CHARGING STATIONS FOR ELECTRIC VEHICLES – TECHNICAL FEATURES AND TRENDS

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Abstract: *One of the prerequisites for achieving the long-term goal of better atmospheric air quality is the transition to a low carbon economy and more sustainable transport through the increased use of electric vehicles. Statistics show that transport generates over 14% of global greenhouse gas emissions and is the main sector in the EU where this indicator is still increasing.*
Electric vehicle technology is constantly evolving and they are gaining in efficiency. Generally, electromobility is about charging, managing and using energy. The success of the automotive industry in the future will be determined by how quickly the development of traction motors and batteries will continue, as well as the charging infrastructure.
In order to ensure the normal operation of electric vehicles, it is necessary to build an adequate infrastructure of charging stations.
The paper deals with the technical features and trends of charging stations for electric vehicles. The results are a summary and assessment of extending the boundaries of electromobility, contributing to a more sustainable future. Relevant conclusions have been done.
KEYWORDS: *ELECTRIC VEHICLES, CHARGING STATIONS, ELECTROMOBILITY*

1. Introduction

In March 2018, the European Parliament approved proposals for new binding targets at European Union (EU) level for a 35% improvement in energy efficiency, a minimum 35% share of final energy from renewable sources and a 12% share from renewable energy sources (RES) in transport by 2030. The energy efficiency target should be met on the basis of estimated energy consumption for 2030 according to the *PRIMES* model. With regard to the new target for the share of renewable energy, Member States should introduce national targets that will allow a maximum deviation of 10% under certain conditions. In 2030, 12% of the energy consumed in transport must be generated by RES. Also, by 2022, 90% of the petrol stations on the trans-European networks should be equipped with high-power charging stations for electric vehicles (EVs). The European Parliament also endorsed the proposal to ensure that consumers producing electricity on their own territory can use it and install storage systems without having to pay any taxes and fees.

Transport is responsible for almost 30% of total EU CO2 emissions, while land transport accounts for 72% of transport emissions, according to European Parliament data. CO2 emissions from passenger transport vary greatly depending on the type of vehicle. Passenger cars are the major pollutant responsible for 60.7% of Europe's total land transport emissions. The problem is largely due to the fact that passenger cars carry a small number of people – an average of 1.7 passengers.

The introduction of mass-market EVs is mainly driven by the need to reduce the high percentage of greenhouse gases emitted by large cities and its impact on climate change. In addition, under good governance, the development of electricity mobility can be one of the key technologies for securing employment and growth for industry. The public benefits of electromobility as a fast-growing industry are beyond creating new jobs and motivating them to think more environmentally and effectively in improving the quality of life.

The environmental benefits of using EVs have been proven, but without using fully RES such as solar and wind, their carbon footprint is to some extent simply displaced by internal combustion engines (ICE) of vehicles to production of fossil fuel electricity. The use of a renewable energy charged EVs guarantees both economical and environmentally friendly transport.

Over the years, current restrictions on the use of ICE vehicles in major cities are likely to increase. The main factor is the low energy efficiency of the ICE – for a 100 km run a vehicle with an ICE consumes 66 kWh at a consumption of 6 liters/100 km. EVs require 15-17 kWh per 100 km (energy cost for generating electricity from power plants is not included here). As with conventional vehicles, the consumption of EVs depends on the technical parameters, the atmospheric and road conditions, and the driving style. *PwC* (*PricewaterhouseCoopers*) predicts that 'between 2025 and 2030, the cost of battery EVs will fall below the cost of ICE cars'. At this stage, the initial price of an EV is higher than the price of a car with an ICE on the same coupe, which is a serious deterrent to its mass demand – potential buyers often only look at the starting price. This is compounded by the unknown at this stage of the operation of EV and the lack of a developed charging infrastructure.

In order to encourage the purchase of EVs, various financial and tax incentives are offered in many countries in Europe, US, Canada and Australia, as well as non-monetary benefits for EV users. Government subsidy on purchase of new EV in Europe (not everywhere in the individual countries) and North America reaches 10 to 30% of its price. In Germany, as of November 1, 2019, the subsidy for the purchase of an EV reached € 6,000 (with a previous subsidy of € 4,000), following an agreement between Chancellor Angela Merkel and the German Automobile Industry Association *VDA*. This applies to EVs with prices up to € 40,000, and for those with prices between € 40,000 and € 60,000, the subsidy is € 5,000. For plug-in hybrids, the subsidy is € 4500 (compared to a previous subsidy of € 3000). The plans are for the subsidy to be given by 2025, with the expectation that between 650 and 700 thousand EVs will be purchased during this period. In Romania, the bonus is more serious – the Government gives € 10,000 when buying an EV, adding another € 1,500 if a car older than 8 years is scrapped.

