MSc Program
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Developing the Public Charging Infrastructure for Battery Electric Vehicles in Romania. Challenges and Opportunities

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Affidavit

I, **SIMONA APOSTOL-SIEGL, MA**, hereby declare

1. that I am the sole author of the present Master's Thesis, "DEVELOPING THE PUBLIC CHARGING INFRASTRUCTURE FOR BATTERY ELECTRIC VEHICLES IN ROMANIA. CHALLENGES AND OPPORTUNITIES", 86 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

The transport sector was responsible for 31% of total economy-wide greenhouse gas emissions in the European Union (EU) in 2019 (IEA, 2022). There is now a considerable market momentum for electric vehicles in road transport, which are expected to play a vital role in reaching the 90% emissions reduction target set by the European Green Deal for 2050. Different studies identified charging infrastructure as one of the critical enablers of the accelerated mass adoption of electric vehicles. The Green Deal estimates that about 1 million (mn) publicly available charging stations will be needed by 2025 in the EU from 208,011 at the end of 2020 (EAFO, 2021). Only 502 public charging points were available in Romania at the end of 2020 or below 0.5% of the EU total (EAFO, 2022). Fast and even deployment of public charging infrastructure will be necessary to ensure the mass adoption of electric vehicles in all the European countries over the following decades.

This Master Thesis aims to identify the main challenges and opportunities related to the deployment of charging infrastructure in Romania. To embrace different dimensions and thereby ensure a holistic view of the sector, an extensive list of criteria has been identified and evaluated through literature review, expert interviews, analysis of specialised academic publications and reports by public institutions and industry associations. The Thesis addresses the following research questions: what is the structure of the electric vehicle and charging infrastructure market, what are the signals set by decision-makers through targets, policy frameworks and promotion actions, what are the implementation steps for new charging infrastructure projects, what are the profitability drivers for investments in this sector. These aspects have been analysed from a local perspective and compared to other countries in the European Union, where the electromobility sector has already reached a more advanced stage.

Charging infrastructure in Romania is in an early development phase compared to other European countries. This brings along essential opportunities and challenges for both businesses and regulators. The market offers significant room for growth for existing players and new entrants and presents yet uncovered business segments such as long-distance fast charging. Nonetheless, more favourable conditions will be needed to attract investors and secure the capital necessary to accelerate the deployment of charging infrastructure. The main challenges lay in the uneven allocation of investment subsidies, strict allocation criteria and lengthy permitting process. A fair and accessible distribution of investments subsidies will play a critical role in supporting investors overcome the electric vehicle market ramp-up period and thereby solving the “chicken-or-egg” dilemma of the sector. Whether the gap versus more developed markets can be closed and the targets set by the European Union can be achieved depends mainly on how decision-makers will overcome these challenges and oversee the creation of a favourable business environment to attract private capital and secure necessary investment volumes.

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1. Introduction

Domestic and international transport was responsible for 31% of total economy-wide greenhouse gas emissions in the European Union (EU) in 2019 (IEA, 2022). Road transport, including cars, vans, trucks, and buses, is the most significant contributor to greenhouse gas emissions (GHG) in the EU, including Romania, making up two-thirds of the transport-related emissions. The European Green Deal (the “Green Deal”) published by the European Commission in December 2019 is setting the EU’s roadmap to reaching carbon neutrality by 2050. The Green Deal calls for a 90% reduction of GHG emissions in transport for the EU to become a climate-neutral economy by 2050.

The field of electromobility and the deployment of electric vehicles (EVs) is currently widely seen as a viable alternative to internal combustion engine vehicles (ICEVs) and is expected to play a vital part in reaching GHG reduction targets in the transport sector over the following decades.

The sales of EV models have steadily increased over the past years, reaching record numbers in 2020 and 2021. Despite the shrinking overall market for new vehicles due to the COVID-19 pandemic, the total number of EVs registered in most European countries increased significantly in 2020 and almost doubled in Romania (EAFO, 2022). The Green Deal estimates a significant further increase of zero and low emissions vehicles, expected to reach 13mn in the EU by 2025. Along with the rollout of EVs, the Green Deal estimates that about 1mn public charging and refuelling stations will be needed by 2025.

According to the European Alternative Fuel Observatory (EAFO), at the end of 2020, there were 1.125mn electric vehicles (EVs) and 0.968mn plug-in electric vehicles (PHEVs) on the road in the EU. This means that more than a six-fold increase in electric cars can be expected over five years to reach the Greed Deal estimation.

A similarly ambitious increase is also targeted for the publicly available charging infrastructure. According to EAFO (2022), at the end of 2020, there were 208,011 publicly available charging points in the EU, which means that almost five times more charging points will be needed in the next five years to reach the one million estimate by the Green Deal.

Great efforts will be necessary by the EU and the member states’ regional and local governments to accelerate the transition towards the mass adoption of electric vehicles and the development of the existing charging network. The currently uneven EV market penetration and distribution of charging stations between different EU countries will raise further complexity in the policies rollout and development strategies. For instance, while over 80% of the public charging stations in Europe are currently concentrated in seven countries (ACEA, 2021), in Romania, there were only 502 public charging points available at the end of 2020 or below 0.5% of the EU total. To reach the Green Deal targets, all member states will need to contribute, and appropriate deployment strategies will need to be found and implemented.

1.1 Motivation

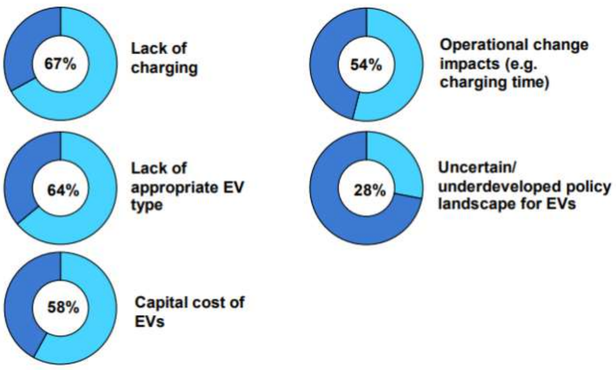
Electric vehicles are not a new invention. However, it is not widely known that electric vehicles were serious contenders for market dominance at the beginning of the 20th century. Gasoline-powered vehicles accounted for only 20% of automobiles produced in 1900 in the United States (U.S.), while the rest were a split between electric and steam engines. According to a recent study that analysed over 36,000 U.S. passenger vehicles models manufactured between 1895–1942, at the beginning of the 20th century, electric vehicles were light and small by today's standards, easy to use, more expensive but also more efficient, and reached about 150 km range (Taalbi & Nielsen: 2021).

Given these competitive characteristics, the same study further analysis the reasons which ultimately led to the combustion engine vehicles increasingly becoming the popular choice in the first decades of the last century. So, it appears that the main reason which prevented the mass adoption of electric cars was the absence of appropriate charging infrastructure.

While electricity was mainly available in urban areas, rural areas were largely uncovered until 1920. At the same time, stores already stored petrol for farming equipment in rural regions. Thus, the adoption of petrol vehicles was favoured. Although the grid networks quickly developed in the following decades, the shift to gasoline engines had already been made by that time and became the dominant choice in the road transport sector. Should the necessary amount of electricity have been available and evenly distributed in the U.S., 71% of vehicles models available in 1920 would have been EVs and over time could have become the technology of choice, winning the market over its gasoline-powered competitor models (Taalbi & Nielsen: 2021).

According to other sources, the success of fossil fuels can be attributed to the low cost of oil and its energy density (Muneer et al., 2017). More details about the energy density of oil and how this advantage is offset by the low efficiency of the internal combustion engine will be detailed in Section 2.2.

A century later, charging infrastructure is still one of the main barriers to the mass adoption of EVs and is being flagged as such by different recent studies. For example, a report of the International Energy Agency (IEA) points out that the lack of charging infrastructure is perceived as the top barrier in the adoption of EV's by the Climate Group's EV100 Initiative, which brings together over 100 companies in 80 markets committed to making electric transport the new normal by 2030. As shown in Figure 1 below, the lack of charging ranks with 67% as the first barrier in adopting EVs, followed by lack of appropriate EV type with 64% and cost of the EVs with 58%.



Note: Percentages reflect the ranking of the barriers as significant or very significant by EV 100 member respondents

Figure 1: Top five barriers to EV adoption reported by EV 100 members *(Source: The Climate Group cited by IEA, 2021)*

Charging infrastructure proved to be a significant impediment in the development of the EV market already over a century ago and has been flagged as an essential barrier also by recent studies. Therefore, an appropriate and even deployment of the charging infrastructure throughout the EU countries represent one of the critical enablers of the accelerated EV adoption required to meet the 2050 decarbonisation targets.

1.2 Scope of the Thesis

The main objective of this Master Thesis (the Thesis) is to assess the characteristics of the EV public charging infrastructure in Romania by looking at the developments so far, current situation, and likely future trends to identify the main challenges and opportunities related to the development of this sector. An extensive list of criteria has been evaluated to embrace different dimensions and ensure a holistic sector view. In this sense, several research questions have been addressed. They have been assessed through literature review, expert interviews, analysis of specialised academic publications, and reports of public institutions and industry associations: what is the current structure of the electric vehicle and charging infrastructure market, what are the signals set by decision-makers through policy framework, promotion actions, and targets, what are the implementation steps for new charging infrastructure projects, what are the profitability drivers for investments in public charging infrastructure. All these aspects will be analysed from a local perspective compared to other countries in the European Union, where the electromobility sector has already reached a more advanced development stage with the aim to identify successful deployment strategies for the charging infrastructure.

The Thesis will analyse the characteristics of the charging infrastructure sector in Romania by addressing targeted research questions (RQ) that have been identified through the literature review on this subject:

RQ1 - Status and forecast: What is the current status of the EV market and charging infrastructure in Europe and Romania; what are the specific conditions of this sector concerning the general economic indicators? What is the estimated number of EVs and charging stations to be reached in Europe and Romania by 2030?

RQ2 - Charging requirements: what types of chargers will be most required in the future? What is the expected development timeframe?

RQ3 - Promotion actions: What mechanisms have been implemented in EU countries and Romania to promote the EV market and charging infrastructure deployment, and what has been their contribution so far?

RQ4 – Implementation and permitting: What are the usual permitting and approval steps for the implementation of a public charging station project in Romania?

RQ5 - Business models: What are the typical business models in the electric vehicle charging sector, and who are the leading players in Romania?

RQ6 – Economic assessment: What are the main triggers for the economic viability of charging infrastructure investments in Romania?

1.3 Structure of the Thesis

For a clearer view on the structure of the Master Thesis, Figure 2 below shows the main chapters of the paper.

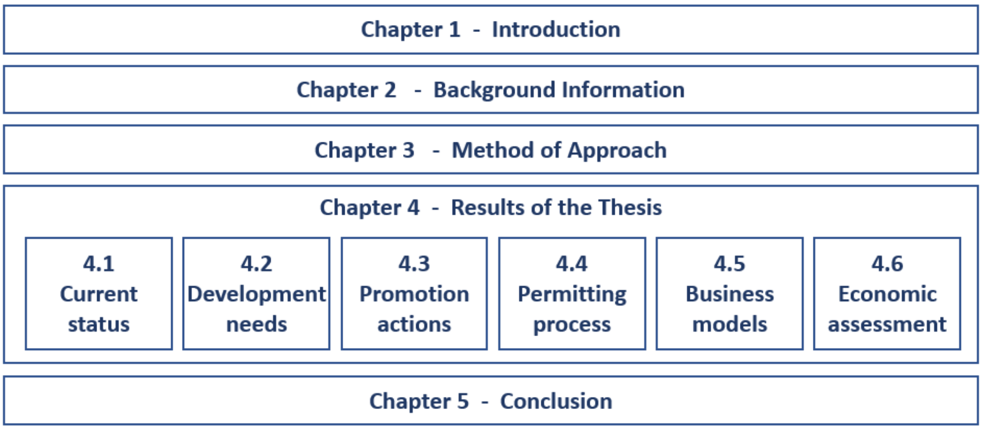


Figure 2: Structure of the Master Theis *(Source: own illustration)*

1 presents the motivation for selecting the subject, the importance of charging infrastructure for the EV market, and a description of the research questions to be addressed.

2 offers a general picture of the EV market status and charging infrastructure in the EU. This chapter also explains the main EV and charging types and related essential technical aspects. An additional section will be dedicated to relevant EU directives and regulations. Further, various EU countries' promotion policies and actions will be analysed.

3 will explain the method of approach, the source of the data, and how the information has been analysed. This chapter will also include the applied calculation methods and the assumptions made.

4 will focus on the results of the Thesis by describing specific aspects of the Romanian market concerning the research topics in scope: current status of the EV and charging infrastructure sectors and expected developments until 2030; particular development needs for the upcoming years, promotion actions for the EV and charging infrastructure and their role in the market development, permitting and approval process for development and installation of new EV charging stations, business models and leading players in the charging infrastructure in Romania, and the triggers for the economic viability of charging infrastructure investments.

Finally, 5 will close the Thesis with the main conclusions pointing out the identified challenges and opportunities related to the development of the public charging infrastructure network in Romania.

2. Background information

2.1 The electric vehicle market

Electric vehicles are often used as a term for all available electrification technologies, i.e., battery electric vehicles (BEVs), plug-in electric vehicles (PHEVs), hybrid electric vehicles (HEVs) and fuel cell electric vehicles (FCEVs). Each of these technologies has different requirements in terms of infrastructure and varying CO2 reduction levels.

	Electrically-chargeable cars 10.5% of EU car sales in 2020		Hybrid electric cars 11.9% of car sales	Fuel cell cars 0.01% of car sales
	BEVs Battery electric	**PHEVs** Plug-in hybrid electric	**HYBRIDS** Full and mild hybrids	**FCEVs** Fuel cell electric
Tailpipe CO2 reduction (On average)	100%	50-75%	Mild: 10-20% Full: 20-40%	100%
Share of 'electrified' cars	24.1%	22.8%	53.1%	0.03%

Figure 3: The electrified vehicle types *(Source: ACEA, 2021)*

According to the European Automobile Manufacturers' Association (ACEA), the electric vehicles can be clustered as follows:

Battery electric vehicles (BEVs) are powered entirely by an electric motor, using electricity stored in an integrated onboard battery which can be recharged by plugging into the electricity grid.

Plug-in hybrid electric vehicles (PHEVs) have both an internal combustion engine and a battery-powered electric motor. The battery can be recharged by the onboard engine as well as by plugging into the grid. The vehicle can run on the electric motor and/or the internal combustion engine, depending on the battery level.

Hybrid electric vehicles (HEVs) have an internal combustion engine and a battery-powered electric motor. Electricity is generated internally from regenerative braking, cruising, and the combustion engine, so no recharging infrastructure is needed.

- Mild hybrid electric vehicles are powered by an internal combustion engine and have a battery-powered electric motor that supports the conventional engine. These vehicles cannot be powered by the electric motor alone.
- Full hybrid electric vehicles are powered by an electric motor and a combustion engine, each of which can power the motor separately or together.

Fuel cell electric vehicles (FCEVs) are also powered by an electric motor. Their electricity is generated inside the car by a fuel cell that uses compressed hydrogen (H2) and oxygen from the air. FCEVs are not recharged by connecting to the electricity grid but require dedicated hydrogen filling stations.

Both BEVs and PHEVs require recharging infrastructure which connects them to the electricity grid. Together they are referred to as electric vehicles (EVs).

PHEVs can usually run solely on electric power for 40-50 km, thereby only contributing to CO2 reduction when used for shorter rides. On the other hand, BEVs are also suitable for long-distance driving and have more potential to contribute to the transport sector's decarbonisation.

While Figure 3 above highlights that BEVs tailpipe CO2 emissions are 0, it shall be noted that the contribution of the electric vehicles to CO2 reduction over the lifetime largely depends on the electricity generation mix. This will be explained in a dedicated section 2.3.

