UDC 339

INFRASTRUCTURE FOR ELECTRIC VEHICLES

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Abstract. *The study reveals the advantages of electric vehicles and the specifics of their maintenance. The focus is on the types of charging stations and whole infrastructure for electric cars in Ukraine. The level of development of infrastructure for electric transport in Ukraine and Poland is analyzed in the end.*

Electric vehicles (EV) are becoming increasingly popular among drivers who want to reduce their environmental impact and save on fuel costs. New technologies and growing environmental awareness are leading to an increase in the production and sale of electric vehicles.

An electric car is a vehicle driven by an electric motor powered by a battery rather than an internal combustion engine. Thus, an electric car should be distinguished from a car with an internal combustion engine that uses fuel, as well as from a trolleybus, since a trolleybus must be constantly connected to the overhead power grid to supply electricity, and thus can only move within the infrastructure available to it [1].

The key advantages of electric vehicles are:

- no exhaust gases;
- noiselessness;
- even if the energy used by an electric car is generated at a thermal power plant, the total CO_2 emissions will be 40-50% less than the total emissions of a gasoline car, since the efficiency of an electric motor is 85-95%, and the efficiency of a gasoline engine does not exceed 30%;
- the price of electricity per 100 km is 5-10 times lower than for fossil fuel, and it depends on the time of day when the battery is charged. This difference will increase as the price of petroleum products rises;
- the development of electric vehicles is a strong impetus for the development of renewable energy sources;
- an electric car is a simpler vehicle than a traditional one, as it has many fewer moving parts. And this will lead to a constant reduction in the cost of electric vehicles, their maintenance and repair with the growth of their mass production [2].

There are several EV types, each with a unique engine and settings (Table 1) [3]:

Table 1 - Classification of electric vehicles (EVs) according to engine technology and settings

Types	Characteristics
Battery Electric Vehicles (BEVs)	Rechargeable batteries are the only power source for BEVs, which are electric automobiles. They don't have a backup generator or a petrol engine. Due to their lack of exhaust emissions, BEVs are regarded as the most ecologically beneficial form of electric car. However, they have a constrained driving range because the battery must be recharged.
Hybrid Electric Vehicles (HEVs)	HEVs are electric cars with petrol engines and electric motors. An electric motor propels the car at low speeds and during acceleration. The petrol engine takes over at higher speeds and when greater power is required. Because HEVs utilize regenerative braking to recharge their batteries, they do not require plugging in. Although they use less fuel than conventional petrol cars, they have some exhaust emissions.
Plug in Hybrid Electric Vehicles (PHEVs)	Hybrid electric vehicles with bigger batteries that can be recharged by plugging a charging cable into an external electric power source in addition to internally by their on-board internal combustion engine-powered generator are called plug-in hybrid electric vehicles (PHEVs). They have a finite range of operations on electric power before switching to the petrol engine. PHEVs provide the ease of daily driving without a plug while allowing for electricity usage or on short journeys.
Fuel cell electric vehicles (FCEVs)	FCEVs react hydrogen gas with oxygen in the air to create power. They don't have a battery, and their sole waste is water vapor. Although FCEVs can be refueled in a few minutes and have a greater driving range than BEVs, there is still a lack of hydrogen refueling infrastructure.
Extended Range Electric Vehicles (ER-EVs)	There are a type of electric vehicle that combines the features of a Battery Electric Vehicle (BEV) and a Plug-in Hybrid Electric Vehicle (PHEV). ER-EVs have a larger battery pack than PHEVs, which allows them to travel longer distances on electric power alone. However, once the battery is depleted, a small gasoline engine generates electricity to power the electric motor and extend the vehicle's range.

Now, let's define what a charging station is. According to the dictionary a charging station means an apparatus or facility with one or more electrical outlets for recharging the batteries of electric vehicles [4].

Figure 1 shows the charging station model [5].