The eco-norms are becoming more serious, and if they have so far sounded like an abstract recommendation, they will soon have a noticeably strong impact. The reason is that from 2020 in Europe, carmakers should have maximum emissions for their entire range of an average of 95 g/km. If they are exceeded, they will be fined by 2021 depending on the excess and the number of cars sold. Exactly electrification is the step of entering the new order. The road to full electromobility goes through the transient period of the different types of hybrids. From now on, due to the aforementioned draconian measures, almost every new model, if not an EV, would be at least a hybrid.

There are currently 1 billion vehicles in use worldwide. About 165,000 vehicles are produced every day. According to the German Solar Energy and Hydrogen Research Center (*ZSW*), at the beginning of 2019, EVs on the roads around the world are 5.6 million. China and the US are the largest markets, with 2.6 and 1.1 million EV respectively. In China, in terms of sales, EVs are already ahead of gasoline models. According to estimates, by 2020, the number of EVs is expected to reach 10% of annual production worldwide. According to the German government's plan for climate protection by 2030, the number of EVs should increase to 10 million. In any case, this is a very ambitious plan. At least so far as nothing in this world is certain. In Germany, statistics reported at the beginning of 2019 the presence of 420,000 electric cars in the country (including hybrids), with a total fleet of more than 47 million vehicles. In Sweden – the Government has announced the most ambitious strategy, involving all cars in the country by 2030 to be independent of coal and oil. The Norwegians set a goal in 2040 to have no gasoline and diesel cars on the country's roads. The state-appointed consulting firm *Poyry* claims that there will be about 1.9 million electric cars on the roads in Norway by 2040.

Currently, all automakers are seeing an increasing effort to electrify product lines to reduce emissions across the range.

Governing body of *Toyota Motor Corporation* (global leader in sales) announced in August 2019 that the company had decided to take forward to electromobility and focus primarily on developing electric vehicles for European markets. Currently, half of their sales in the EU come from hybrids. The logic of the Japanese is that once Europeans buy their hybrids, they will quickly reorient themselves to purely electric cars. So *Toyota* will gradually replace its conventional models for Europe with electric ones. *Honda Motor Co.* unveiled news of its electric future in September 2019 – the strategic plan for Europe's *Electric Vision*, which envisages 100% of European brand sales of EVs by 2025. In October 2019, *Volvo Cars* unveiled the *XC40 Recharge*, the company's first all-electric car and the first model of the latest *Recharge* concept for cars. The company's ambition is that 50% of global sales by 2025 be entirely electric cars and the rest are hybrids. *Recharge* will be the all-inclusive name for all electric and hybrid *Volvo* cars. *Volvo*'s strategy is to make a super fast transition to EVs, which means adding a new model of electricity every year from now on for the next few years.

In November 2019, *PSA Groupe* (manufacturer of *Peugeot*, *Citroen* and *Opel*) and Italian carmaker *FIAT - Chrysler* agreed to a $ 48 billion merger. According to *CNN*, the merger will form the third largest automaker in the world and help to distribute the huge costs of developing electric and autonomous cars. The new venture will be able to meet the challenges of vehicle electrification, Internet connectivity and unmanned cars steering.

There are 262 million registered vehicles in the EU in 2018. About 2 million or less than 1% of them are classified as electric or hybrid vehicles. In Bulgaria in August 2019, the Ministry of the Interior reported 984 EVs and 6,631 hybrids registered, i.e. 7615 in total, with all registered vehicles exceeding 3.8 million. In percentage terms, most EVs are sold in Norway. This is a well known fact. There, 49.14% of new cars sold in 2018 were electric, to date, out of a total of 2.7 million vehicles on the move, over 220,000 are electric. Iceland ranks second with 19.14% and Sweden with 8.01%. Next in this ranking are the Netherlands, Finland and "barely" in sixth place comes China with 4.44%. But these nearly 4.5% are equivalent to 1,053,000 EVs. Today, the leader in the EV market in China is the *BAIC Group* (officially *Beijing Automotive Industry Holding Co., Ltd.*), followed by *BYD Auto Co., Ltd.* US ranks 15th with 2.09% but real 361,000 sales (about 3 times less than China), while Norway's leader sold 73,000 EVs – Figure 1 [1].