The BEV and PHEV market has constantly been increasing over the past few years, reaching unprecedented levels in some European countries like Norway, Sweden, Nederland, where the vehicle stock and sales share have reached significant levels in the last decade. Figure 4 shows the cumulative EV sales from 2009 to 2018 and the 2018 EV sales share. Norway is a particularly remarkable example, with over 260 thousand electric vehicles on the roads in 2018 and a sales share in 2018 of over 50%.

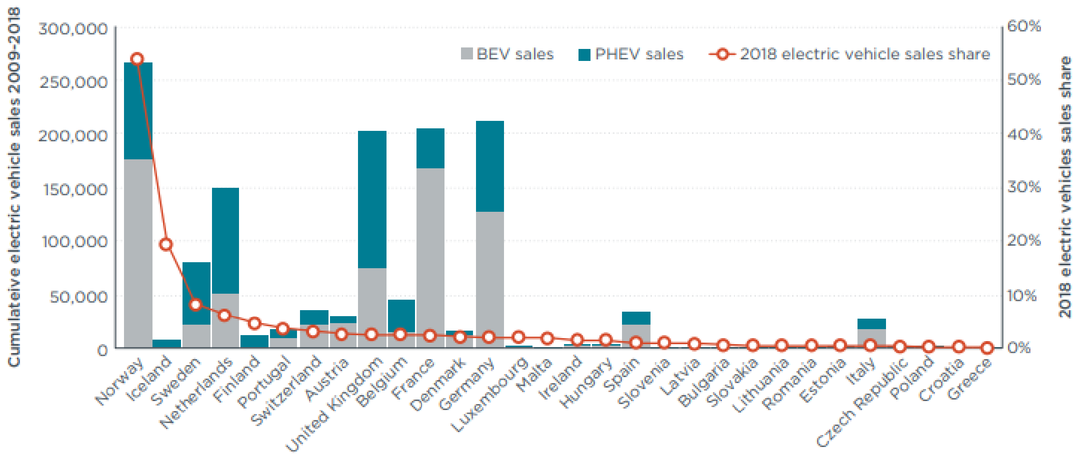


Figure 4: Cumulative electric vehicle sales from 2009 to 2018 and 2018 electric vehicle sales share *(Source: Wappelhorst et al., 2020)*

The sales of electric vehicles registered a significant increase in nearly all European countries in 2020 despite the COVID crises. This triggered a decrease in conventional vehicle sales on almost all markets. As shown in Table 1 below, at the EU level, petrol car demand dropped to 4.7mn units in 2020 (just 539,709 units more than in 2014), after having reached a record 7.5mn vehicles registered in 2019. The number of diesel cars sold dropped by almost 2.6mn units over the same timeframe. At the same time, sales of battery-electric vehicles in the EU more than doubled between 2019 and 2020 and sales of plug-in hybrids tripled in the same period.

Table 1: New car registrations in the EU by fuel type *(Source: ACEA, 2021)*

	2014	2015	2016	2017	2018	2019	2020
Petrol	4,174,069	4,752,707	5,481,409	6,205,957	7,055,394	7,514,812	4,713,778
Diesel	5,359,263	5,762,740	5,890,470	5,551,109	4,655,747	4,106,951	2,778,817
Electrically-chargeable	55,356	119,323	118,542	168,901	240,347	387,325	1,045,082
→ Battery electric	30,820	49,231	53,215	84,070	131,954	247,371	538,023
→ Plug-in hybrids	24,536	70,092	65,327	84,831	108,393	139,954	507,059
Hybrid electric	139,280	174,695	226,940	359,093	503,618	742,084	1,182,792
Fuel cell	32	165	113	218	230	483	749
Natural gas (CNG)	97,214	78,511	57,609	49,553	65,023	68,129	55,028
Other (LPG + E85)	141,452	140,321	118,430	156,710	164,270	186,141	153,344

Overall, in 2020 conventional fuel types (petrol and diesel combined) still dominated EU car sales in market share (75.5%). However, almost a quarter of all cars sold were alternatively powered. Electrically chargeable vehicles accounted for 10.5% of all new car registrations in the European Union in 2020, compared to a 3.0% market share the year before. Battery electric cars made up 5.4% of all new car sales, with plug-in hybrids at 5.1% (ACEA, 2021).

Concerning the charging infrastructure, according to a recent report by the European Automobile Manufacturer's Association (ACEA, 2021), out of the 224,237 charging points available in the European Union in 2020, almost 30% were located in the Netherlands (66,665), another 20.4% in France (45,751) and 19.9% in Germany (44,538). The gap between number three Germany and number four Italy is wide (Italy at 5.8%), and the share of chargers decreases rapidly after that. The Netherlands – the country with the most infrastructure – has almost 1,000 times more charging points than the country with the most undersized infrastructure (Cyprus, with 70 charging points). An overview of the current status of the charging infrastructure in the EU countries is presented in Figure 5 below.

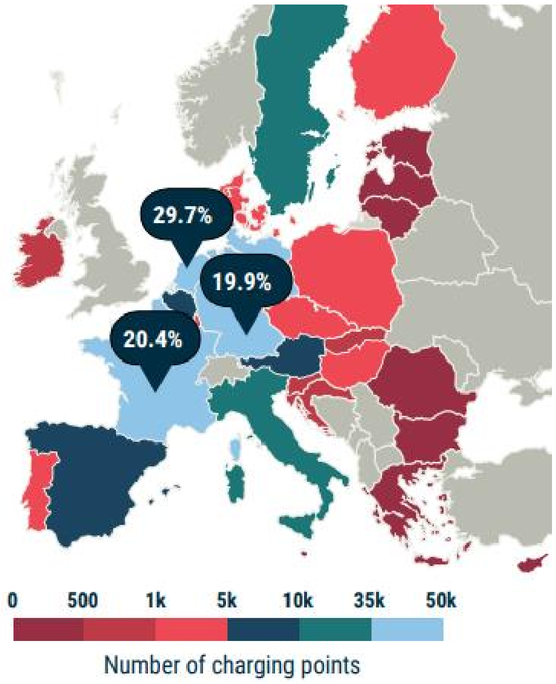


Figure 5: Distribution of electric vehicle charging points in EU *(Source: ACEA, 2021)*

Romania, with 593 charging points (317 ≤ 22 kW and 176 > 22kW), is among the countries with the least charging points in the EU (ACEA, 2021). More details on the current status of the charging infrastructure in Romania is presented in section 4.1 of this Thesis.

2.2 Advantages and challenges of electric vehicles

Considering electric vehicles compared to conventional combustion engines, there are clear advantages and disadvantages.

The functional principle of the electric propulsion systems provides for a clear significant advantage related to efficiency. Electric vehicles can reach up to 95% efficiency, which is about three times higher than the efficiency of a combustion engine.

On the disadvantages side, the electric propulsion system has a relatively heavyweight, especially in the case of hybrids. This is mainly due to the power electronics, the electric machine, and the heavy battery system (Scrosati et al., 2015:10).

When looking at the comfort and the drive characteristics, the acceleration and power transfer of the electric system shows a clear advantage over the combustion engine.

The relatively low energy density of the batteries, despite continuous progress in battery science over the last years, is one of the main disadvantages of battery vehicles. By comparison, fossil fuels have a very high energy density. In contrast, Table 2 below shows the densities of energy stored in automobile fuels.

Table 2: Mass and volumetric densities of energy stored in automobile fuels *(Source: Muneer et al., 2017: 13)*

	Mass density (kWh/kg)	Volumetric density (kWh/l)
Lead-acid	0.04	0.08
Nickel metal hydride	0.09	0.11
Lithium-ion	0.08	0.12
Compressed hydrogen, 350 bar	1.01	0.71
Petrol	6.06	8.81

Among the most important disadvantages of electric vehicles, the higher cost and limited range remain important despite significant improvements over the last years. Nonetheless, some recent studies estimate that further progress on these two aspects can still be expected, with an estimation that EVs will reach cost parity with internal combustion engine vehicles (ICEs) within this decade and the average range expected to go up to 500 km within five years (Eriksen et al., 2021:23, 25).

In addition, the cost in operation for electric vehicles is much lower than the cost of internal combustion engine vehicles. In Romania, a study shows that small EVs reach breakeven with similar class ICEs in terms of the total cost of ownership at only 8,000 km yearly milage and assuming five years useful life (Nemes & Fundulea, 2021).

Another advantage of EVs is the tailpipe o emissions detailed in section 2.3. When looking at the entire lifecycle, including energy production, the CO2 emissions of EVs become negligible only if renewable energies have an essential share in the energy generation mix.

To summarise, Table 3 below shows EVs' main advantages and disadvantages.

Table 3: List of selected advantages and disadvantages of EVs *(own table based on Scrosati et al., 2015:10)*

Field	Advantage	Disadvantage
Powertrain & storage	High efficiency of the powertrain *(90% vs ca. 30% for ICEs)*	Many electric propulsion systems are heavy *(mainly due to the sizable battery needed to support a reasonable range)*
Battery technology	Rechargeability of the battery system *(via grid or recuperation)*	Limited cycle time and complex cell technology
Comfort/drive characteristics	Outstanding acceleration and power transfer compared to ICEs *(torque characteristic of the electric engine)*	Limited electric range *(low energy density of today's batteries)*
Costs	Decreasing life cycle costs (*lower maintenance and operation costs)*	High purchasing costs and components costs (*battery price per kWh USD 250 – 600 depending on battery type)*
Ecology/sustainability	Zero emissions at the tailpipe	Overall emissions (based on today's energy mix)
Storage & charging process	Intelligent energy solutions *(possible integration of EVs into smart grids)*	Lack of sufficient public charging infrastructure in some regions

2.3 The importance of renewable energies for the electric mobility

One of the main advantages of BEVs is that they are nearly emissions-free in operation when the electricity is coming from renewable sources. However, the less energy is generated by renewable sources, the more carbon-intensive the operation of BEVs is. In some countries where fossil fuels continue to occupy an essential share of the electricity generation mix, the emissions triggered by the BEV operation is nearly comparable to ICEVs.

BEVs are also more carbon-intensive in production than ICEs, referred to as the "ecologic backpack" of the electric vehicle (Schwedes & Keichel, 2021:133). However, over the lifetime, the production emissions are offset by the lower emissions in operation.

To demonstrate the contribution of renewable energy to the decarbonisation of the road transport sector, a simulation showing the lifetime CO2 equivalent emissions for several vehicle types in a few energy generation scenarios has been calculated. According to the calculation, considering the current energy mix in Romania (https://electricitymap.org/, 2022), a compact electric vehicle with an estimated consumption of 15 kWh / 100km (Schroeder & Traber, 2011) can be expected to break even at around 62,000 km with an ICE emitting 120 gCO2 / km (EU standard after 2012) and 88,000 with an ICE emitting 95 gCO2 / km (EU standard after 2020). Therefore, in Romania, the "ecological package" of a BEV will be offset in operation between 62 and 88 thousand km, which is well below the expected lifetime of such vehicles. Figure 6 below illustrates several breakeven scenarios.

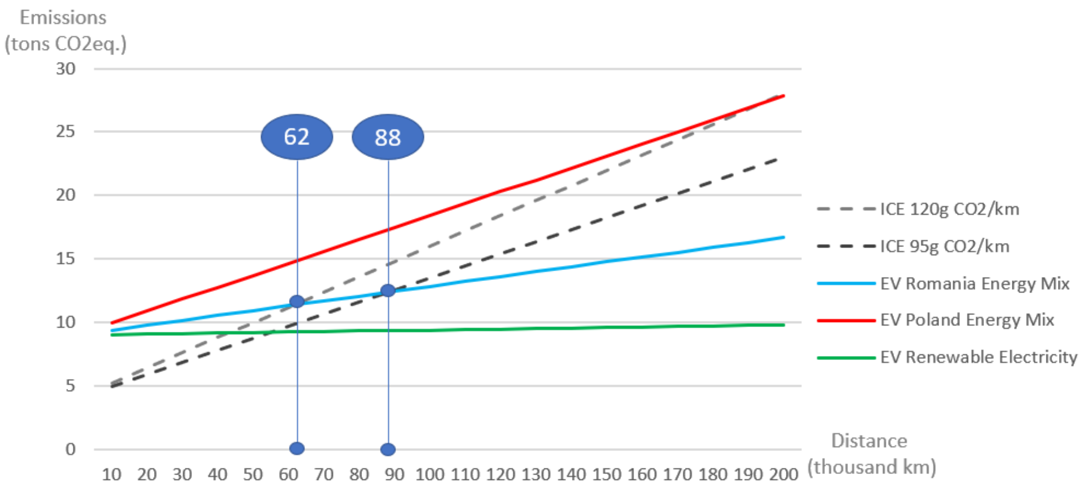


Figure 6: Breakeven simulation for different vehicle types and energy mix scenarios *(Source: own illustration)*

In countries such as Poland and the EU, where the energy mix is still primarily dominated by fossil fuels as the main primary energy source, EVs are not less polluting than ICEs. However, as energy generation is shifting towards renewable sources, BEVs are becoming vital in reducing CO2 emissions in the mobility sector. Their essential contribution is shown in Figure 6 by the 100 % renewable electricity scenario in which a compact EV reaches the emissions break-even after only ca. 43,000 km of operation.

Therefore, as countries continue to decarbonise electricity generation, emissions from both usage and production will continue to reduce, making EVs an increasingly attractive proposition for lowering greenhouse gas emissions globally.

2.4 Charging technology – Basic principles

Charging technologies made significant progress in the past years, and currently, there are multiple options available on the market, from slow to rapid charging. Charging infrastructure is now broadly available from domestic single-phase slow chargers to single-phase fast and three-phase rapid chargers in the public and semi-public space. Furthermore, other options are being explored, such as battery swapping stations where drivers can swap their discharged battery with a charged one (Muneer et al., 2017: 102; Sarker et al., 2015: 902).

Type of power supply

Currently, there are three options available for recharging electric vehicles: wired, inductive or wireless and battery swapping.

This Thesis will focus on *wired charging,* the most common and widely spread technology.

For the sake of completion, the main characteristics of inductive charging and battery swapping will be presented.

Wireless charging using induction – refers to the battery charging using an electromagnetic field to transfer energy to the vehicle. This method is currently unavailable commercially, nor are any commercial vehicle types foreseen for inductive charging yet. Inductive charging may become an exciting alternative for the future given its numerous potential advantages: no equipment or cables required, no or minimal impact on the cities' streetscape, charging while driving by inductive roads (Filho & Kotter, 2015:57).

Battery swapping stations (BSS) could be the fastest way of recharging electric vehicles but has several drawbacks: the high cost of swapping stations, additional batteries needed, standardised battery models required, vehicles suited for battery swapping (not available at the moment) (Filho & Kotter, 2015:57).

“From the power system perspective, the BSS is then a sizeable, flexible demand, and from the EV owner’s perspective, it is a service provider that can supply them with a fully charged battery on request at a fee. This service is similar to gasoline stations’ service to internal combustion vehicles.“ (Sarker et al., 2015: 902)

For *wired charging,* two options are available: charging with alternating current (AC) and charging with direct current (DC). All batteries require DC power to be set while the power from the electricity grid is usually AC. For this reason, the conversion from AC to DC must take place at some point in the charging process:

- *Charging AC power*: power levels are low enough to allow the installation of the converter in the vehicle; therefore, the AC power from the electricity grid is passed by the charging station to the car where the conversion to DC takes place; AC charging cables are usually loose cables with plugs on both ends.
- *Charging DC power*: a bigger and more costly converter would be required for fast charging with higher power levels. In this case, the conversion from AC to DC takes place at the charging station level, which then delivers the DC power to the vehicle; due to the higher power levels and related safety concerns, DC charging cables are permanently fixed to the charging station.