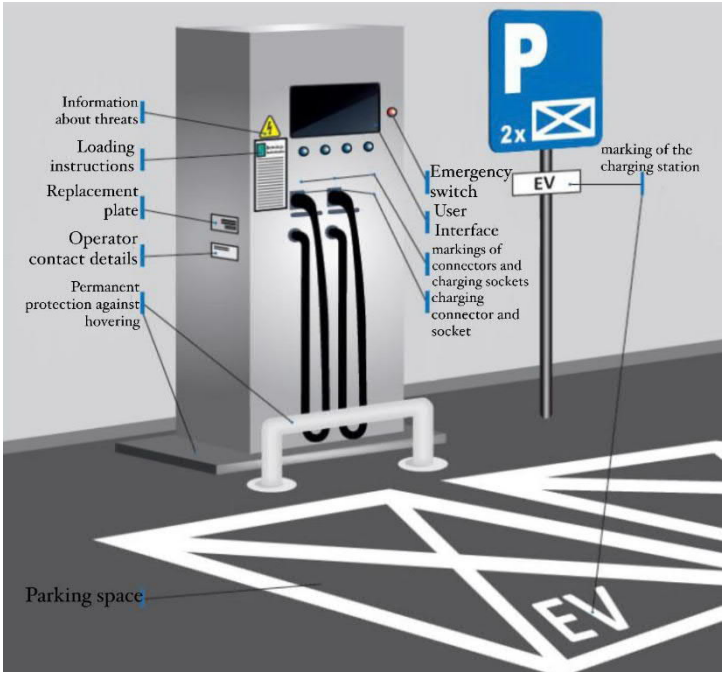

Figure 1 - Charging station model

There are four main types of charging stations for electric vehicles, as well as one highly specialized installation [6]:

- Mode 1. An outdated modification. The principle of operation of the charging station for electric vehicles of this group is based on the conversion of alternating current, for which a special adapter is used. It can be connected to a household outlet without auxiliary adapters. Charging takes 12 hours or more, depending on the battery capacity. They are gradually falling out of use due to low security.
- Mode 2. A standard model that uses alternating current. It is suitable for domestic or commercial use for various types of electric vehicles equipped with standard connector connectors. The main difference is the presence of a built-in protective unit incorporated into the cable design. Charging time is 6-8 hours for a battery with a capacity of 20-24 kWh.

- Mode 3. Models with maximum power under the conditions of AC use. Compatible with Type 1 and Type 2 connectors for single-phase or three-phase power supply, respectively.
- Mode 4. These are fast charging stations for electric vehicles that use direct current during operation. They have increased power, and therefore are not suitable for all models of electric vehicles. If a car fits the standard, it takes 30-40 minutes to charge it to 80%. The main installation locations are city parking lots or gas stations along major roads. The disadvantage is the need for a separate power line to the station.
- Tesla Supercharger. This is a kind of electric power supercharger, the use of which is limited to Tesla cars. It allows charging the battery by 50% in 20 minutes, and takes 75 minutes to fully recharge. The power output is 135 kW of direct current. The connectors have certain regional features for the US and the EU.

Now let's take a look at the various EV charger connectors available (Figure 2 and Table 2) [7].

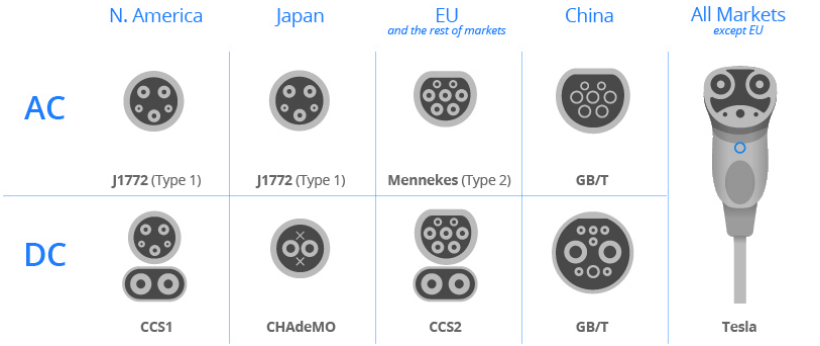

Figure 2 - Electric vehicle connectors to chargers

Finding the optimal location of electric vehicle charging points is one of the first elements of the process of implementing a new charging station. There are two types of charging stations for electric vehicles depending on their purpose. The first are home stations, i.e. the slowest ones, which are most often used at home, where it is possible to connect the car all night, or in the parking lots of private companies, where employees can leave the car for many hours.

Table 2 - Electric vehicle connectors to chargers

Slow charging connectors	
Slow charging (AC)	AC or slow charging stations are just "smart" AC switches that supply existing AC power (without affecting or converting it) via a cable to an electric vehicle to an onboard charger.
Type 2 MENNEKES (Europe)	The Mennekes type 2 connector consists of several contacts. This connector ensures safe and efficient charging of electric vehicles with a power of up to 22 kW. The peculiarity of the Mennekes type 2 connector is the ability to transfer data between the electric vehicle and the charger. This allows you to control the charging process, exchange information about power, charge status and other parameters between the vehicle and the charging infrastructure.
Type 1 CCS COMBO 1 (USA/Japan)	Combines direct current (DC) and alternating current (AC) charging capabilities in a single connector. It provides AC charging capability with a maximum power output of up to 7.4 kW. In addition to AC charging, the CCS Combo 1 type 1 connector also allows for direct current (DC) charging of electric vehicles using additional charging stations that support this function. This allows for faster charging with power outputs of up to 80 kW or more.
Type 2 CCS COMBO 2 (Europe)	It is an evolution of the Mennekes Type 2 connector and offers full compatibility with it. It supports alternating current (AC) charging with a maximum power of up to 22 kW and direct current (DC) charging with a maximum power of up to 350 kW, which enables very fast charging of electric vehicles. The CCS Combo 2 type 2 connector allows data transfer between the electric vehicle and the charging station, which allows you to monitor the charging process, exchange information about power, charge status and other parameters. This contributes to more efficient and intelligent charging of electric vehicles.