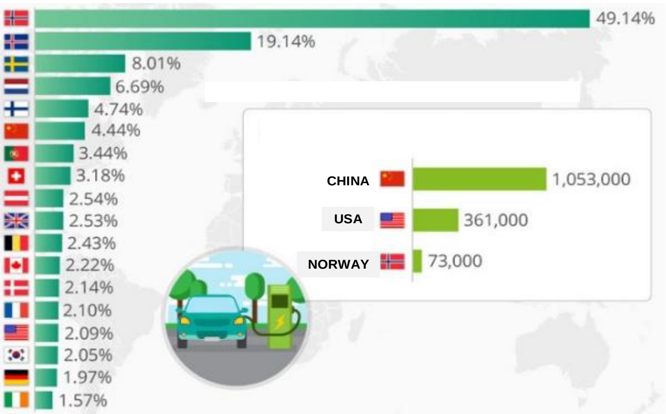

Fig. 1 *Number of EVs sold.*

Battery makers are working to improve the chemistry of lithium batteries so they don't require as much toxic material, and to enhance energy density to make batteries lighter. These developments will lessen the environmental impacts of EVs and improve their efficiency. The following parameters explain why EVs are becoming more attractive every day. A *Bloomberg Inc.* study says the average cost of batteries (with an inflation index) dropped from $1,160 per 1 kWh in 2010 to $176 in 2018. That is, eight years ago, a *Tesla Model 3* battery (75 kWh) would cost nearly $90,000. Today, such a battery costs about $13,000. This continues to be a very high price, but its downward trend continues. The future of EVs depends on the development and introduction of cheap, compact and efficient batteries. The battery will become the core of mobility. The battery supplies various types of motors as well as all electronics on board [2].

The other deterrent to the decision to buy an EV continues to be infrastructure. But there are already countries that have built the necessary infrastructure to switch the entire fleet of electricity. The Netherlands is the leader here, with an average of 19.3 charging points per 100 km. Local *Vattenfall Nuon* has announced that it will equip each *McDonald's* with at least two charging stations. For comparison, in the US there are only 0.9 stations per 100 km. In these statistics, the second place is for China, where there are 3.5 charging stations per 100 km. They look small, but let's not forget that 10,000 km (!) of highways are built annually in the Celestial Empire.

There are over 100,000 available charging stations in Europe to date. They are located in parks, on the streets, in hotels, in supermarkets, in public buildings and more. Construction on the road network is governed by the general rule that a high-speed charging station must be accessible every 120 km. In Germany, for example, the charge points are around 17,000, excluding those in everyday life. European statistics say that 70% of all charges are made at or around the workplace, so expanding the public charging network is an important but not critical factor.

In order to promote the use of hybrid and fully EVs, it is necessary to build charging station infrastructure. According to a number of studies, one of the main problems for potential consumers of EVs is precisely the lack of a well-developed charging infrastructure. Building charging infrastructure is a powerful factor in accelerating the entry of electric and hybrid (grid-powered) vehicles. This process should be stimulated, especially at the initial stage of development. However, charging EVs can create significant additional energy needs that can be met in a practical and cost-effective way through RES, including the supply of solar and wind power to the electricity grid.

Increasing the use of EVs is also an opportunity for the development of the energy system, with the potential to add the necessary flexibility to the power grids and maintain the integration of high RES shares. Electric vehicles promise to play a crucial role in the global transition to the use of sustainable energy, and in particular to the generation of renewable energy. There are several reasons for this, but the most important is that in addition to transforming the transport sector, EVs also provide an excellent opportunity to significantly increase RES shares in the overall energy mix.

Such approaches offer an attractive perspective especially for cities to decarbonise transport and at the same time reduce atmospheric and noise pollution, reduce dependence on fuel imports and introduce new urban mobility models.

2. Technical considerations

What is an Electric Vehicle – An electric vehicle is any vehicle driven solely by an electric motor powered by a rechargeable battery. Together with a voltage converter, energy distributor and/or gearbox/transmission, these components make up an electric drive module. Technically, the concept of driving an EV is like that of conventional cars – a power unit generates traction with the help of energy. For EVs, the drive unit is an electric motor that operates through electricity stored in an onboard traction battery. The electric motor transmits the movement of the wheels through a gearbox or transmission, usually single-stage. There are also built-in electric motors that are mounted directly into the wheels. In this way, the drive is direct, without any couplers/converters, thereby achieving an even higher level of energy efficiency.

The charging topic is usually a subject of great interest and discussion. With a somewhat average approach to AC charging, *Volvo* launches in 2020 with an 11 kW on-board charger. *Hyundai Kona*, by comparison, comes with 7.4 kW single-phase on-board charger and will also receive 11 kW three-phase from 2020. It's an average approach because the ‘gold’ standard of 22 kW, available in several EVs, is a goal that more and more carmakers are moving toward. *Audi e-tron* and *Porsche Taycan* also have an 11 kW base on-board charger and a 22 kW as an option. The *Renault ZOE* 22 kW on-board charger has been standard equipment since 2013. With the electric *Smart* it is also an option. And this is important in terms of usability.

In Europe, EVs are not exotic for a long time, but there are still prejudices, myths and real inconveniences when using them: the charge lasts too long; charging stations are few and inconvenient; expensive rechargeable batteries. With the last generations of EVs, these problems have been practically solved. Many carmakers claim the ability to charge 5-10 minutes for a run of 100 km, and for a full charge of the battery – 30 minutes. However, these exceptional indicators are only possible for heavy duty charging stations (for example, 270 or 350 kW) and in household networks the charge lasts 4-5 times longer. The main reason for this situation is the rapid development of technologies related to EVs: autonomous mileage and the ability to charge fast. The trend is that by the end of 2019, 10% of all vehicles sold will be EVs, by 2020 – 12% and by 2025 – 20%, but there remains a concern that reliable battery life will be beyond the warranty for EVs. Usually, during the warranty period, the only operating cost is for fuel - this applies to both ICE cars and EVs. Servicing an electric motor is much simpler than that of a gasoline or diesel engine, and in general the reviews are based on software checks, calibration and other electronics settings. The battery may be subject to more detailed service tests over a period of time and to maintain its good condition, the rules and recommendations for use must be followed.