Various charging modes, plug types, identification and billing systems have been created and rolled out for AC and DC charging. The following sections aim to provide a basic understanding of their main characteristics.

Charging Modes

The International Electrotechnical Commission (IEC) has defined four charging modes for control and safety to guarantee safe and efficient charging (DIN EN IEC 61851-1). The charging modes defer mainly through the complexity of the system and charging speed (Filho & Kotter, 2015:59) (Cichowski, 2021: 26).

Mode 1 – charging from regular plugs up to 16 Amperes, without specific safety and communication features. Cables and plugs are required to match the car and wall sides.

Mode 2 – charging from regular plugs with a special cable featuring an in-cable-control box (ICCB) to control power level and protect users and vehicles. Both Mode 1 and 2 are used without requiring a particular infrastructure (e.g. home charging) or where the regulator decided to simplify the charging system (e.g. Norway, where many charging networks make use of regular sockets).

Mode 3 – uses dedicated charging equipment that guarantees safe use and enables the communication between charger and vehicle. In this case, a special cable and plug combination is necessary.

Mode 4 – This mode is usually used for fast charging with power levels higher than 50 kW and entails using an AC/DC converter inside the charging equipment. DC power is delivered to the vehicle (no conversion is required inside the car).

Plug Types

The plug type refers to the design of the plug with which the vehicle is connected to the charging equipment.

Domestic socket – Charging power levels of up to 3.7 kW (230 V, 16 A) can be reached with a domestic socket with the appropriate fusing and a mode 2 charging cable. This charging method is available for all-electric cars and is most common for charging in private garages.

CEE plug – CEE plug is available in various alternatives: (i) as a single-phase current version with a charging power of up to 3.7 kW (230 V, 16 A); (ii) as a triple-phase current version plug (CEE 16) which allows for charging at power levels of up to 11 kW (400 V, 26 A); (iii) as a triple-phase current version plug (CEE 32) which allows for charging power levels of up to 22 kW (400 V, 32 A).

Type 2 plug (Mennekes) – This plug type is the most common in Europe for charging three-phase AC power in public or semi-public spaces. Almost all vehicles and chargers work with Type 2 plugs and are equipped with loose cables. The type 2 plug can support the charging with AC power of up to 43.5 kW (400 V at 63 A) and simple charging with one-phase AC power of max 3.7 kW (230 V at 16 A). Table 4 below shows the possible charging powers according to norm IEC 62196-2:2011.

Table 4: AC charging powers *(Source: own table based on Gehrlein & Schultes, 2017)*

AC	230 V	400 V
13 A	3.0 kW	9.0 kW
16 A	3.7 kW	11.0 kW
32 A	-	22.0 kW
63 A	-	43.5 kW

The CEE plug is the cheaper, more robust and more accessible charging alternative to the Type 2 plug and is still available in some semi-public charging locations in Europe. However, Type 2 is increasingly becoming the standard in Europe and is recognised as the safer option for public places given the information exchange between charger and vehicle and the possibility to lock the plug at both vehicle and plug end (Gehrlein & Schultes, 2017:13).

Combined Charging System (CCS) – The CCS plug is an enhanced version of the Type 2 plug and, since 2014, the EU comprehensive mandatory standard. CCS has two additional power contacts for quick charging and supports AC and DC power levels.

CHAdeMO – This quick charging system was developed in Japan and allowed up to 50 kW charging capacities at the appropriate public charging stations. The following manufacturers offer electric cars compatible with the CHAdeMO plug: BD Automotive, Citroën, Honda, Kia, Mazda, Mitsubishi, Nissan, Peugeot, Subaru, Tesla (with adaptor) and Toyota (Gehrlein & Schultes, 2017).

Tesla Supercharger – Tesla uses a modified version of the Type 2 Mennekes plug Typeits supercharger.

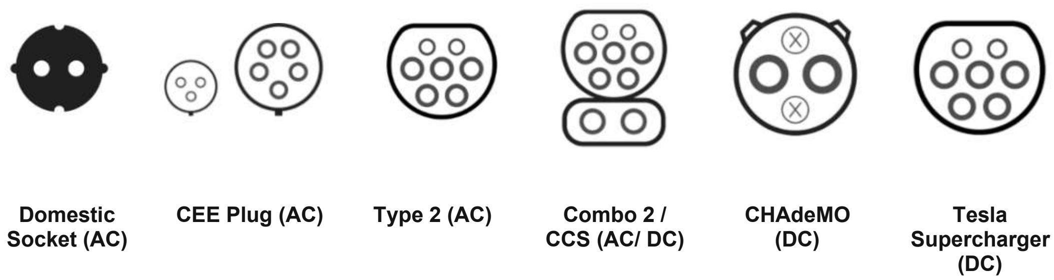


Figure 7: Plug types (Source: own illustration)

Identification and billing systems

The identification and billing system provides the connection between the vehicle and the charging services provider to allow for the vehicle identification at the charging point, the authorisation of the charging session and execution of the payment. Different charging networks have made use of different identification and billing systems. These systems' harmonisation and standardisation allow interoperability (roaming) between various charging networks. Interoperability between different networks is enabled by the availability of higher-level systems, which provides for the settlement of payments between different network operators part of the roaming network (Filho & Kotter, 2015:60).

There are several options available regarding identification and billing. The best known at the moment is the use of Radio Frequency Identification (RFID), but other methods are also available or in development, such as identification using a mobile phone (SMS, App, QR code) or direct communication between the car and the charger (plug-and-charge).

The EV is then billed for the energy or charging time (unless charging is included in the flat-rate subscription agreement). In the case of roaming, the system identifies the vehicle and driver to the belonging network and allows for the reconciliation of the payment between the networks (Filho & Kotter, 2015:61).

EU Standards

Directive 2014/94/EU of the European Parliament and the Council on the deployment of alternative fuels infrastructure (AFID or Directive) had a considerable impact on the interoperability of alternative fuels infrastructure. The Directive has ensured standardisation of recharging plugs early in the development of the market, thereby avoiding multiple standards being used by players in different European markets. The plug types utilised across the EU are nowadays largely standardised, as highlighted in the previous section *Plug types*.

However, the current technical specifications under the Directive also prove improvement potential in various areas, particularly communication protocols and payment systems standardisation. For example, ad-hoc payments are usually impossible in the EU, while restrictive web apps or RFID card payments are widely utilised.

Improving the roaming platforms functionality, simplifying the contractual base, and improving ad-hoc payment possibilities are key improvement areas to ensure national and cross-border interoperability in the EU. These areas of improvement are also acknowledged in the proposal for a regulation of the European Parliament and the Council on the deployment of alternative fuels infrastructure published in July 2021. This Regulation replaces the Directive 2014/94/EU and sets new EU broad standards for alternative fuels charging infrastructure.

Business roles

There are two prominent roles in the EV charging industry: charge point operator (CPO) and electromobility service provider (EMSP).

EMSPs – enter contracts with end-customers and typically includes charging, search & find, routing and other services. It is the legal entity that the end-customer has a contract (business-to-customer (B2C) relationship) with for all services related to the EV. The EMSP is the owner of the data of the EV users in its portfolio.

CPOs – install and maintain charging hardware. Furthermore, CPOs are responsible for the charging sessions and is the owner of all the data related to the charging station. The CSO offers charging services (access to physical infrastructure and energy) to the EMSP based on a business-to-business (B2B) relationship.

CPOs and EMSPs can either have a direct contractual relationship or through an intermediary called a marketplace operator.

Marketplace Operators – The marketplace is a virtual B2B environment for services related to electromobility. Electromobility services include authentication and authorisation, EV charging, CS reservation, routing, and clearing services.

Clearing services – refer to either (i) contract clearing (validation of EV users) or (ii) financial clearing (reconciliation of charge detail records which enables EMSPs to pay for the charging session to the CPOs) (Medina et al., 2015).

Charging time

Battery charging times depend on the power of the charging equipment, EV's battery capacity, the efficiency of the charging process and the charging technology of the EV (Cichowski, 2021: 27). This section explains the calculation formula for the charging times, an overview of specific charging duration estimates for different EV types and other factors that influence the charging times.

To calculate the charging time, the equation below has can be used (Muneer et al., 2017: 102):

$$CT = \frac{BC}{P} \qquad (1)$$

Where:

CT = Charging Time (h)

BC = Battery Capacity (kWh)

P = Power (kW)

For exemplification, Table 5 below illustrates the charging times for Renault Zoe EV (22 kWh battery) and Nissan Leaf (24 kWh battery) for different charging power options.

Table 5: Charging times for 22 kWh and 24 kWh EV batteries *(Source: own table based on Muneer et al., 2017)*

Classification	Phases	Current (A)	Voltage (V)	Power (kW)	Charge time 22 kWh battery (h)	Charge time 24 kWh battery (h)
Very slow	1	10	230	2.3	9.6	10.4
Slow	1	16	230	3.7	6	6.5
Fast	1	32	230	7.4	3	3.3
AC rapid	3	32	230	22.1	1	1.1
DC rapid	3	63	230	43.5	0.5	0.6

In addition to the parameters presented above, several other factors influence charging time:

EV type – the charging technology integrated into the electric car plays a role just as important as the power of the charging equipment and decides to which degree the charger's power output can be utilised.

Battery charging status – the charging process progresses linearly during most of the charging period. However, the battery's chemical reaction slows down for the last 10%-20% of the charge for fast and rapid charging. This is explained through the so-called "mating analogy" (Sera, 2013, cited by Muneer et al., 2017).

The battery's primary function is to convert chemically stored energy into electric energy and vice versa. A battery cell is composed of a positive electrode plate (cathode) and a negative electrode plate (anode) separated by a chemical medium (electrolyte). The lithium-ion battery is currently the most popular choice for EVs - when discharging, the battery's anode releases electrons and ions. The chemical medium allows only ions to travel to the cathode. The electrons have to take an external route to reach the cathode. This external flow of electrons powers the EV motor. While recharging, the ions and electrons flow in the opposite direction moving from cathode to anode (Muneer et al., 2017: 103). As charging progresses, the time needed for the ions to match or react to one another becomes longer as the matches become fewer. Therefore, after reaching ca. 80% of the battery capacity, the charging process slows down.

Outside temperature – the ideal charging temperature ranges between 15˚C and 25˚C. Therefore, at temperatures outside this range, the charging duration is slower. The battery may need to be pre-heated on very cold days to optimise the charging process (Cichowski, 2021: 20, 28).

Charging alternatives

The previous sections described the various options available regarding charging technology and standards, identification, and billing, charging services, and business models.

The morphological box analysis (Medina et al., 2015 after Kley et al., 2011; Markkula et al., 2013) presented in Figure *8* below summarises the different options related to other parameters as described in the previous sections to illustrates the complexity of the electro-mobility field and a multitude of options and models.

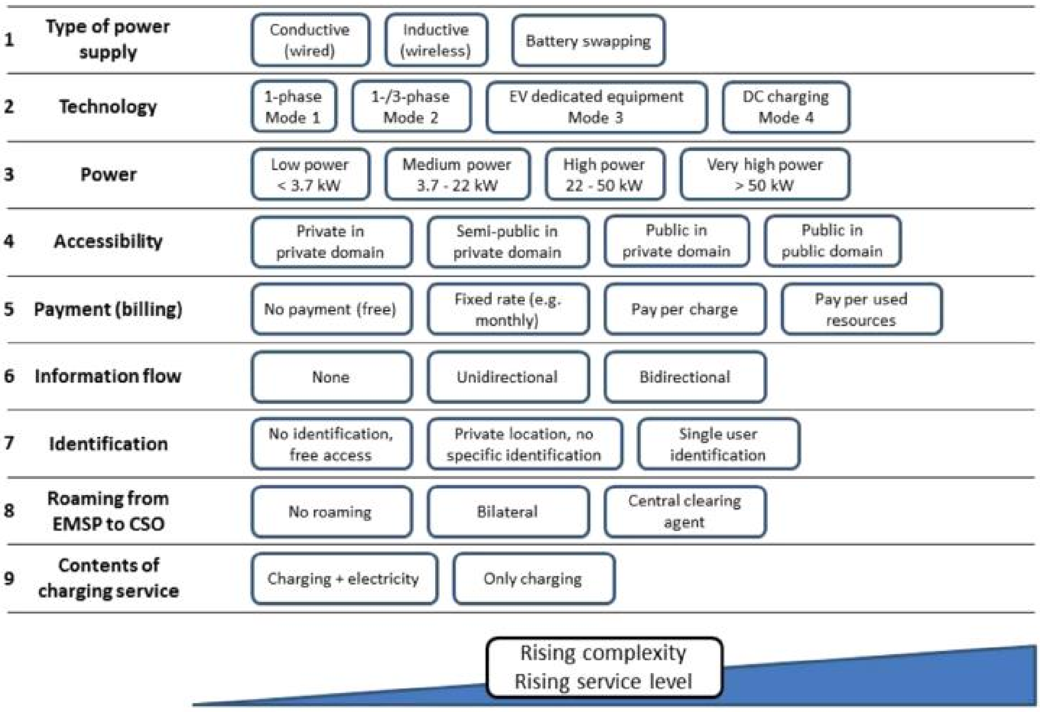


Figure 8: Morphological box for different charging alternatives for EVs *(Source: Medina et al., 2015 after Kley et al., 2011; Markkula et al., 2013)*

As observed in Figure 8, the morphological box illustrates different categories of relevant parameters for EV charging. For each category, the possible attributes are listed. Each class consists of two to four characteristics. The characteristics are organised from left to right, the left end presenting the least complexity and service level. Moving to the right, complexity increases and provides a higher customer service level and thus higher customer value. The morphological box thus provides a quick overview of the available possibilities and helps illustrate the importance of different services offered.

2.5 Policies and regulations for the EVs and charging infrastructure in the EU

Governments around the world have set targets to increase electric vehicle market share. Electrification of vehicles is an important measure to reduce environmental impacts and greenhouse gas emissions in the road transport sector. Electric propulsion is energy efficient, does not cause local emissions and reduces noise.

There are multiple instruments that governments and local authorities can adopt to encourage the mass adoption of electrified vehicles and, along with it, the rollout of public charging infrastructure. When analysing measures implemented by different countries over the last decade, some stand out in terms of achieved results reflected mainly by the share of EVs in the current vehicle stock. While countries like Norway and Nederland have seen strong growth in the EV sector, most European countries lag behind.

In December 2019, the European Commission adopted the European Green Deal, which calls for a 90% reduction in greenhouse gas (GHG) emissions in transport for the EU to become a climate-neutral economy by 2050.

In the European Climate Law provisionally agreed in April 2021, the European Commission communicated its target to reduce net emissions of greenhouse gases (GHG) by at least 55% until 2030 compared to 1990 as an intermediate milestone in its pursuit to reach climate neutrality by 2050.

In line with these commitments, for the road transport sector, new CO2 emissions performance standards have been set for new passenger vehicles through the EU Regulations 2019/631. The Regulation sets EU fleet-wide CO2 emission targets to be applied from 2020, 2025 and 2030 and includes a mechanism to incentivise the uptake of zero- and low-emission vehicles. For 2020-2024, Regulation 2019/631 confirms the EU fleet-wide CO2 emission targets set previously, which places a limit of 95g CO2/km for passenger cars. Starting in 2025 and 2030, Regulation (EU) 2019/631 sets stricter EU fleet-wide CO2 emission targets, defined as a percentage reduction from the 2021 starting points. For passenger vehicles, these are a 15% reduction from 2025 on and a 37.5% reduction from 2030 on.

The Regulation 2019/631 has been preceded by several consecutive emissions reduction targets for the passenger vehicles. For a better overview, Figure *9* below shows the reduction plan of the CO2 emissions for new passenger vehicles in the European Union after 2012. According to EU's specifications, until 2012, the CO2 emissions of 65% of the latest passenger vehicles had to comply with the 120g CO2/km maximum limit. Until 2015, the share of new passenger vehicles has been gradually increased to 100%. Starting 2020, the emissions limit has been reduced to 95g CO2/km for all new passenger cars. These limits must be regarded as general benchmarks, as specific values have been allocated to each vehicle producer and calculated as an average for new passenger vehicles sold (Yay, 2015:36).

