1)	135 (with limiter)	70	22	160
Tesla Roadster	BEV (M1)	200	53	22	393
Chevrolet Volt	REV (M1)	160	111 (el. engine	16	40 - 80 el. engine (up to 610 in total)

Analysis of the main technical characteristics of EV shows that these can travel more than 100 kilometers on a single charge and can fully meet the needs of city driving this is also confirmed by the results of pilot projects carried out in foreign countries (Pevec, Babic, Podobnik, 2019;). The example of the Tesla Roadster model demonstrates that there are all the technological possibilities for EVs to match or even surpass cars with internal combustion engines, in terms of speed, driving quality and driving distance. Thus, according to the technical characteristics of EV, the user has reasons not to choose an electric vehicle. The small increase in the number of electric cars can be explained by to completely different factors. Almost 10 years ago, poor technical characteristics were named as the main disadvantage of EVs: low power, low distance covered by one charge, etc. User surveys show (Anfinsen et al. 2019; Zeinab et al. 2015) that currently there are other reasons preventing the purchase of EV: price, lack of charging infrastructure, small class and unsuitability for family trips. Respondents also name human reasons, i.e. lack of trust in new technologies. In recent years, one of the main reasons, named by many interviewees is energy crises, that is, expensive electricity, which affects the charging adjusts the demand for already much more expensive cars.

CONCLUSIONS

The analysis of the Lithuanian electric vehicle fleet showed that since 2017, all types of electric vehicles have been in operation: HEV - Hybrid Electric Vehicle, PHEV - Plug-in Hybrid Electric Vehicle, EREV - Extended Range Electric Vehicle; BEV - Battery Electric Vehicle.

After performing a statistical analysis of electric vehicles for 2020-2022, it was determined that the total number of EV's in Lithuania is increasing every year: from 2020 to 2022, the total number increased by 2.7 times. Pure electric vehicles (BEVs - Battery Electric Vehicles) are also being registered every year. From 2020 to 2022, the number of pure electric vehicles increased 3 times, and the number of plug-in hybrid electric vehicles (PHEVs) increased 2.4 times.

In 2022, the most popular M1 class electric vehicle was manufactured by "Nissan". This represents 22 percent of the total number of electric vehicles. The most popular model of Nisan was "Nisan Leaf". 16 percent of the electric vehicles registered (M1 class) were Volkswagen" models: "Volkswagen UP" and "Volkswagen Golf". The rest 15 percent were manufactured by Tesla. The most popular models were considered to be Model S, Model X and Model 3.

In 2022, the most popular electric vehicles in the N1 class segment were produced by Volkswagen. This accounted for 44 percent of the total number of registered electric vehicles. Respectively 26 percent were manufactured by "Nisan". The third place in terms of popularity was occupied by Renault's N1 class electric vehicles, which are practically non-existent in the M1 class segment.

Analysis into the main technical characteristics of electric vehicles showed that the ones can travel more than 100 kilometers on a single charge, so can fully meet the needs of city driving. The survey of also revealed that many potential electric vehicle buyers cited low range on a single charge as the main deterrent to purchasing an EV. Other reasons were for that also were named: the high price of electric vehicles and the lack of charging infrastructure. Recently, many electric vehicle users have named another reason: high cost of charge.

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