EVs retain a lower percentage than their original value after three years compared to a traditional ICE cars. This is largely related to the capacity of the battery, which gradually decreases over the life cycle. It is very important what the battery management system (BMS) is and gives them cooling and heating control. Without such a system, the battery can fall by half its capacity for several hours (this is a case with a *Nissan Leaf* battery, for example).

Given that the average European travels 40 to 80 km per day, EVs with a mileage (under the conditions of the new European cycle of movement *WLTP* – Worldwide Harmonized Light Vehicle Test Procedure, introduced from September 1, 2017) of 200 km or more are ideal for daily use.

Battery manufacturing and charging and maintenance infrastructure are the second key (after refinement for the motor part in the first place) direction in the electromobile industry. The construction of a new charging station takes into account the energy consumption of the EVs available in the region, the stability of the energy network, accessibility and investment costs. Infrastructure for the maintenance of EVs and battery charging is a sector that is about to develop at a rapid pace.

Charging stations are classified as Level 1, 2 and 3 stations. Charging stations Level 1 and 2 are conventionally called conventional and accelerated charging stations. They are not AC/DC voltage converters. These charging stations provide the required AC voltage for the on-board EV charger with a maximum load of 15 A for Levels 1 and 3, and 2A for Level 2.

Level 1 charging stations are mainly intended for home (garage) use. Slow charging stations, typically 22 kW, are mainly used for charging in households and the workplace. Because of their slow charging, the EV's battery is connected to the network for a longer period of time, which increases the ability to provide services to improve the flexibility of the energy system. Level 2 includes charging stations intended for general use which, in addition to adapting the electrical parameters of the power supply network to the electrical and structural parameters of the EV, also provide the performance of additional functions such as power consumption and cost estimates; accepting orders for recharging EVs; security functions; information on the EV and the condition of the battery; communication dialogue with the electricity provider or charging station operator, etc. Level 2 charging stations are suitable for public charging, e.g. public parking lots, supermarket parking lots, airports, stations, metro stations, corporate parking lots and more. Levels 1 and 2 do not require investment in the transmission network and the available reserves in the transmission network can provide the necessary power for the power supply. Level 3 charging stations are designed for fast charging. The duration is 10 to 30 minutes. The main difference between Level 2 and Level 3 is that Level 3 provides a DC voltage for recharging the battery of an EV. The power required to supply such a charging station is approximately 50 to 400 kW, depending on the functional electrical architecture of the charging station – for one or many subscribers. However, this cannot be ensured by the available electricity grid and the construction of this type of charging station is accompanied by new design and construction. Level 3 charging stations are equipped with buffer batteries to absorb peak loads. To provide additional electricity and reduce the power supply to these charging stations, systems for the supply of electricity from RES are also in operation. Characteristic of Level 3 charging stations is the bidirectional flow of energy - from the power grid to the battery and vice versa. This technical capability allows the charging station to become a smart grid cell. Level 3 charging stations replace 8 to 20 Level 2 stations. They are designed to absorb large flows of users [3].

Figure 2 presents the types of charging stations [10].

Fig. 2 *Types of charging stations.*

Many consider EVs as the technology of the future, but it is not so simple. The supply networks of the charging stations, which are low-voltage, at this rate of development of the production of EVs, will be loaded with about 30% more in 5-10 years. In most European countries, EVs are powered by low voltage 0.4-1 kV, from private or public charging stations. This low-voltage network is not designed for as many EVs (as one in every three cars is supposed to be an EV). In a single local power network for 120 households, charging 36 EVs would cause overload at the connection points.

To avoid this problem, €11 billion is needed to be invested by electricity providers in order to rebuild the grid infrastructure to provide 50% of the power supply to EVs. From an economic point of view, it is recommended that instead of this costly investment, take action is to make the charging process more flexible: charging to take place in the evening after 10 pm and to implement smart software solutions to manage the process. If this is achieved for about 90-92.5% of all EVs, then the peak of the network load will decrease significantly and this is a real alternative to the expensive expansion of the conventional network.

As many as 120 million EVs could be up and running by 2030, and the more EVs are on the road, the greater the collective fleet's appetite for energy. Today charging energy demand amounts to around 20 billion kilowatt-hours, with forecasts calling for it to rise to 100 billion kilowatt-hours by 2025 and 280 billion kilowatthours by 2030 [4]. This is a tall order to fill – 2030 is just ten years down the road. More efficient EV chargers could help meet rising energy demands and deliver more power.