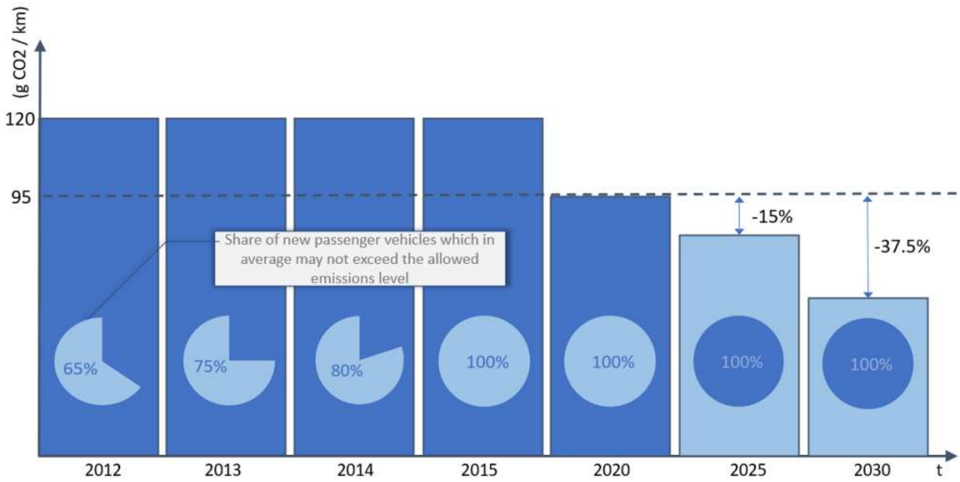


Figure 9: Phased plan for the reduction of CO2 emissions of new passenger vehicles in the European Union *(Source: own illustration based on Yay, 2015)*

According to the European Commission, as the new target started applying in 2020, the average CO2 emissions from new passenger cars registered in Europe have decreased by 12% compared to the previous year, and the share of electric vehicles tripled. The targets set for 2025 and 2030 oblige vehicle producers to release an increasing number of BEVs and PHEVs models to meet, on average, the maximum permitted CO2 emissions levels.

In line with the ambitious GHG reduction targets, the European Commission highlights the importance of proper rollout of alternative fuels infrastructure as a critical success factor for the transition to a nearly net-zero car fleet in the EU by 2050.

On 14 July 2021, the European Commission has issued “Fit for 55”, a package of proposals aimed at putting the European Union on track to reaching the goals mentioned above and Green Deal targets. One of the proposals is to replace the previous Alternative Fuels Infrastructure Directive 2014/94/EU with a fixed Regulation (the “Proposal” or the “Regulation”) to set clear strategic goals for the national policy frameworks regarding the deployment of the alternative fuel infrastructure. The regulation also acknowledges that the lack of proper spread of charging infrastructure can be a significant barrier in the mass adoption of EVs: “The increased deployment and use of renewable and low-carbon fuels must go hand in hand with the creation of a comprehensive network of recharging and refuelling infrastructure based on a geographically fair manner (…), the broad mass of consumers will only switch to zero-emission vehicles once they are sure they can recharge or refuel their vehicles anywhere in the EU and as easily as is currently the case for conventionally fueled vehicles.”

The Proposal further sets optimisation targets for its preceding Directive 2014/94/EU of the European Parliament on the deployment of alternative fuels infrastructure (AFID) to overcome main shortcomings: different levels of targets ambition among EU member states, the lack of harmonised support policies, interoperability issues, communication standards, including data exchange among the various actors in the electro-mobility ecosystem, the lack of transparent consumer information and standard payment systems.

To ensure uniform and faster rollout across the EU countries and stricter control of implementation targets, the Proposal’s objectives will be implemented through a Regulation instead of a Directive (AFID) as in 2014. This tool will also allow for rapid deployment of charging infrastructure to meet intermediate milestone targets by 2025.

The Proposal seeks to ensure the availability and usability of a dense, widespread network of alternative fuels infrastructure throughout the EU to enable easy movement through the EU. The specific objectives are: (i) ensuring required infrastructure to support the required uptake of alternative fuel vehicles in all Member States to meet the EU’s climate objectives; in terms of climate objectives, “Fit for 55” also targets close to zero emissions in the transport sector until 2050. For road transport, this effectively means banning the sale of ICEVs latest by 2035; (ii) ensuring the infrastructure’s full interoperability; and (iii) ensuring complete user information and adequate payment options.

More precisely, Alternative Fuels Infrastructure Regulation sets the following targets to be implemented in each Member state concerning charging infrastructure for light-duty vehicles:

1. *Number*: for each battery-electric light-duty vehicle registered in their territory, a total power output of at least 1 kW needs to be provided through publicly accessible charging stations; this effectively means that the sum of all installed power capacities of the public charging stations in on member state should equal the number of EVs on the roads.

   The European Commission's 2014 AFID suggested a ratio of 10:1 for the number of electric vehicles per public charging point.
2. *Distance*: along with the Trans-European Transport Network core network, publicly accessible recharging pools dedicated to light-duty vehicles shall be deployed in each direction of travel with a *maximum distance of 60 km in-between them* and should contain at least one 150 kW power charging station by 2025 (min 300kW in total) and at least two 150 kW power charging points (min 600 kW in total) by 2030. The Trans-European Transport Network (TEN-T) is a planned network of roads, railways, airports and water infrastructure. The European Commission adopted the first action plans on Ten-T networks in 1990.
3. *Payment*: All operators of public charging points shall permit EV recharging on an ad-hoc basis by accepting electronic payments methods widely acceptable in the European Union. In this sense, for public charging stations with power equal to or higher than 50 kW, payment card reading devices at the charging points terminals shall be adopted soon. For charging points of lower power, devices use an internet connection with which, for instance, a Quick Response code can specifically be generated and used for payment transactions.

   It can be observed that RFID cards that are currently widespread as primary identification and payment tools but which are a significant interoperability barrier are obsolete in the public space according to the new European Commission Regulation.
4. *Tariffing*: "Prices charged by operators of publicly accessible recharging points shall be reasonable, easily, and comparable, transparent and non-discriminatory". The level of prices may only be differentiated on a selective basis according to an objective justification. According to the Regulation, the fees must be transparently displayed at each charging point to indicate at least the price per session, per minute, or kWh. E-roaming charges shall also be

transparently displayed and must as well remain non-discriminatory and reasonable. Cross border roaming fees will not be allowed.

5. *Signposting*: The Regulation obliges Member States to take the necessary measures to ensure that appropriate signposting is deployed within parking and rest areas on the TEN-T road network where alternative fuels infrastructure is installed to enable easy identification of the exact location of the alternative fuels infrastructure.

The targets set through the Alternative Fuel Infrastructure Regulation Proposal are consistent with the scope of other policies and programs, which leads to a harmonised implementation approach across sectors and member countries:

- The Energy Performance of Buildings Directive (EPBD) addresses the requirements of private recharging infrastructure for rollout in buildings.
- Clean Vehicles Directive aims to accelerate the deployment of low- and zero-emission vehicles.
- European Commission's hydrogen strategy and smart energy system integration promote hydrogen and battery electric vehicles charging infrastructure in line with the development targets envisaged for the EU vehicle fleet.
- The European Green Deal by facilitating the deployment of growing numbers of zero- and low-emission vehicles in line with the zero-pollution ambition in the European Green Deal, complementing the Euro 6 (for cars and vans) and Euro VI (for buses and lorries) pollutant emission standards.
- Intelligent Transport Systems Directive on EU-wide real-time traffic, information services shall specify the relevant data types to be made available in alternative fuels infrastructure roll-out.

2.6 Promotion actions for EVs and charging infrastructure in the EU

Beyond the regulations and directives imposed at the EU level, countries in Europe are implementing their own national or local promotion actions with the scope to either reach EU targets or to implement internal decarbonisation plans. This section reviews different promotion instruments for electric vehicles and charging infrastructure. The promotion instruments available at the national and local levels are illustrated in Figure 10 and will be explained further in this section.

Electric vehicle purchase and operation	Electric vehicle charging infrastructure
National • BEV purchase benefit • PHEV purchase benefit • BEV registration tax benefit • PHEV registration tax benefit • BEV ownership tax benefit • PHEV ownership tax benefit • EV company car benefit for employees	**National** • Public charger promotion • Private and workplace charger promotion
Local • EV parking benefit • EV charging benefit • EV infrastructure use and access benefit	**Local** • Public charger promotion • Private and workplace charger promotion • EV curbside charging program • EV-ready building codes • EV charging interoperability requirements

Figure 10: Selected promotion actions *(Source: Wappelhorst et al., 2020)*

Promotion actions for electric vehicles

Currently, most legislative bodies provide subsidies and financial incentives for encouraging customers to buy electric vehicles. In some countries such as Norway and Netherlands, these instruments proved remarkably successful, while others lag behind. In all cases, however, a link between vehicle purchasing rebates and the sale of EVs can be observed.

A study from 2014 published by the International Council for Clean Transport (ICCT) evaluated the response to fiscal incentives in 2012-2013 and how these were reflected by the market share of BEVs and PHEVs. The analysis results are based on broad-ranging sales data, national taxation policy information and direct electric vehicle purchasing rebates linked to their impact on the evolution of the market share of electric vehicles in the same period (Nikowitz, 2016:48).

Figure 11 below illustrates the relation between the level of inventive per vehicle type (as a percentage of vehicle base price) and the market share of the respective vehicles for 2012 and 2013.

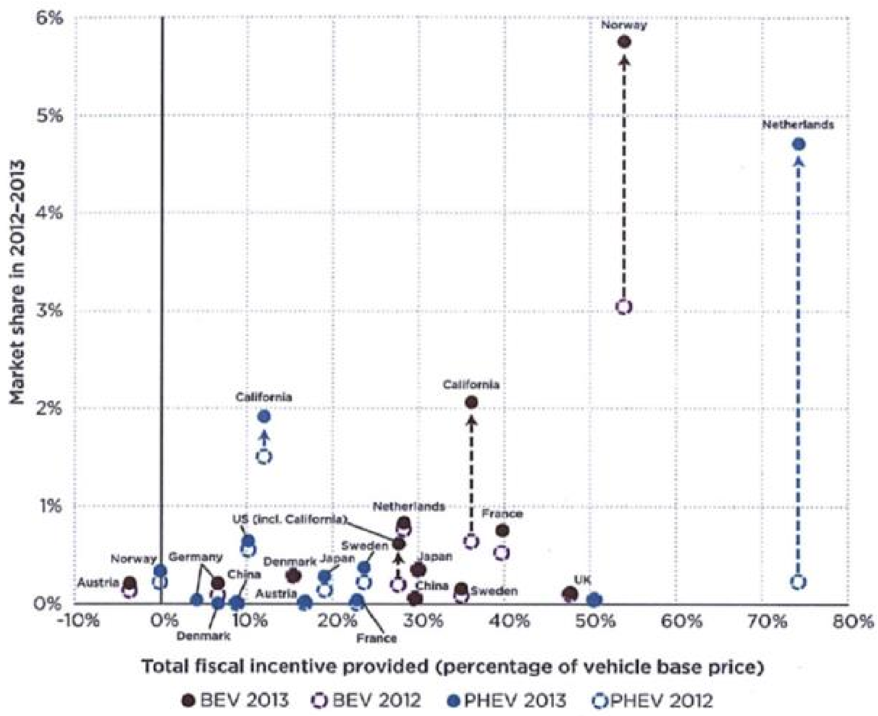


Figure 11: 2012 and 2013 market shares vs total fiscal incentive provided, i.e. the percentage of vehicle base price for BEVs and PHEVs (only company car market share for PHEVs shown here), in per cent *(Source: Mock & Yang cited by Nikowiz, 2014)*

As observed, Norway and Netherlands had the highest BEV and PHEV share sold in 2013 with 6% and almost 5% of all vehicles sold. As Niklowitz (2016: 48) points out, the structures of the two markets are very different; however: in Norway, almost all EVs sold are BEVs, while in the Netherlands, the market is PHEVs dominated.

Norway incentive scheme included a EUR 11,500 subsidy for BEVs, which is associated with the 6% market share of BEVs in 2013 (a 90% increase compared to the previous period). Similarly, the Netherlands offered a EUR 38,000 subsidy for acquiring PHEVs in the same period, associated with a market share of almost 5% EVs in 2013 and a 1900% increase compared to the previous year (Nikowitz, 2016:49).

These two examples point out how national incentive schemes can have a powerful impact on consumers' decisions and significantly boost the EV market.

In Romania, described in detail in section 4.3 to follow, the availability of the direct subsidy program "Rabla Plus" had a remarkable success. In 2020, for instance, despite a general regression of total vehicle sale volume on the background of the COVID crises, the EV sales almost doubled.

Apart from direct subsidies, there are several other fiscal incentive types offered by most countries in Europe separately or in combination with direct subsidies. Fiscal incentives are defined as reduced purchase and/or annual tax for EVs.

- *VAT* – According to Nikowitz, Norway is the only analysed country that applied a VAT exception for BEVs acquisition (not for PHEVs); all other countries use VAT which sometimes ends up being higher than the VAT quote used for the purchase of the conventional vehicles due to the higher price of EVs which in some jurisdictions qualifies them for a higher taxation level (Nikowitz, 2016:49).
- *One-time purchase/registration tax* – some countries offer an exception from the registration tax for EVs; for example, in Nederland, the vehicles which fall below a certain CO2 emission level are exempted from the registration tax. Both BEVs and PHEVs qualify for this exemption. Other countries like Norway and Denmark apply similar rules.
- *Other* – annual circulation taxes and company car taxes are examples of other fiscal instruments that may favour the EV drivers.

In addition to the monetary instruments, local authorities sometimes offer other benefits for EV drivers, such as preferential parking rules and access to inner cities, utilisation of fast lanes and even free charging for EVs.

Filho & Kotter point out also other instrument types which are being used in some jurisdictions (2015:36):

- *Communication* – communication of arguments and persuasion, including information and education (e.g., education in schools, government information and awareness campaigns).
- *Organisation* – actions by the government and public institutions that can act directly, using their forces to achieve goals rather than outsourcing and incentivising third parties. This may include allocating means, capital, resources, and infrastructure needed to act (e.g., governments acting as launching customers, buying their EV fleet, installing public charging points).

According to the same analysis, the organisational instruments appear to be the prevalent focus area in many countries, along with the financial incentives. Countries with a particular focus on organisational mechanisms are, for instance, Denmark, Belgium, Germany, Netherlands, and Sweden (Filho & Kotter, 2015:37).

For instance, the Center for Green Transport, in cooperation with the Danish Energy Agency, was set up a decade ago to encourage the exchange of experiences regarding EVs between communities. A few years later, in 2014, Cowas Electric was founded to provide objective information on electromobility to communities, companies, and private individuals and strengthen the sector's competitiveness on an international level.

National promotion actions for charging infrastructure

National promotion actions play a critical role in deploying public charging infrastructure. In 2018, almost all national governments provided funding for deploying the public charging infrastructure. "Beneficiaries of the various national programs covering a range of consumer groups including municipalities, associations, public institutions, small and medium-sized businesses, or residential collectives. Funding amounts ranged from EUR 4.8mn by the Finnish government to EUR 300mn allocated by the German government with varying funding periods" (Korkia, 2019 cited by Wappelhorst et al., 2020).

Table 6 below shows examples of subsidy programs in different European countries. It can be observed how other instruments are being adopted in different countries. The most common co-funding program scheme foresees fixed amounts per hardware unit capped to a certain percentage of the eligible investment costs. The fixed amount depends mainly on the kilowatt power rating of the equipment and can widely vary. For example, in Austria, subsidies of between EUR 200 and EUR 10,000 are offered based on this criterion.