Fast charging (DC)	
J-PLUG	It provides alternating current (AC) charging with a maximum power output of up to 7.4 kW. The J1772 type 1 connector does not support direct current (DC) charging. For faster DC charging, electric vehicle owners in the United States and Japan should use special charging stations with the CCS Combo 1 connector, which combines DC and AC charging capabilities in one connector.
TESLA SUPERCHARGER (USA/Japan)	It allows Tesla electric vehicles to be charged with direct current (DC) with very high power. This network of charging stations is located along highways and major travel routes. Charging at Tesla Supercharger stations can be significantly faster than at conventional alternating current (AC) charging stations, allowing Tesla electric vehicles to receive a significant amount of charge in just a few minutes.
GB/T (China)	GB/T connectors have several varieties, such as GB/T 20234.2-2015 and GB/T 20234.3-2015, depending on the power and type of charging stations. They are used for charging electric vehicles with alternating current (AC) and ensure appropriate safety and standardization of the charging process.
CHADEMO	It supports alternating current (AC) charging with a maximum capacity of up to 62.5 kW and direct current (DC) charging with a capacity of up to 400 kW, which enables relatively fast charging of electric vehicles. This standard is designed to ensure ease of charging and interoperability between different electric vehicles and charging stations. The CHADEMO connector is used in public charging stations and is supported by many Japanese and international electric vehicle manufacturers.

The second category is commercial stations, which are intended for public use. They are characterized by higher power and the number of outlets and are located in high-traffic areas where charging time is an important factor, such as near highways, parking lots, or shopping centers.

Currently, the best place to charge an electric vehicle is the owner's home. Around 80% of EV charging cycles take place at the car owner's residence. This shows how important it is to correctly locate public charging

station networks. The ideal location of a public charging station from the customer's point of view is related to:

- easy access for a large number of current and potential owners of electric vehicles, including people with disabilities, in accordance with the principle of universal design;
- visibility due to clear signage;
- adaptation to the needs of the client in terms of the expected charging time, type of plug, power level and other parameters;
- the possibility of saving time for drivers waiting for the charging process to be completed.

The type and power of the installed charger is adapted to the location where it is used. High-speed charging stations are designed primarily for highways and large transport hubs, while the slowest charging technologies can be successfully used in places of residence and work where cars are parked for a long time.

As of the end of July, more than 64.3 thousand electric vehicles were registered in Ukraine, of which about 62.2 thousand were cars and more than 2 thousand were trucks. Compared to July 2022, a year ago there were about 40.3 thousand electric vehicles on Ukrainian roads. That is, there was an increase of about 60% over the year. The positive trend is also evidenced by the fact that last month alone, Ukrainians purchased 4.6 thousand zero-emission vehicles. This is another record on the market: 70.4% more than in July 2022 and 1.3% more than in June 2023.

Ukraine still has an underdeveloped charging infrastructure. We have about 3.2 thousand public charging stations with about 11 thousand connectors. The problem is that these charging stations are often located not at regular gas stations, but in hard-to-reach places. In addition, electric vehicles come to Ukraine from different markets, which means they have different types of connectors. This causes difficulties during charging [8].

As for the charging station network, the top three providers are currently as follows: Toka, Ecofactor and Yasno. You can have an up-to-date map of charging stations on your smartphone in the PlugShare app. As we can see in Figure 3, the app has found 468 charging locations [9].

OKKO was the first company in Ukraine to build a network of ULTRA FAST chargers on the main routes. Electric chargers with a capacity of 120 and 150 kW allow to charge a car up to 80% in 30 minutes. Fast charging stations have already been installed on the Kyiv-Odesa and Kyiv-Lviv-Slavske highways. There are plans to cover even more areas (Figure 4) [10].

Now let's look at the electric vehicle infrastructure in Poland.