Today's DC charging stations for EVs commonly work on about 400 V. With a typical charging power of about 50 kW, this equates to a charging time for a 400 km range of about 80 minutes. While it is possible to increase the output power of a 400 V charging station, the capacity of the conductive pins in the charging plug would still restrict the output power to roughly 100 kW. Under these conditions, it would take about 40 minutes to transfer the energy for 400 km worth of driving. The limited power capacity of the pins can be improved significantly by cooling the charging plugs, which then extends the power of the 400 V charger to the point where the target range can be achieved with a charging time of approximately 30 minutes.

The rationale behind this move is explained by the formula for electrical energy: $E = U \times I \times t$, where U is the voltage, I the current and t the time. The charging time $t = E / (U \times I)$ can thus be achieved with a constant current I by increasing voltage U. By switching to a two-fold higher voltage of approximately 800 V, the charging time can theoretically be reduced to about 15 minutes with the same electrical load on the charging pins. It should be noted that the charging speed may drop to avoid overheating the battery cells.

The first mass production OEM to capitalize on the benefits of 800 V electrification will be *Porsche* with its first fulltime EV, the *Taycan*, scheduled for launch in 2019. The first fast charging park equipped with *Porsche*'s *800 V Turbo Chargers* is located at the Berlin-Adlershof Technology Park [5]. This EV park has four customer parking spaces that are equipped with *Porsche* charging technology. Of those four spaces, two of them have *800 V Turbo Chargers* developed by *Porsche Engineering Services GmbH*. This technical concept can even work with *Teslas* with an adapter [6].

Both *Volkswagen* (with the *Budd-e* all electric van concept) and *Mercedes* (with the launch of Generation *EQ*) have confirmed that their vehicles will be capable of charging at power levels up to 150 kW for fast charging. Both OEMs have also confirmed that they envisage a future step-up to 300+ kW and 800 V.

Obviously with more carmakers adopting the 800 V standard the network will need to expand to service the needs of the consumer. This is exactly what pioneering technology provider *ABB* intends to do with its *Terra HP High Power Charge system* [7]. Ideally suited for use at highway rest stops and petrol stations, *Terra HP*'s high capacity has the ability to charge both 400 V and 800 V EVs at full power, with a charge time as little as 8 minutes for a range of 200 km [8].

Another operator focused on the expansion of the fast-charger network is *ChargePoint* who, with the roll out of their ultra-fast DC *Express Plus* charging solution, will be able to support an output of up to 400 kW accommodating charging voltages from 200 V to 1000 V; including today's 400 V EVs and 750 V buses, and tomorrow's 800 V EVs. *Express Plus* can charge the current generation of EVs, such as the *Chevy Bolt* and *Tesla*'s *Model 3*, at their maximum rate. What's more, the system is also capable of delivering the maximum charging speed to future EVs running off 800 V and delivering 350+ kW.

With consumer convenience top-of-mind, another supplier, *Continental*, developed its *'AllCharge'* technology as a 'universal charger' system capable of supplying a maximum of 350 kW at up to 800 V via the EV's powertrain [9]. *Continental* has turned the existing electric powertrain into a 'charger,' dubbed the *'AllCharge'*, capable of both AC and DC modes, using a single cable connector:

- In the case of AC current, the current flows from the charging station via the electric motor to the inverter, where it is converted into DC current before being supplied to the battery.
- In the case of DC current, the current from the charging station flows directly through the inverter to the battery.

In twenty years' time the industry may just look back at this early roll out of 800 V electrification as one of the defining moments of electromobility.

Different brands of EVs with different technical characteristics are manufactured worldwide. Air pollution from the emissions for the production of electricity needed to charge the batteries depends on the consumption of electricity per unit of road (kWh/km). For each vehicle in the technical specification, this indicator, experimentally determined when driving on a specific test cycle, is indicated. At the same mass and aerodynamics of EVs, this indicator depends on the type of battery and electric motor, the electronic control system and the use of different auxiliary systems (lighting, signaling, air-conditioning, etc.).

Here, too, as with conventional cars, traffic, driving style, temperature, power consumers in the passenger compartment, load, etc. have a great influence. It is also necessary to add that regenerative braking is a source of charge for the batteries – the regenerative braking system recharges the battery every time it slows down (often without applying the brakes), capturing the kinetic energy that is lost in conventional cars in the form of brake heat.

For EVs, a maximal consumption of 20 kWh/100 km can be assumed.The mileage is good to calculate according to the *WLTP* standard. For their part, lithium battery manufacturers typically give a guarantee of 8 years or 160,000 km for 70% of the charging capacity.