In other countries, co-funding is granted up to a certain level of the eligible investment costs varying from 30% in Finland to 60% in Spain.

Other incentive models set geographic targets for the infrastructure rollout, such as Norway, which aims to install charging stations every 50-highway kilometre.

In Romania, different incentives programs are currently available and are mainly known for public bodies and municipalities. A separate section 4.3 explains the presently available financing schemes in detail.

Table 6: Selected national public charger promotion actions in 2018 *(Source: Wappelhorst et al., 2020)*

Market	Program	Funding source
Austria	National support program for the installation of public charging stations (pedestal or wall box). The support ranges between €200 and €10,000 depending on the kilowatt rating of the charging station. Beneficiaries include companies, associations, religious denominations, and public authorities.	Austrian government (Kommunalkredit Public Consulting GmbH, 2019)
Finland	National support program for the development of electric vehicle public charging infrastructure with a total €4.8 million in 2017–2019. The subsidy rate for fast charge points is 35%; for normal charge points it is 30%. The investment aid is aimed at companies.	Finnish government (Korkia, 2019)
France	Since 2016, the French government has been running the Advenir program, including subsidies for public charging points. Companies and public entities can receive up to 40% of the costs for the supply and installation of a charging point to a maximum of €1,860.	French government (République Française, 2018; Avere-France, 2019)
Germany	The German government is supporting the expansion of public fast and normal charging points with €300 million from 2017 to 2020. Beneficiaries are private investors as well as cities and municipalities.	German government, Federal Ministry of Transport and Digital Infrastructure (Federal Ministry of Transport and Digital Infrastructure, 2019)
Netherlands	The Dutch government granted help for publicly accessible charging infrastructure for electric cars with the framework of the Green Deal "Publicly Accessible Electric Charging Infrastructure." The program ran from mid-2015 to July 2018 with a total budget of €7.2 million. Beneficiaries were local and regional authorities.	Dutch government, Ministry of Economic Affairs and Infrastructure and Ministry of Water Management (Netherlands Enterprise Agency, n.d.)
Norway	Programs focus on the deployment of fast charge points at least every 50 km on the highway network. The company Enova has pledged support for NOK50.5 million (€5.3 million) for the establishment of 230 fast charge points.	Enova, owned by the Ministry of Petroleum and Energy (Ministries' security and service organization, 2017)
Spain	Aid program in 2018 for the implementation of the recharging stations including public charging stations within the framework of the MOVALT Infrastructure Plan. A total of €20 million were made available (including funding for private charge points). Grant amounts were 60% of the eligible investment for public entities and 40% of eligible for other companies.	Spanish government (Institute for Diversification and Energy Saving, 2018)
Sweden	Funding program for the installation of public charging infrastructure with a maximum of 50% of the investment cost.	Swedish government, Ministry of the Environment and Energy (Sweden's Parliament, 2015)
Switzerland	The Swiss government plays a supporting role in the coordination and planning of the public charging infrastructure. The responsible body is Energie Schweiz (Swiss Energy).	Swiss government (Federal Office of Energy, n.d.)
United Kingdom	On-street Residential Chargepoint Scheme, launched 2016, provides grant funding for local authorities to install on-street charging points. The allocated budget is £6 million (€7 million) from 2017 to 2020.	Department for Transport (Office for Low Emission Vehicles, 2019)

Local promotion actions for EVs and charging infrastructure

In the introduction of this section, Figure 10 summarises the types of instruments usually applied to encourage the development of both the EV market and charging infrastructure. In this section, Figure 12 shows concrete examples of the actions taken by different municipalities in 2018 for both EV rollout and charging infrastructure deployment differentiating between the national measures and the local action plans. This type of view allows observations on whether the actions are being adopted predominantly top-down or being decided at the regional level (Wappelhorst et al., 2020).

EV related actions are mainly established centrally at the national level (dark green areas in Figure 12) and rolled out at the municipality level. Out of the 91 actions for EVs implemented in the analysed municipalities, 68 are national (75% of the total). For charging infrastructure, on the other hand, most of the promotion actions are being decided locally, with only 22 out of 59 actions taken at the national level (37%). For the municipalities in the scope of this analysis, 50% more promotion actions target EV purchasing with 91 actions instead of 59 actions targeting public infrastructure deployment. All cities take communication and organisational measures without exceptions and are decided exclusively at the local level.

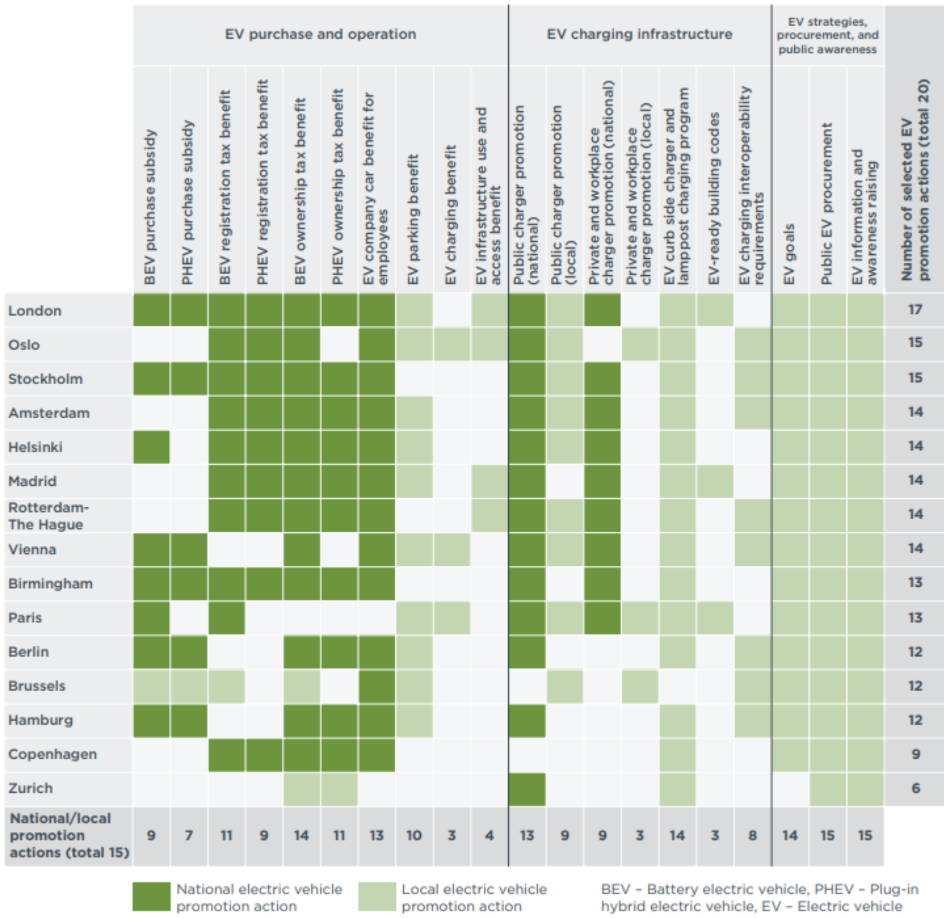


Figure 12: Electric vehicle promotion actions applied in 2018 for at least six months in selected European metropolitan areas *(Source: Wappelhorst et al., 2020)*

Filho & Kotter reached a similar conclusion pointing out that "Downstream financial policies have been the backbone of the early market phase of EVs" (Filho & Kotter, 2015:49). These were targeted predominantly at compensating up to a certain degree for the higher EV acquisition costs and have encouraged early customers to explore this segment.

Filho & Kotter highlight that electric mobility-related policy mainly targets the EV value chain, in particular downstream segments, i.e., the customers (2015:50). Within this category of downstream oriented approach, most instruments are financial. The most common financial instruments are tax incentives, rebates and specific other local benefits (e.g. free parking). Netherlands and Norway, for example, have a high number of tax incentives encouraging both individuals and companies to acquire EVs.

These instruments triggered a significant increase in the EV market share in the mentioned countries, as illustrated by Figure 11. Filho & Kotter also highlight that fewer countries explicitly focus on charging infrastructure promotion actions and note little correlation between the EV-related policies and policies targeted at charging infrastructure deployment (Filho & Kotter, 2015:49).

3. Description of the research method

To answer the research questions explained in section 1.3, different approaches have been applied and will be detailed in this chapter for each topic separately.

The information presented in 2 Background information, has been collected mainly through literature review, analysis of specialised academic publications and industry reports. For the sake of accuracy and given the specific market dynamics, no journal older than 2015 has been referred to for this analysis. Furthermore, the EU policies and directives relevant to this sector have been analysed and summarised principal conclusions.

RQ1 - Current status and forecast: What is the current status of the EV market and charging infrastructure in Europe and Romania; what are the specific conditions of this sector concerning the general economic indicators? What is the estimated number of EVs and charging stations to be reached in Europe and Romania by 2030?

> *To answer these questions, the starting point was to analyse the current status of the EV and charging infrastructure market in Romania based on the most recent information extracted from official databases such as European Alternative Fuel Observatory (EAFO), European Automobile Manufacturers' Association (ACEA), European Federation for Transport and Environment. Further, additional data from Eurostat on economic indicators have been used to demonstrate the correlation between the sector trends and the economic situation in Romania vs the EU. Finally, forecasted figures for the EV and charging infrastructure market provided by industry reports have been analysed, and expected trends and pace have been determined. For the forecast, data provided by European Federation for Transport and Environment and the Romanian Reconstruction and Recovery Plan (PNRR) have been referred to. For a more explicit comparison between the past and future trends in the EU and Romania, the compound annual growth rate has been used to reflect the mean annual growth rates of the GDP per capita*

(historical numbers), expected EVs and charging points numbers (projections). The equation used for the calculation is:

$$CAGR = \left(\frac{V_n}{V_0}\right)^{\frac{1}{n}} - 1\ x\ 100 \qquad (2)$$

Where:

CAGR = Compound Annual Gross Rate (%)

V_n = Ending Value

V_0 = Beginning Value

n = number of years

RQ2 - Charging requirements: what type of chargers will be most required in the future? What is the expected development timeframe?

To answer this question, a few industry reports have been analysed to identify the projections of the specialists regarding future global and European development trends in the sector. The cited reports have been released by McKinsey and the European Federation for Transport and Environment. To correlate the identified trends to the situation on the Romanian market, data from EAFO has been referred to determine the EV models most common in Romania and their charging characteristics (plug types and maximum charging capacity). The latter have been retrieved from specialised online platforms. Fourteen vehicle models issued between 2015 and 2021 have been analysed and empirical conclusions regarding their charging capacity and implied charging requirements for the public space have been drawn. The conclusion reached has been cross-checked with the European Federation for Transport and Environment information.

RQ3 - Promotion actions: What mechanisms have been implemented in EU countries and Romania to promote the EV market and charging infrastructure deployment, and what has their contribution so far?

An extensive review of the relevant Romanian laws and regulations has been performed to identify currently available subsidy schemes for promoting electric vehicles and charging infrastructure. The recognised methods have been cross-checked in discussions with specialists from different Romanian public funding consultancy firms. For information on the details of the application process, eligibility criteria, thresholds, etc., the relevant laws, ordinances and official calls for a proposal have been analysed: the European

Commission's Connecting Europe Facility call for proposal and various regulations by the Ministry of Environment, Ministry of Energy and Ministry of European Investments.

RQ4 – Implementation and permitting: What are the usual permitting and approval steps for implementing a public electric vehicle charging station in Romania?

To answer this question, a detailed expert interview has been conducted with one of the local partners of Schönherr, a well-known law firm with a footprint in Central and Eastern Europe. The discussion focused on identifying the specific steps of the approval and permitting process for the construction and the grid connection of new charging stations. The information obtained in the interview has been completed and cross-checked with the information provided by official public reports on the topic.

RQ5 - Business models: What are the typical business models in the electric vehicle charging sector, and who are the leading players in Romania?

Firstly, the business models of the charging industry have been identified and clustered depending on the underlying revenue streams. Furthermore, the most relevant industry players have been identified through a review of internet sources and specialised industry reports. The main features of their business models, way of operating and market position (where available) had been collected.

RQ6 - Economics: What are the main triggers for the economic viability of the charging infrastructure investments in Romania?

This section presents the results of a high-level assessment of the economic feasibility for different EV charging infrastructure use cases to identify the primary triggers for viable investments in this type of asset. This paper does not aim to provide exact results but rather estimate the economic potential of different charging technologies and scenarios. The Return on Investment (ROI) as a profitability indicator has been chosen and calculated following the steps below.

The Total Annual Revenue (TR) has been calculated as the product of the average charging price in EUR / kWh (CP), the number of charging events per annum (N_{CE}) and the average energy demand per charging events in kWh (D_{CE}):

$$TR = CP \cdot N_{CE} \cdot D_{CE} \qquad (3)$$

Where:

TR = Total Annual Revenue (EUR / annum)

CP = Average Charging Price (EUR / kWh)

N_{CE} = Number of Charging Events per Annum

D_{CE} = Average Energy Demand per Charging Event (kWh)

The charging prices have been determined as an average based on the current charging tariffs applied by Romania's most important charging networks. The average energy demand per session has been assumed to be constant (20 kWh) in line with the approximation used by cited literature sources (specific sources will be explained in section 4.6). The revenue calculation will be done for multiple scenarios where charging events vary between one and ten per charging point.

For simplification, only the difference between the charging prices (CP) and the electricity prices, further called the Margin (CP-C_{el}), has been considered for calculating Annual Gross Profit by using a formula derived from the original equation. The Margin is assumed to be naturally hedged against fluctuations in the electricity prices which would be passed through to the customers by increasing the charging tariffs. Nonetheless, a few sensitivities on the Margin level have been calculated to reflect situations when the charging tariffs cannot entirely absorb the electricity price changes. The cost of the electricity sold has been determined based on data retrieved from the Romanian National Authority for Regulating the Energy Sector (ANRE). By subtracting the Cost of Electricity, the Annual Gross Profit can be determined:

$$GP = TR - TC_{el} = (CP - C_{el}) \cdot N_{CE} \cdot D_{CE} \qquad (4)$$

Where:

GP = Annual Gross Profit (EUR / annum)

TR = Total Annual Revenue (EUR / annum)

TC_{el} = Total cost of electricity sold (EUR)

C_{el} = Cost of electricity (EUR / kWh)

The Annual Net Profit is the profit that remains after all expenses and costs have been subtracted from the Annual Gross Profit:

$$NP = GP - OPEX - OC - T - I + OR \qquad (5)$$

Where:

NP = Annual Net Profit (EUR)

OPEX = Operating Expenses (EUR)

OC = Other Costs (EUR)

T = Taxes (EUR)

I = Interests (EUR)

OR = Other Revenues (EUR)

The Operating Expenses (OPEX) estimation has been based on average values retrieved from five peer-reviewed articles and academic publications referring to investment cases with similar characteristics. The same approach has been used to estimate the total Capital Expenses (CAPEX). Still, only the annualised value has been deducted from the Annual Gross Profit (see the Levelized Investment Cost explained below). The latter represents the amortisation costs and associated Interest amount. The expenses related to the Taxes have been neglected in this simplified calculation, and the Interests expenses have been indirectly included in the Levelized Investment Cost. Other business costs such as rental parking spaces have also been excluded, as this is considered less of a concern for fast charging long-distance stations (Schroeder & Traber, 2011). Other Revenues (investment subsidies and advertising revenues) have been included only as a test case but have been excluded from the base case and main sensitivity scenarios.