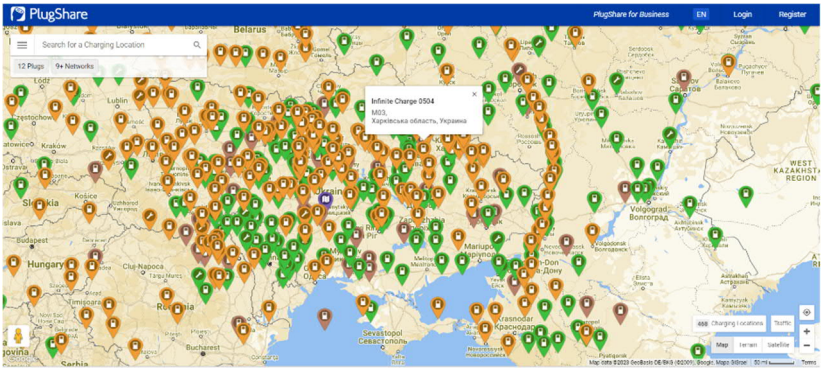

Figure 3 - Map of charging stations in Ukraine

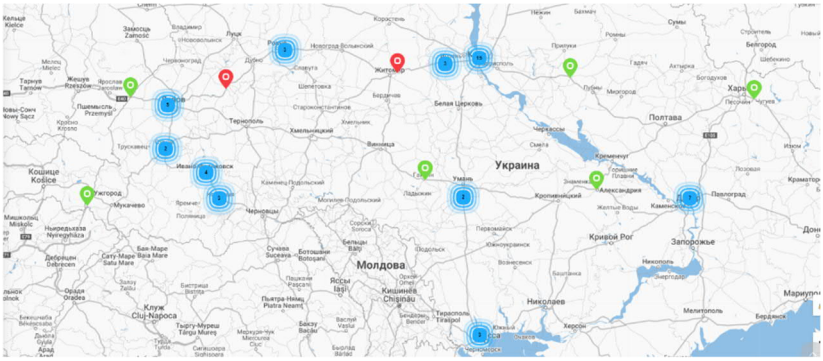

Figure 4 - Map of ULTRA FAST chargers by OKKO in Ukraine

In Figures 5 and 6, we see the latest information for 2023, which shows that the number of electric vehicles is actively growing (in March, 67127 cars and in June, 80232) [11, 12]. For the successful operation and maintenance of this transport, it is important for the country to maintain the proper state of infrastructure for electric vehicles.

Due to the fact that electric mobility in Poland is at an early stage of development, there are relatively few charging stations for electric vehicles compared to gas stations designed for traditional vehicles.

However, it should be remembered that the development of a network of publicly accessible charging stations is a fundamental condition for the development of the electric vehicle industry.

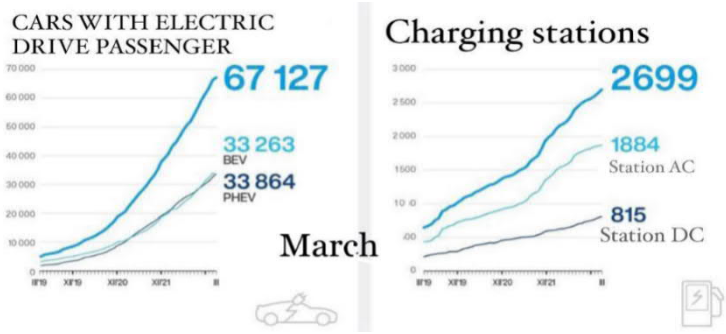

Figure 5 - Statistics about EVs and charging stations in Poland in March 2023

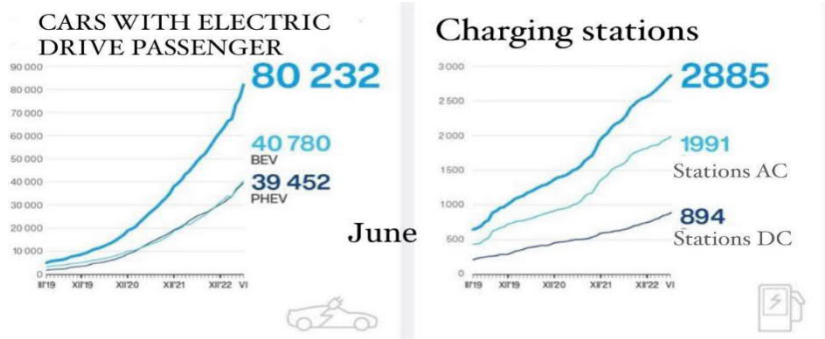

Figure 6 - Statistics about EVs and Charging stations in Poland in June 2023

Limited access to a charging station, especially during long trips, is one of the main concerns of potential buyers of electric vehicles, and low demand does not allow for the development of this solution.

In the first half of 2023, the total number of new chargers increased slightly, but the growth in the fast charging (DC) segment was very significant. There is a noticeable upward trend in the number of stations designed to charge passenger cars, but so far, no station in Poland has been adapted to serve electric trucks.

Conclusion

To sum up, Ukraine has a good chance to quickly switch to electric transport. To do this, we need a better (non-war) period, financing, a strategy for implementing it, and specialists. Over time, as the demand for electric transport grows higher and higher, prices will fall, and so it will be

more affordable for everyone. As soon as the number of vehicles starts to increase, the infrastructure has to be improved and developed first.

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