Manufacturers make EVs, as well as those with ICEs, more and more complex wheeled machines, whose computers perform millions of calculations per minute and implement connectivity to various systems within kilometers. For many operations, vehicles collect, store, process and transmit different types and volumes of data. Specifically for EV, the possible information is: travel mode selected, how long the charging plug was plugged in, where and how the charging was (fast, partial, etc.) and how low the battery was, charging mileage readings, quality of the electrical system, the position of the last charging stations used, and about 100 last EV shutdown positions. Each trip sends a data packet that contains the date, time, GPS position, temperature and battery charge. All of these data can be inferred from driving style, EV usage profile and running time and rest.

How far can EVs travel between two charges? This is one of the most frequently asked questions by those interested in zero-emission vehicles. A new test showed the real distance that some of the most popular EVs can travel. Published data show that actual results are lower than those reported by carmakers. The test, according to the organizers, aims to determine really how far EVs can go with a single charge to help people make the right choice when buying an EV. The results of tests involved 12 of the most popular EVs in the world are presented in Table 1 [11].

Cars, including electric ones, are usually parked for 95% of their service life. These downtime, combined with adequate battery storage capacity, can make EVs an attractive solution for additional flexibility in the power grid.

Table 1: *Results from tests carried out.*

EV	Mileage declared, km	Real mileage, km	Full charge price, $
Hyundai Kona Electric	470	417	11.27
Jaguar I-Pace	470	407	15.46
Kia e-Niro	484	407	11.39
Tesla Model S 75D	489	328	13.15
Hyundai Kona Electric 39 kWh	312	254	6.87
Renault Zoe R110	299	235	7.86
Nissan Leaf	270	206	7.04
BMW i3 94 Ah	254	195	6.08
Volkswagen e-Golf	232	188	5.56
Hyundai Ioniq Electric	280	188	4.65
Smart Fortwo EQ	159	95	3.17
Smart Forfour	159	92	3.15

Any EV can play the role of a storage microsystem with the potential to provide a wide range of network services. According to analyzes by the *IRENA* (International Renewable Energy Agency), the battery capacity of EVs in the future may exceed that of stationary batteries. The analysis also shows that in 2050, there will be a capacity of about 14 TWh of EVs batteries to connect to the grid, compared to 9 TWh of stationary energy storage batteries.

At the same time, uncontrolled charging can increase peak network pressure, which will necessitate corresponding upgrades at the power level. Uncontrolled charging of EVs has led to an increase in electricity production and consumption, several studies show. However, the impact on peak consumption can sometimes be much greater. According to a study from the United Kingdom, if the number of EVs reaches 10 million by 2035, evening peak consumption will increase by 3 GW for uncontrolled charging and by only 0.5 GW if charging is smart. If more than 160 million EVs are in use by 2030, a large number of them are concentrated in certain geographical areas and their charging is uncontrolled, the local electricity grid will be congested. In order to avoid such a situation, it will be necessary to strengthen and update the network in these areas. However, with smart charging, these investments can largely be avoided. It is typically used with slow charging infrastructure in low voltage distribution networks. For example, the operator of the Hamburg electricity distribution system analyzes and concludes that a 9% share of EVs would result in insufficient capacity of 15% of the power lines. To prevent this, a smart charging solution is being implemented and devices are being monitored for loading at different points in the charging infrastructure.

If the use of the charging stations is subject to a preliminary annual subscription and the electricity consumed is paid at nominal prices, the charging station may be profitable. The technology of manufacturing charging stations is well known and many are commercially available as finished products. What is missing are uniform agreed international standards to which charging stations and their components such as plugs, cables, colors, voltage specifications, and more, meet. In addition, there is often a lack of regulations for the sale of electricity from such stations, uncertainty about municipal investment in such (charger) infrastructure, unknown government policy regarding investment in charger infrastructure, a cumbersome and costly licensing process for chargers.

With regard to the production and operation of charging stations, it is necessary to establish uniform global standards for the physical attachment of rechargeable batteries to charging stations; for a communication protocol between the charging station and the electricity providers and the EV owner; for communication protocol between the charging station and the EV, and for switching on and monitoring the operation and management of the charging station when networked to a 'smart grid' system in perspective. At this stage, there are many technological uncertainties about the development prospects of rechargeable batteries. Now there is a process of intense search, accompanied by huge financial investments in research and development. This is also catalyzed by the search for oil substitutes and finding ways to store electricity produced. There is evidence of the development of lithium batteries based on nanotechnologies with an energy density of 2000 Wh/l and 45000 charge/ discharge cycles.

According to expert analyzes, the massive entry of EVs into the EU, which will begin in the next 5 years, will lead to the emergence of new technologies, industries and professions, EU Member States failing to keep up with new technologies and their information and infrastructure security will suffer significant commercial losses and will be subject to amercements for the use of gas and diesel transport and the insufficient capacity of national charging station networks [12].