The Annual Net Profit has then been compared to the Levelized Investment Cost in order to obtain a Return on Investment (ROI) figure which according to Schroeder & Traber (2011) can be used as indicator of profitability for this type of investments:

$$ROI = \left(\frac{NP}{IC} - 1\right) \cdot 100 \qquad (6)$$

Where:

ROI = Return on Investment (%)

LIC = Levelized Investment Cost (EUR)

For the calculation of the Levelized Investment Cost, the following formula has been applied:

$$LIC = \frac{CAPEX}{\frac{(1+i)^n - 1}{(1+i)^n \cdot i}} \quad (7)$$

Where:

CAPEX = capital expenditure

i = interest rate

n = the lifetime of the project

ROI represents only a short-term horizon assessment that gives a rough indication of whether a charging station investment case can achieve profitability under various conditions. The ROI concept is a simple measure that does not require assumptions on the uncertain long-term cost and revenue dynamics.

Despite ROI's limitations, this approach makes the analysis more straightforward. It allows focusing on the impact on profitability results triggered by selected parameters: the number of charging events (N_{CE}) and the Margin. The aim is to highlight the sales volume (i.e., number of charging sessions) necessary for a positive Annual Net Profit in several Margin scenarios (base case, pessimistic case, optimistic case, and actual margin case). Although this approach reduces the accuracy of the results, the future of electro-mobility is challenging to predict. The assumptions considered are expected to be sufficient to point out the main profitability drivers for this type of investment.

The conclusions reanalysed the analysed questions are presented in the last chapter, focusing mainly on the identified challenges and opportunities of the charging infrastructure sector in Romania.

4. The public charging infrastructure in Romania

4.1 Status and forecast

In Romania, the electric vehicle market development has been in line with the EU trends over the past few years. After the first EVs were registered in Romania in 2013 (38 in total), the number of registrations continued to increase over the past decade, reaching 3,890 in 2020 (EAFO, 2022). The newly registered EV market share increased from 1.4% in 2019 to 3.1% in 2020. Comparatively, the percentage of newly registered EVs in 2020 at the EU level has been 10.5% (ACEA, 2021).

An overview of the EV market development in Romania over the past few years is shown in more detail in Figure 13.

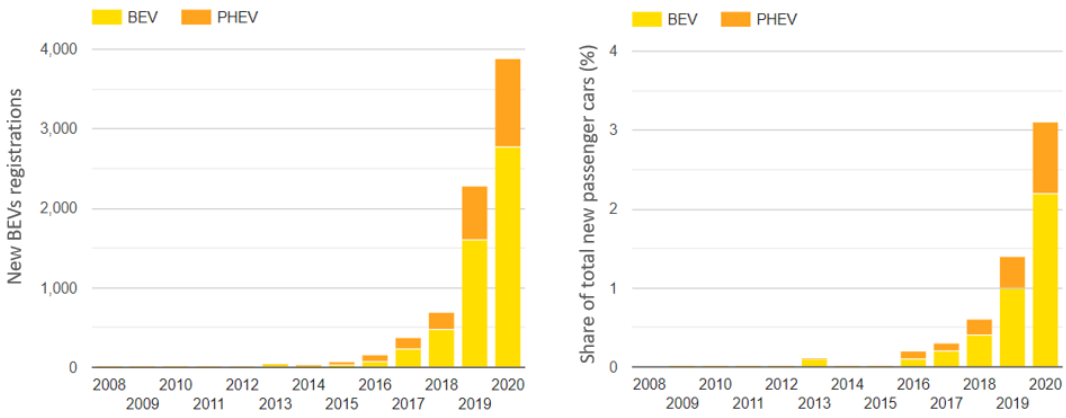


Figure 13: The EV market in Romania by number of new EV registrations (left) and share of the total new registered vehicles (right) *(Source: EAFO, 2022)*

Concerning the public charging infrastructure, Romania, with 502 charging points in 2020 (317 ≤ 22 kW and 185 > 22kW), is among the countries with the least charging points in the EU. Also, in terms of charging point sufficiency metrics, with 15 EVs per charging point, Romania is behind the EU average of 10 EVs per charging point in 2020, representing the European Commission's target set in the current AFID (please refer to section 2.5). The evolution of the charging infrastructure sector in Romania is illustrated in more detail by Figure 14 below.

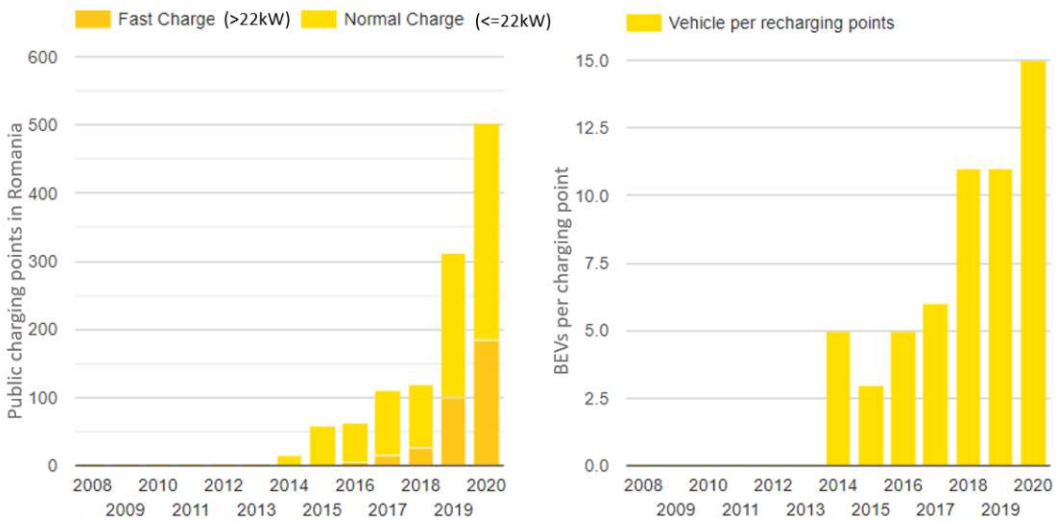


Figure 14: Number of public charging points in Romania (left) and number of EVs per charging point (right) (Source: EAFO, 2022)

Although the developments of the past few years are remarkable when looked at from a local perspective, with ca. three recharging points per 100 thousand inhabitants and ca. 39 EVs per 100 thousand inhabitants in 2020, Romania is seriously lagging behind other countries in Europe. Figure *15* shows the position of Romania compared to other European countries in terms of EV market penetration and charging stations' concentration.

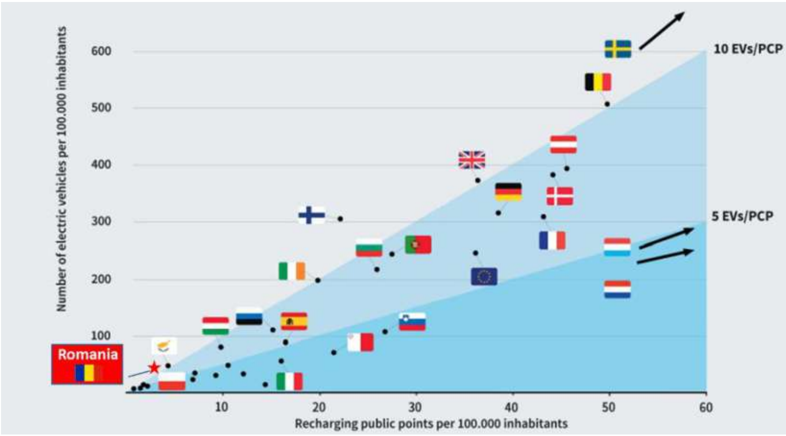
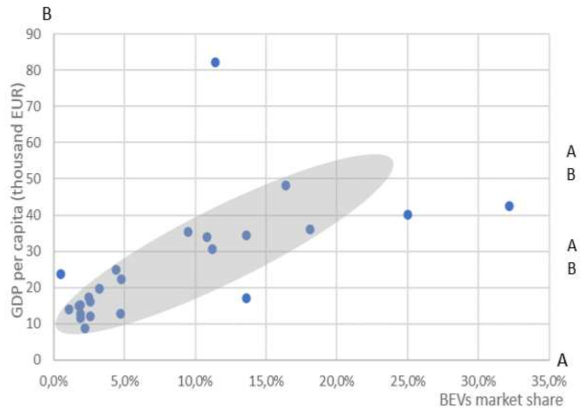


Figure 15: Overview of EVs and public chargers across the EU countries *(Source: own adaption for Romania based on Mathieu, 2020)*

One of the main reasons for this comparatively weak development is the relatively high cost of EVs. According to ACEA (2021), "the market uptake of electrically-chargeable vehicles (ECVs) is directly correlated to a country's GDP per capita".

Figure 16, showing the EVs market share on the x-axis and the GDP per capita on the y-axis, demonstrates the above-mentioned direct correlation between the two parameters. The graphic shows that a higher GDP per capita usually implies a higher EV market share. Romania, and other countries like Croatia, Czechia, Eastland, Latvia, Lithuania, Slovakia, and Poland, having a GDP per capita below 15,000 EUR, also have a lower market share of EVs between 1%-3%. The only exception is Hungary, with a GDP per capita of 12,680 EUR in 2020 and a higher EVs market share of 4.7%. At the opposite pole, countries like Austria, Belgium, Denmark, Finland, France, Germany, Nederland, Sweden, all with a GDP per capita above 30,000 EUR, already reached more substantial EVs market shares of over 10%. As also concluded by ACEA (2021), "There is a clear split in the affordability of ECVs between Central-Eastern Europe and Western Europe, as well as a pronounced North-South divide running across the continent."



	AT	BE	HR	CY	CZ	DK	EE	FI	FR	DE	GR	HU
A	10%	11%	2%	1%	3%	16%	2%	18%	11%	14%	3%	5%
B	35	34	12	24	17	48	15	36	31	34	16	13

	IT	LV	LT	LU	NL	PL	PT	RO	SK	SI	ES	SE
A	4%	3%	1%	11%	25%	2%	14%	2%	2%	3%	5%	32%
B	25	12	14	82	40	13	17	9	15	20	22	43

A - Market share of EVs (%, 2020) B – GDP per capita (thousand EUR, 2020)

Figure 16: Market share of EVs in correlation with the GDP per capita level, 2020 *(Source: own graphic based on Eurostat and ACEA data)*

With EUR 9,120 EUR GDP per capita in 2020, Romania belongs to the countries with the lowest level of GDP per capita in the EU. However, as shown by Figure 17, after it acceded to the EU in 2007, the GDP per capita in Romania has been growing at a much higher compound annual growth rate (CAGR) of 3.48% than the EU-28 average 0.75%. Based on this, combined with the fact that that the EVs costs are reducing expecting to reach cost-parity with ICEVs within this decade (Eriksen et al., 2021:23), it can be assumed that the development of the EV market will further continue at an accelerated pace in Romania and the gap versus the other EU countries will be in part compensated within the following years. Direct subsidies for EVs are also expected to play an essential role. The current promotion actions framework will be analysed in detail in section 4.3.

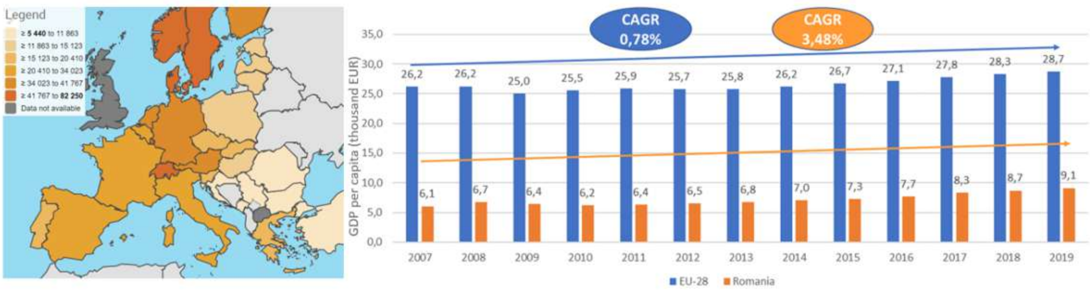


Figure 17: GDP per capita in the EU: Overview of the GDP per capita in Europe (left) and compared evolution of the GDP per capita in EU-28 and Romania between 2007 and 2019 (right) *(Source: own illustration based on Eurostat data)*

Recent projections by the European Federation for Transport and Environment confirm this assumption (Mathieu, 2020). According to this study, until 2030, there will be 44mn EVs in the EU, out of which 0,37mn in Romania. Compared to 2020 levels published by EAFO (2022), the compound annual growth rate (CAGR) in the EU will be 36% and in Romania 48%.

It shall be noted that local Romanian forecasts published in Romania's National Recovery and Resilience Plan estimate double the number of electric vehicles In Romania by 2030, namely 0.7mn.

According to the Eurostat database (2022), the total number of passenger vehicles in 2018 in the EU-28 was ca. 268mn and almost 7mn in Romania. Considering 2018 as a reference year and assuming that the entire stock remains unchanged until 2030, it appears that the gap between the EU and Romanian EVs market share is slowly closing. The market share of EVs in the EU in 2030 will be ca. 16% and in Romania between 5% and 10% (depending on the forecast scenario) compared to ca. 0.8% and 0.1% respectively in 2020. On the other hand, it appears that the projections for 2030 are very modest considering the Fit-for-55 target of reaching carbon neutrality by 2050 in the transport sector. Thus, a very steep market increase after 2030 will be needed to achieve this goal.

Regarding the charging infrastructure, the same study forecasts 2.9mn charging points in the EU and 12,000 for Romania by 2030 (Mathieu, 2020). Also, the number of charging points will have to increase in Romania faster than in the EU, with a CAGR of 37% in Romania vs 30% in the EU.

Figure 18 gives an overview of the forecasted EVs and charging points per 100.000 inhabitants until 2025 and 2030.

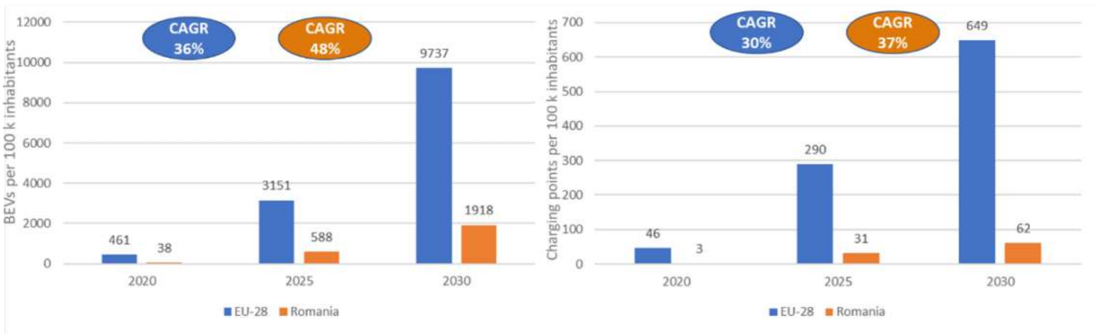


Figure 18: Total number of EVs per 100 thousand inhabitants (left) and the total number of charging points per 100 thousand inhabitants (right), in thousand units *(Source: own illustration based on data from Mathieu, 2020 and EAFO, 2022)*

4.2 Development areas

In an article by McKinsey from 2018, it is shown that when looking at possible development scenarios of different charging infrastructure use cases, it can be expected that the energy demand generated by EV charging in public locations will develop at the most accelerated pace until 2030. Slow charging at home is expected to decrease most in energy demand (Engel et al., 2018). The underlying reason for this development is that as EVs costs are reducing, expecting to reach cost-parity with ICEVs within this decade (Eriksen et al., 2021:23), more middle and lower-income households without home-charging options will increasingly purchase EVs, thereby generating demand for public charging options. The increase of rapid DC charging infrastructure can also be seen as a natural effect of the general EV market development (described in detail in section 4.1), which triggers more long-distance travel and highway charging needs.

As shown in Figure 19, public and long-distance charging are expected to make up for 51% of the total energy demand for charging by 2030, with rapid DC chargers (>50kW) and fast AC charges (22-50 kW) as leading underlying technologies.