ACEA, *Eurelectric* and *Transport & Environment* (*T&E*) issued a joint statement in September 2019 calling on the European institutions to support the rapid creation of smart charging infrastructure for EVs. *ACEA* is the European Automobile Manufacturers Association, of which *BMW Group*, *CNH Industrial*, *DAF Trucks*, *Daimler*, *Fiat Chrysler Automobiles*, *Ford of Europe*, *Honda Motor Europe*, *Hyundai Motor Europe*, *Jaguar Land Rover*, *Groupe PSA*, *Renault Group*, *Toyota Motor Europe*, *Volkswagen Group*, *Volvo Cars* and *Volvo Group* are members. *Eurelectric* represents the interests of more than 3,500 companies in the European electricity industry, and *Transport & Environment* (*T&E*) is a leading European clean transport campaign group, with over 60 member organizations in 25 countries.

The three associations unite on the importance of lawmakers and policymakers reforming important regulations, such as the upcoming *Alternative Fuel Infrastructure Act* (*AFID*) and the *EU Buildings Directive* (*EPBD*), to allow EVs to reach every home, workplace and road .

This will require a massive deployment of strategically located smart charging infrastructure across the European Union. Intelligent (or smart) infrastructure means that charging systems are designed to provide convenient and easy access and use, communication with centralized computer systems with interactive features and technical solutions designed to avoid power grid congestion. To this can be added the *V2G* (*Vehicle to Grid*) functionality by which the battery energy of EVs can be fed back through charging stations to the grid. *Automotive News Europe* notes that *Nissan Leaf* is certified as an energy source in Germany, Denmark and the UK, allowing it to connect as a *V2G*.

According to the three associations, such developments will provide clear benefits for consumers, the electrical system, the automotive industry and the public at large.

Where to charge

The average charging price varies depending on the astronomical charging time, charging speed, and point selected. In the UK, the *Compare The Market* app allows you to choose your charging point while traveling in Europe and how much it will cost you – Table 2 [13]. In Germany, where the share of RES is 41% of the generated energy, electricity costs € 0.2/kWh. In Denmark, which has long been proud of its highest share of wind energy, the *NewMotion* app is worth € 0.3/kWh.

Some countries allow consumers to choose electricity providers. *UKPower* is an energy benchmarking service that helps UK consumers compare charging prices between energy providers and possibly save money by switching. There are similar opportunities in Germany. According to the *North Rhine-Westphalia Consumer Association*, customers can choose from at least 20 different providers that cover the whole country, potentially saving up to 20-30% of their electricity bills.

The lack of a sufficiently developed network of charging stations for now makes plug-in cars more convenient for urban environments. In this case, electromobility means freedom of movement in urban centers and green areas with limited traffic.

However, the larger the battery of an EV, the longer it will take to charge a standard outlet. There are sites like international plugshare.com that indicate where public charging stations are.

On October 12, 2017, *Shell* acquired *NewMotion* – Europe's largest network of charging stations with 170,000 registered users and over 100,000 available charging points, in Bulgaria they are 11. The convenience of charging an EV is a request to visit a gas station, which is completed in a smartphone application. This makes driving comfortable and time-saving and well-planned. It is no coincidence that *NewMotion*'s ambitious motto is: "We will break down the concept of charging EVs for the different 'levels' of charging and help you understand how to use them.".

At the end of 2017, one of the leading markets, the Netherlands, has a total of 107,000 charging stations registered public and private. At Europe level, charging stations are already several hundred thousand – if we are talking about smaller stations. Higher power DC charging stations are up to 15-16% of the total 17,000 in Germany, for example, according to data from a branch organization quoted by the *DPA* (German National News Agency). The government plans to encourage electric mobility in Germany envisage increasing the number of charging stations to 50,000 within two years.

In October 2018, *Google Maps* has already called the charging stations for EVs. One of the main features of *Googlé Maps* is to help the users to arrive at a designated location without significance for this type of vehicle.

That is why, the information about the closest charging stations for EVs would have been raised in time. Now you can find similar information for the closest electric charging stations. Detailed information can now be found on the nearest electric charging stations by offering a route to them that matches the battery charge remaining in the electric vehicle's batteries. For picking up the nearest electric charging station, it is sufficient in Search field to be filled in *EV charging* or *EV charging stations*. Online service offers geographical coordinates, type of connectors, free charging places for EVs, prices for charging, etc. For all stations, the data from the previous users - pictures, ratings, opinions and answers to the most frequently asked questions - are available.

To date, *Google Maps* maintains a network of *Tesla* and *Chargepoint* charging stations (worldwide, including Bulgaria), *SemaConnect*, *EVgo*, *Blink* (for the United States), *Chargemaster*, *PodPoint*, *Chargefox* (for the territory of Europe). The list will gradually increase and complete.

Table 2. *Prices according EV charging* [13]

Country	Price, €/kWh	Charge price, €	Price for 100 km
ESTONIA	0.12	11.57	2.78
HUNGARY	0.12	11.57	2.78
CZECH REPUBLIC	0.12	12.46	2.99
LITHUANIA	0.12	12.46	2.99
ICELAND	0.13	13.35	3.20
TURKEY	0.13	13.35	3.20
POLAND	0.14	14.24	3.42
FINLAND	0.15	15.13	3.63
SLOVAKIA	0.15	15.13	3.63
LATVIA	0.16	16.02	3.85
NETHERLANDS	0,16	16.02	3.85
SLOVENIA	0.16	16.02	3.85
FRANCE	0.17	16.91	4.06
GREECE +	0.17	16.91	4.06
LUXEMBOURG	0.18	17.80	4.28
NORWAY	0.18	17.80	4.28
SWITZERLAND	0.18	17.80	4.28
SWEDEN	0.19	18.69	4.50
UNITED KINGDOM	0.2	19.58	4.50
AUSTRIA	0.2	20.47	4.92
SPAIN	0.21	21.36	5.14
IRELAND	0.23	23.14	5.56
PORTUGAL	0.23	23.14	5.56
BULGARIA	0.09	7.08	2.36
ITALY	0.24	24.03	5.77
BELGIUM	0.25	24.92	5.99
GERMANY	0.29	29.37	7.06
DENMARK	0.3	30.26	7.28

Groupe PSA (a carmaker of *Peugeot*, *Citroen* and *Opel*) has been active in the field of electric mobility this year and, in addition to launching several new EVs, also purchased the English *ChargePoint* network through the French operator *ENGIE*.

In August 2019, *TomTom* announced that it was updating the list of charging stations and their data in the navigation of EVs. This is true of the automakers *TomTom* works with.

ABB has been selected as a major technology partner and supplier in a pilot project to build a network of EVs charging stations across Europe. The project is the work of *IONITY*, the first service station has been opened in Neuenkrach, Switzerland, on the *A2* motorway. *IONITY* is a joint venture of *BMW Group*, *Daimler AG*, *Ford Motor Company* and *Volkswagen Group* with *Audi* and *Porsche*. The enterprise project includes six of *ABB*'s most advanced high-speed charging stations, *Terra High Power*, with a power of 350 kW and a 200 km mileage in just 8 minutes. By 2020, *IONITY* plans to operate a network of approximately 400 fast charging stations in 24 European countries [3].

The *Volkswagen Group* has announced its intention to significantly expand the company's investment in EV charging infrastructure, with plans to install 36,000 charging points in Europe by 2025. *Volkswagen* is already involved in the deployment of some charging networks, such as *IONITY*, but the German carmaker plans to expand its own direct involvement in EV charging. *Volkswagen* is aiming for a rapid breakthrough in the world of electromobility and is redoubling its efforts in the charging infrastructure. Across Europe by 2025, the *Volkswagen Group* will install a total of 36,000 charging points; 11,000 of these will be developed by the *Volkswagen* brand. They will be installed at *VW*'s factories and at around 3,000 *Volkswagen* dealerships in all major cities.

New obstacle in the way of electric vehicles

The high prices for EVs and the shortage of charging stations have already added another barrier to the massive entry of electric cars for everyday use. In Germany, Europe's largest overall car market, starting from April 1, 2019, there is a new mandatory requirement for each charging station to have meters installed to show drivers how much electricity is being charged. A similar measure is under consideration across the European Union. However, one of the conditions is to find manufacturers for these meters. And although in Germany the measure has already been introduced and has been in force since April 1, 2019, similar charger adaptations are still not being manufactured, according to industry experts cited by the *DPA* [14].

Charging stations now show EV owners how many minutes they can drive in a single charge. However, it turns out that there are currently no measuring devices available for DC charging stations, and the union of *BMW Group*, *Daimler AG*, *Ford Motor Company* and *Volkswagen Group*, is working to install such devices on German highways. *IONITY* noted that they are in talks with the German authorities and expect the necessary technology to be adapted to the current charging stations will be available in the next months. The charging stations already installed will be upgraded, not dismantled.

3. Conclusions

It is well known that the optimal solution never depends on one component only, but on the exact coordination of all components. Therefore, it is important to always analyze and evaluate the overall solution, both from a technical standpoint and in terms of costs and benefits.

For each country at this stage, the entry of EVs is at different rates. There is still a lack of awareness among the population of how electronics and propulsion developments are changing the world of transport, as well as the lack of enough companies to supply EVs with the corresponding approved quotas from carmakers. Soon new EVs will emerge, capable of traveling more serious distances in a single charge. Diversity is already there and will be much greater. A well-organized awareness campaign is needed, accompanied by a real presence on the roads of EVs, engaging companies with the supply of new and companies to convert vehicles with ICE into EVs, offering financial instruments for leasing batteries and/or the entire EV, as well and local or national incentives for EV users. There is a need for a specific legal framework with appropriate measures, which would create additional opportunities for more intensive use of EVs.

Generally speaking, despite the many breakthroughs, one thing stands out and that is that it often takes decades for people to understand and to perceive something.

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