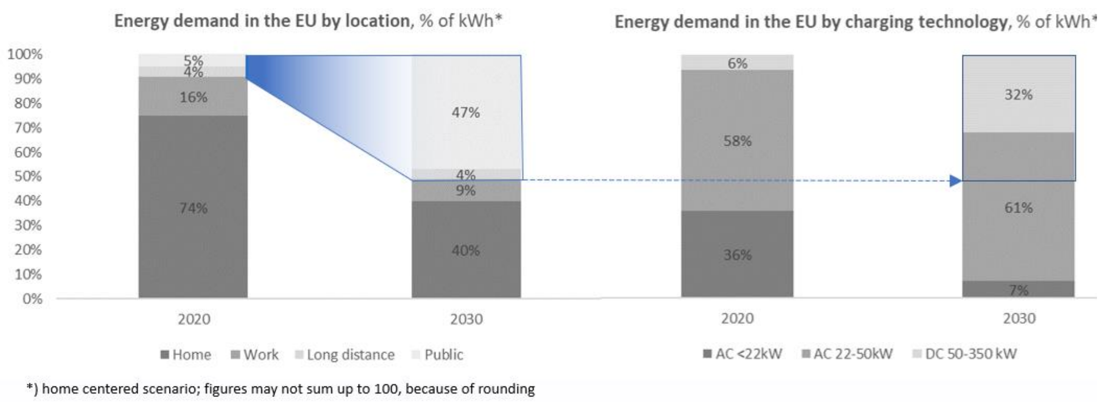


Figure 19: Energy demand in the EU by location and charging technology, % of kWh
(Source: own illustration based on Engel et al., 2018)

Considering this development trend, public charging infrastructure is expected to require the most rapid roll-out pace over the next decade, with massive capital expenditure needed due to the significantly higher costs of the underlying technology.

Given the expected importance of this segment, the analysis in the following chapters of this Thesis will focus mainly on the challenges and opportunities of deploying public and long-distance charging infrastructure in Romania.

Table 7 above below presents the most common use cases for charging infrastructure and their main characteristics, pointing out in the highlighted grey columns the use cases that have the most relevance.

Table 7: Use cases for EV charging infrastructure by technology, accessibility, billing and charging time *(Source: own illustration)*

Use case	Single-family home	Multifamily home	Workplace	**Public**	**Long distance**	Fleet depot
Technology	AC<22kW	AC<22kW	AC<22kW	**AC<22kW AC 22-50kW**	**AC 22-50kW DC 50-350 kW**	AC<22kW AC 22-50kW DC 50-350 kW
Charging time *	8-10 hours	8-10 hours	8-10 hours	**8-10 hours 2-3 hours**	**2-3 hours <1 hour**	8-10 hours 2-3 hours <1 hour
Power supply	Conductive	Conductive	Conductive	**Conductive**	**Conductive**	Conductive
Mode	1 / 2	2	2 / 3	**3**	**4**	2 / 3 / 4
Plug	Domestic socket / CEE / Type-2	Domestic socket / CEE / Type-2	Domestic socket / CEE / Type-2	**Type-2**	**CCS / CHAdeMO**	Type-2 / CCS / CHAdeMO
Accessibility	Private	Private (shared)	Private (shared)	**Public Semi-public**	**Public**	Private

The parameters choice presented in Table 7 is the most common but shall not be considered exhaustive.

- *Public and semi-public charging* – conductive power supply, Mode 3 charging, Type-2 plug, AC power, 22-50 kW chargers, public or semi-public access on private property (e.g., retailers, restaurants, hotels etc.), charging time usually below 4 hours.

- Long-distance charging – conductive power supply, Mode 4 charging, CCS (EU standard) and CHAdeMO plugs, DC very high power (50-350 kW) chargers, public access on private property, charging time usually below 1 hour.

Furthermore, to understand more precisely what type of charging technology currently serves the BEV market best in Romania, an analysis of Romania's battery electric vehicle fleet (2020 level) has been conducted. Figure 20 shows the most popular EV types at the end of 2020 and their share of the market (EAFO 2022). As it can be observed, at the end of 2020, Renault Zoe was the most popular EV model in Romania, with 1,446 vehicles on the roads in total, representing 28% of the EVs in Romania. The next most popular model was the BMW i3 with 603 vehicles on the road and 11% of the market, followed closely by Nissan Leaf with 525 vehicles and 10% of the market.

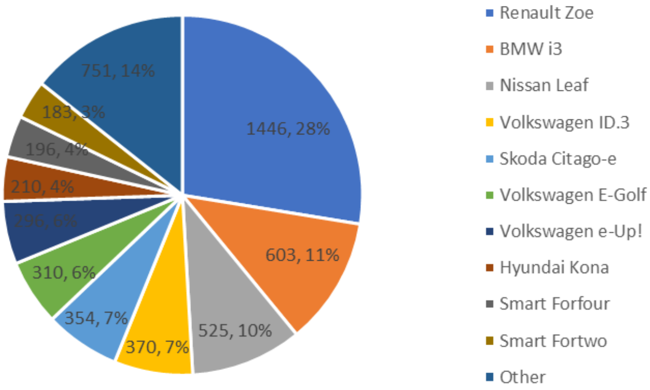


Figure 20: Top ten EV models fleet in Romania (2020), by units and share of the total (Source: own illustration based on data from EAFO, 2021)

Table 8 shows the average charging times and charging limitations of the most popular EV models in Romania (total market share of 75%) produced between 2016 and 2020.

Table 8: Plug types and maximum charging power for the seven most popular EVs in Romania, in total 75% of the fleet in 2020 *(Source: own table, based on internet sources www.pod-point.com)*

EV Model / isssue year	Connector type / Maximum Charging Power	
	AC	DC
Renault Zoe R110 ZE50 2020	Type 2 Max AC 1-phase rate: 7.4W Max AC 3-phase rate: 22kW	CCS (Max DC rate: 46kW)
Renault Zoe Q90 ZE40 2018	Type 2 Max AC 1-phase rate: 7.4W Max AC 3-phase rate: 22kW	Type 2 (Max AC rate: 43kW)
Renault Zoe R110 ZE40 2018	Type 2 Max AC 1-phase rate: 7.4W Max AC 3-phase rate: 22kW	n.a.
BMW iX3 2021	Type 2 Max AC 1-phase rate: 7.4W Max AC 3-phase rate: 11kW	CCS (Max DC rate: 150kW)
BMW i3 2018	Type 2 Max AC 1-phase rate: 7.4W Max AC 3-phase rate: 11kW	CCS (Max DC rate: 50kW)
BMW i3s 2018	Type 2 Max AC 1-phase rate: 7.4W Max AC 3-phase rate: 11kW	CCS (Max DC rate: 50kW)
Nissan Leaf 3.ZERO e+ 2019	Type 2 Max AC 1-phase rate: 6.6kW Max AC 3-phase rate: 6.6kW	CHAdeMO (Max DC rate: 100kW)
Nissan Leaf 2018	Type 2 Max AC 1-phase rate: 3.6kW Max AC 3-phase rate: 3.6kW	CHAdeMO (Max DC rate: 50kW)
Volkswagen ID.3 2020	Type 2 Max AC 1-phase rate: 7.2kW Max AC 3-phase rate: 11kW	CCS (Max DC rate: 50-125kW)
ŠKODA CITIGOe iV 2020	Type 2 Max AC 1-phase rate: 3.6kW Max AC 3-phase rate: 7.2kW	CCS (Max DC rate: 40kW)
Volkswagen e-Golf 2017	Type 2 Max AC 1-phase rate: 7.2kW Max AC 3-phase rate: 7.2kW	CCS (Max DC rate: 40kW)
Volkswagen e-UP 2016	Type 2 Max AC 1-phase rate: 3.6kW Max AC 3-phase rate: 3.6kW	CCS (Max DC rate: 40kW)
Volkswagen e-UP 2020	Type 2 Max AC 1-phase rate: 3.6kW Max AC 3-phase rate: 7.2kW	CCS (Max DC rate: 50kW)
Dacia Spring 2021	Type 2 Max AC 3-phase rate: 6.6kW	CCS (Option) (Max DC rate: 30kW)

Based on the observations made regarding the plug types and charging power limitations, it can be concluded that:

- *Plug types* – EU standard plug types are widely available for new EV models, Type 2 for AC and CCS for DC. For only one vehicle model CHAdeMO plug is still required for DC charging. When looking at the older EV models, it can be observed that Type 2 plugs have been available for all EV models newer than 2016 as standard for AC charging.
- *DC Charging* – no EV models currently popular on the Romanian market can properly use ultra-rapid 350 kW charging. Charging at 350 kW is in principle possible, but the EVs can absorb up to their maximum kW capacity per hour, making 350 kW unjustifiably expensive. It can also be noted that while the maximum DC charging capacity was usually 40-50kW a few years ago, the newer models can currently charge at between 100 kW and 150 kW per hour. Therefore, some EV models can charge double the range in km in the same period.
- *AC charging* – most EV models can charge at up to 11 kWh, with a few exceptions where 22 kW charging is possible. Also, in terms of AC charging capacity, an increase can be noticed with the newer models. EV models issued 2015-2017 were able to charge at only 3.6 kW – 7.2 kW per hour. Further, it shall be noted that Renault Zoe (also older models), which represents almost 1/3 of the EV market in Romania, can charge at up 22 kW.

Note: Dacia Spring, issued in 2021, is likely to become a prevalent model on the Romanian market, given that Dacia is a Romanian brand, and the acquisition costs are moderate. Dacia Spring DC charging is not available in the standard configuration but can be bought as an option with a maximum of 30 kW charging capacity.

Therefore, AC charging equipment with a power of 11 kW and DC equipment with a power of up to 150 kW are sufficient at the moment to optimally serve the EV market in Romania. In the short-medium term, an AC charging capacity of 22 kW can be expected to become suitable to most EV models. For DC, while at the moment 50 kW seems to be the maximum charging capacity for most EV models issued before 2018 and for the newly issued Dacia Spring, an increase in terms of charging power can be observed in newer EV models with 150 kW expected to become widely accepted on the short to medium term.

This conclusion is also confirmed by Mathieu (2020:22) in a study referring to the EU market in general. “The amount of energy delivered with ultra-fast charging surpasses the energy delivered by regular fast (50 kW) chargers around 2026 (in 2019, 90% of the new fast chargers as regular fast chargers vs only 13% in 2030)”. According to the same study, the share of electricity charged at 11-22 kW remains relatively constant until 2030, which means that the number of chargers of this category must continue to grow in line with the increase of the EV market.

A summary of the charging powers for which the most need for development can be expected within the next few years is shown in Table 9: Expected development needs of the public charging infrastructure in Romania until 2030 (Source: own table) below.

Table 9: Expected development needs of the public charging infrastructure in Romania until 2030 *(Source: own table)*

	Short term (until 2025)	Medium-long term (2025-2030)
Public	11-22 kW (AC)	22 kW (AC)
Long-distance	50-150 kW (DC)	≥150 (DC)

4.3 Promotion actions and subsidies

Promotion actions for electric vehicles

In Romania, the main subsidy scheme for BEVs and PHEVs acquisition, “Rabla Plus” (“Clunker Plus”), was introduced in 2015. The program is managed by the Environmental Fund Administration (AFM), an autonomous institution functioning under the Romanian Ministry of Environment. The guidelines of the RABLA Plus program have been lastly published in the Ministry of the Environment Order No. 323/2020.

Rabla Plus grants financial support by allocating a so-called “eco-label” to vehicle buyers to support the acquisition of a BEV or PHEV. Depending on the type of vehicle to be purchased, the value of the eco-label in 2021 was:

- 45,000 RON (ca. EUR 9,000), but no more than 50% of the retail price for purchasing a new electric vehicle excluding motorcycles.
- 20,000 RON (ca. EUR 4,000), but no more than 50% of the retail price for purchasing a new PHEV, excluding motorcycles, with CO2 emissions of no more than 50 g/km.

- 5,500 RON (ca. EUR 1,100), but no more than 50% of the market price for purchasing an electric motorcycle (increased from 3,500 RON in the previous cycles of the programme).

Vehicles bought through Rabla PLUS cannot be sold for one year after purchase.

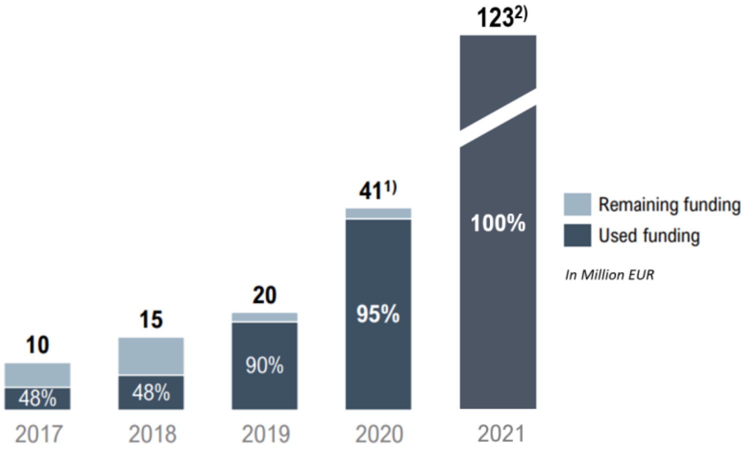
The eco-ticket can be combined with the scrappage ticket of an old vehicle (ca. EUR 1,500 additional subsidy under the Rabla program).

The total value of the subsidy value can thus be as high as EUR 10,500 for BEVs and EUR 5,500 for PHEVs.

Although the subsidy program is already in place since 2015, 2019 was the first year the budget has been almost depleted. In 2020, the initial allocation of EUR 29mn for Rabla Plus, already much higher than in the previous years, was further increased to EUR 41mn in the second half of the year to sustain the unprecedented demand from private individuals. In October 2020, the scheme’s scope was also expanded to cover the acquisition of used EVs and PHEVs no older than six months and allow the usage of eco-vouchers for models produced by Tesla, with the manufacturer announcing the launch of a local dealership soon after. By the end of the year, ~97% of the funds allocated for private individuals, and ~92% for companies, had been used.

2021 has set a record in terms of budget allocation to Rabla PLUS. AFM positively responded to the market signals and decided to triple the volume of Rabla PLUS. From the initially allocated EUR 81mn in the first half of 2021, AFM agreed to issue an additional EUR 41mn in August 2021, leading to a total ca. EUR 123mn budget for 2021. According to press announcements end of November 2021, Rabla PLUS budget has already been depleted for 2021, and the program has been put on hold until early 2022. However, the Environment Ministry has been pointing out that at least a similar size budget (EUR 123m) will be made available for this program also in 2022 with to aim to support the acquisition of approximately 10,000 new EVs.

The evolution of the funds allocated to Romania's financial subsidy scheme and the depletion degree is also illustrated in Figure 21 below.



1) Includes the extra allocation of EUR 12mn, which became available starting October 2020
2) Includes the extra allocation of EUR 41mn, which became available starting August 2021

Figure 21: Evolution of total available funding through the government incentive scheme
(Source: own illustration based on Nemes & Fundulea, 2021)

The number of newly registered BEVs increased by over five times between 2018 and 2020 from 690 to 3,890 (refer to Section 4.1), reflecting the success of the subsidy program Rabla PLUS.

Promotion Actions for Charging Infrastructure

(i) Romania's National Recovery and Resilience Plan

The Recovery and Resilience Mechanism is the largest financial instrument created by the EU to provide financial support to the member states to ensure a rapid economic recovery. The purpose of the Recovery and Resilience Mechanism is to mitigate the economic and social impact of the COVID-19 triggered crisis and support the European economies to become more sustainable and better prepared for the challenges and opportunities offered by the transition to a greener digital economy. The regulation was approved at the European level on 12 February 2021.

Of the total EUR 672.5bn for the Recovery and Resilience Mechanism at the EU level, 37% will be used to meet climate objectives. Romania can benefit from around EUR 29.2bn of these funds, split between EUR 14.2 bn grants and EUR 14.9bn loans, out of which nearly 42 % are allocated to green reforms. To use this financing instrument, each EU Member State has been assigned to propose its Recovery and Resilience Plan, setting out its priority areas for investment to overcome the crisis, support economic recovery and increase resilience.

The Romanian National Recovery and Resilience Plan (PNRR) has been built in line with the priorities set by the European Recovery and Resilience Mechanism and is structured on six pillars: (I) green transition; (II) digital transformation; (II) smart, sustainable and inclusive growth; (IV) social and territorial cohesion; (V) health and economic, social and institutional resilience; (VI) policies for the next generation of children and young people. Each pillar comprises several areas of intervention, a total of 33. After several alignment rounds, the EU approved the Romanian National Recovery and Resilience Plan (PNRR) in October 2021.

Within Pillar I Green Transition, one of the areas of intervention is intended for sustainable transport (4th Component), with a total budget of EUR 7.62bn.

Component 4 sees the modernisation and interoperability of the transport network in Romania as a critical social and economic development factor. Along with other initiatives in the road transport, railway and subway segment, Component 4 (C4) also targets the development of the alternative fuel infrastructure in line with the AFID strategy (please refer to section 2.5) and correlated the Connecting Europe Facility.

This reform aims to develop the infrastructure for alternative fuels for road vehicles, to reach 30,000 charging points by 30 June 2026.

The national target for electric charging points consists of:

- 1,836 existing electric charging points.
- 2,896 electric charging points (of which 264 electric charging points are proposed through the PNRR motorway network development projects) will be implemented on the national road/highway TEN-T network in Romania by 2030.
- 13,283 charging points in the Local Fund component (C10) of the PNRR (urban and rural), of which 13,200 high-power charging points distributed as follows: 4,000 in the municipalities of the county capitals; 1,876 in other municipalities; 1,600 in cities; 5,724 in municipalities.
- 2,000 recharging points in the Renovation wave component (C5) of the PNRR (urban environment), of which 1,000 high power and 1,000 low power recharging points;
- at least 10,000 other high-power and normal-power recharging points financed from national sources, additional EU funding (including Cohesion Policy) and/or private sources (including concessions).

The roll-out policies are not yet entirely defined. Still, according to interviewed specialists on European Funds allocation, the budget will be allocated through municipalities and public institutions and not directly to private companies.

(ii) Connecting Europe Facility ("CEF")

Apart from the incentive schemes available at the national level, the European Commission also encourages charging infrastructure deployment through a program currently available dedicated to all EU member states. European Climate, Infrastructure and Environment Executive Agency (CINEA) has launched in September 2021 a call for proposals under the Connecting Europe Facility (CEF) as a transport funding instrument, which makes EUR 7bn funds available for projects aiming to build, upgrade and improve European transport infrastructure.

The facility responds to the European Green Deal and the Sustainable and Smart Mobility Strategy (SSMS) adopted by the European Commission in December 2020. The strategy lays the foundation for how the EU transport system can achieve the transformation targets and sets concrete milestones to keep the transport sector's transition towards a sustainable future on track.

According to the European Commission, the increased deployment and use of renewable and low-carbon fuels must go hand in hand with the creation of a comprehensive network of recharging and refuelling infrastructure to enable the widespread uptake of low- and zero-emission vehicles in all transport modes and points out that no EU region or territory shall be left behind.

Alternative Fuels Infrastructure Facility (AFIF) represents one of the streams mentioned above of the Connecting Europe Facility and has a EUR 375mn budget (CEF-AFIF). CEF-AFIF has been established as a multiannual program with five submission deadlines from January 2022 until September 2023. CEF-AFIF will provide the incentive with other funding programs (such as Recovery and Resilience Facility) to reach the Green Deal and SSMS objectives.

The CEF-AFIF will fund alternative fuels infrastructure by combining grants with financial support from financial institutions like the European Investment Bank (EIB).

CEF-AFIF targets various infrastructure projects along the TEN-T connection corridors (railways, inland waterways, maritime and inland ports, roads, rail-road terminals and multimodal logistics platforms). The initiatives related to the TEN-T road network includes, among others, a program targeting the alternative fuels infrastructure, including electricity fast-charging and hydrogen refuelling infrastructure on the TEN-T road network. Under this facility, non-refundable grants are foreseen to support the roll-out of electricity fast-charging infrastructure of a minimum power output of 150kW on the TEN-T road network.

Figure 22 below shows the eligibility map for the first and second submission cycles in January and June 2022. The map on the left shows in red the road network eligible for the financing of charging points of over 150 kW power. In comparison, the illustration on the right shows the regions eligible for funding charging points above 350 KW power. Both maps consider a target distance between charging points of 60 km. Currently, available charging points of over 350 kW are marked on the two maps with blue points. It can be observed that most charging points appear to be concentrated in central and northern Europe in countries like Germany, Netherlands, Belgium and Finland. However, most of the already installed chargers seem to be up to 150 kW. Central and North European Countries broadly qualify for the CEF-AFIF aiming to install 350 kW stations but do not qualify for 150 kW installations that appear to be already sufficiently deployed in these regions.

Romania is eligible for the CEF-AFIF financing of 150 kW and 350 KW on almost all corridors under Ten-T, with few exceptions in the capital city area. After the first two application rounds, the eligibility map will be updated to reflect the newly approved projects; thus, more restrictions on eligible corridor sectors can be expected.

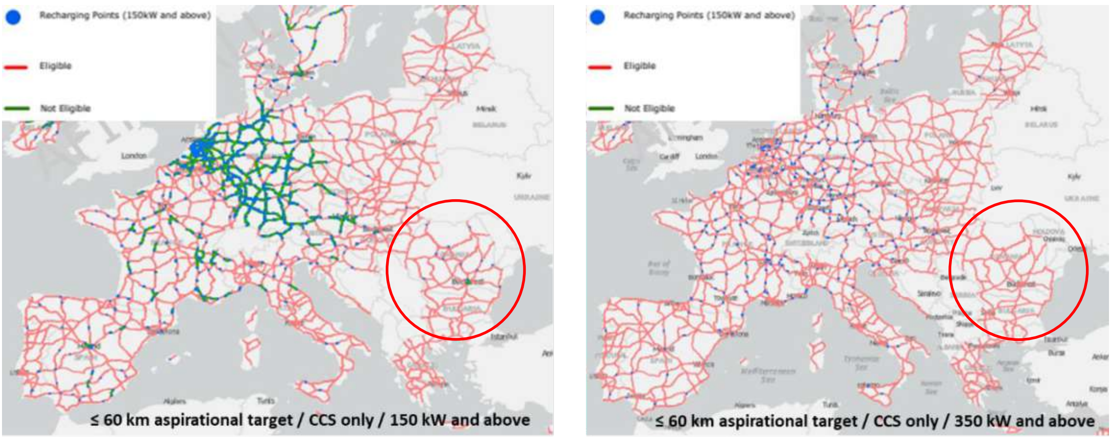


Figure 22: CEF-AFIF Eligibility Map for the 1st and 2nd submission cycle, recharging points on the TEN-T comprehensive road network *(Source: European Commission, CEC-AFIF, 2021)*

CEF-AFIF also foresees other restrictions, among which the most important is a minimum application amount of EUR 1mn (more locations /projects can be bundled) and a cap on the financing amount of EUR 30,000 for 150 kW stations and EUR

60,000 for the 350 kW stations. At least 10% of the total project costs must be supported by equity or financed by one partner financial institution. Moreover, grants may not contribute to profit generation (i.e., surplus revenues + EU grant over costs). For-profit organisations must declare their incomes and, if there is a profit, it will be deducted from the final grant amount.

The facility is open to all EU member states, and the application process and awarding is managed centrally by the European Commission bodies. Eligible participants may be public and private institutions established in any European Union member state.

(iii) Government Funds - Environmental Fund Administration (AFM)

The Romanian Ministry of Environment launched in December 2021 a funding program for charging infrastructure deployment. The program is managed by the Environmental Fund Administration (AFM), an autonomous institution functioning under the Romanian Ministry of Environment. The program is exclusively dedicated to public institutions and municipalities as beneficiaries. Players of the private sector do not qualify to benefit from this funding scheme. The guidelines regarding the application process have been published in the Ministry of the Environment Order No 1962/2021.

The program's total budget is RON 500mn (ca. EUR 100mn), and applications are only possible until March 2022.

The AFM program is financing up to 100% of the eligible investment costs but only up to ca. EUR 38,000 for each charging station. From a technical point of view, a charging station must contain at least two charging points, one of min. 22 kW AC and one of min. 50 kW DC. The grid capacity at each location must allow for simultaneous charging at both charging points. The regulation also sets additional technical requirements to be complied with, such as plug types (Type 2 for AC and CCS for DC) compliance with international quality standards and communication protocols (OCPP).

The regulation only allows a maximum of EUR 160,000 for each institution and sets up certain limits for municipalities depending on their size. As such, charging stations in Bucharest can be financed for up to EUR 1.6mn in RON equivalent; for smaller cities, lower limits have been established of between EUR 200,000 and EUR 800,000 in RON equivalent.

(iv) Government Funds – ElectricUp Program

The program launched by the Romanian Ministry of Energy through its Order number 3581/21.12.2020 intends to support the installation of solar PV panels and recharging stations for electric vehicles.

The maximum amount of the grant awarded is EUR 100,000 and represents financial support of up to 100 % of the eligible costs. The program finances PV systems with an installed capacity of 27 – 100 kWp for their electricity consumption. Surplus energy can be delivered to the national distribution network. Furthermore, the program foresees at least one recharging station of 22 kW for electric vehicles and plug-in hybrid electric vehicles with at least two charging points, with or without public access.

The program is addressed to small and medium enterprises from any sector and economic operators in hotels, restaurants, and cafes. The program is planned to have a multi-annual character for the period 2021 – 2027 period with several funding cycles.

The first application was launched at the beginning of 2021. In November, the Energy Ministry announced the list of 1,430 approved projects to benefit from the almost EUR 100mn allocated to the first financing cycle. Seven hundred ninety-nine applications did not meet the eligibility criteria and have been rejected. Further, 307 projects of approximately EUR 20mn would have qualified for the financing but exceeded the allocated budget. The budget extension evaluates a potential increase of the allocated amount.

The first cycle of the ElectricUp proved to be very successful with 2,536 applications and EUR 100mn allocated budget. Through its character, this scheme supports the deployment of small photovoltaic installations. Still, it can be expected to have a marginal contribution to the extension of the AC charging network at semi-public locations.

4.4 Permitting and approval process

The implementation of new public charging stations in Romania requires several permits and approvals in most cases. To identify the applicable permitting path, the following aspects shall be considered in the planning phase:

(i) Are there new facilities planned for the charging station in scope?
(ii) Will a direct contract with the grid operator be required?

Answering these questions is the basis for deciding whether a building and/or grid connection permits are required (Schönherr, expert interview Jan 2022).

On the first point (i), it shall be noted that the facilities to be constructed could be limited to only a newly built foundation or concrete slab as the basis for the charging station or may refer to other connected facilities (e.g., transformer stations, access roads, parking places, carports etc.). As a general rule, a building permit is required for all facilities involving the construction of a foundation or concrete slab (Schönherr, expert interview)

Based on this criterion, it can be assumed that most charging points in the public and semi-public space using already existing facilities such as parking spaces, garages, sidewalks will not require a construction permit. For long-distance charging stations along the highways and transit roads, a construction permit will be necessary in most of the cases either for the charging points (if not built on an existing site) or for other connected facilities such as transformer stations which are required due to the specific higher power of these chargers. For simplification, it will be assumed that no building permit is required for public and semi-public charging stations, while for long-distance charging stations, a building permit is necessary.

For the second point, (ii) shall be differentiated between the counterparties chosen for the electricity supply. A connection permit will be required if the network operator is the direct counterparty for the electricity supply. If an intermediate third party supplies the electricity for the charging station (e.g., retailer, hotel, restaurant, etc.), only a contract with the respective party will be required. No specific connection permit from the grid operator will be needed in this case. It shall be noted that the respective third party must already have a connection permit with enough capacity to allow for the additional consumption of the individual charging station (Schönherr, expert interview).

Therefore, it can be assumed that this type of arrangement with an intermediary is only viable for low power charging stations of up to 11 kW in the semi-public space. Higher power chargers and stations with more charging points will require separate contracts between the charging station operator and the grid operator. Furthermore, as the utilisation rate of the charging stations continues to increase, it can be expected that in the medium-long term, all charging stations independent of their charging power will require direct agreements with the network operators and an explicit connection permit.

Table 10 below illustrates in a simplified form the types of permits required for electric vehicle charging stations placed on the locations in the scope of this analysis as explained in Section 4.2.

Table 10: Permits required for the installation of new charging stations in Romania *(Source: own table)*

Permit Type / Location	Semi-Public	Public	Long Distance
Building permit	No	No	Yes
Connection Permit	No	Yes	Yes

Building Permit

The process for obtaining a building permit to construct a charging station and/or annexe facilities is the same as for any other type of building in Romania. However, as explained previously, for most of the public stations, no construction permit will be required (Schönherr, expert interview Jan 2022). When needed, the process for obtaining the building permit can be very long and complex and can take up to 12-18 months.

To obtain the building permit, the following key milestones need to be accomplished (Schönherr, 2021):

- *Obtaining the urbanism certificate* – before initiating a new process, and urbanism certificate must be applied to the local authorities for information purposes. The application contains a high-level description of the constructions planned. The response delivered by the authorities (within 15-30 days) reflects the initial view of the authorities if the project design is in line with the general urbanism plan applicable for the respective location. Should this not be the case, the land must be regulated in this respect by a zonal urbanistic plan or detailed urbanistic plan. The outcome of this initial step is to obtain a list of all endorsements, approvals, and/or authorisations to be obtained from various authorities to initiate the planning phase. After all required documents are received, the urbanistic certificate for construction will be issued by the relevant local authority. The urbanism certificate should list all necessary approvals, endorsements and other documents necessary to obtain the building permit and usually include validation by the regional grid operator and additional licenses as the case may be for a specific location (environment, neighbours' approval etc.).

- *Preparation of the technical documentation* – the technical documentation for authorising construction works is drawn up by authorised specialists. It needs to be detailed in the technical project in line with the requirements of the urbanism certificate and other permits or authorisations requested through the urbanism certificate.
- *Issuance of the building permit* – based on the documents described in the urbanism certificate, the detailed project plan, title over the project land and proof of payment of the construction permit fee, the building permit can be applied for and will be issued by the competent local authorities within 15 to 30 days. The building permit entitles the developer to start construction within 24 months (possibly extending to 36) based on obtaining the grid connection permit and connected authorisations. The construction permit fee is 1% of the value of the construction works (including installations).

Connection Permit

Obtaining the technical connection permit ("aviz tehnic de recordare" or ATR) and the connection contract is a critical milestone in securing the grid network's necessary capacity, which is essential for the proper operation of the charging station.

The connection process consists of the following key steps (Schönherr, 2021):

- *Preliminary information phase (not mandatory)* – as a preliminary step before launching the project, the developer of a new charging station may request the network operator a confirmation on the availability of the necessary grid capacity at the planned location and other general information concerning the connection conditions, the documents required, the applicable fees, etc.
- *Technical connection permit* – The connection application must be filed with the distribution network operator. Based on the application and the information provided in the annexed documents (including the technical and energetic data, urbanism certificate, site plan, title to the project land, etc.), the network operator then determines the connection solution (one or more solutions possible). This step may take between 1 and 3 months depending on voltage lines at the project location (1 month for low-medium voltage and three months for 110 kV network or higher voltage); if the solution study outlines more than one connection solution, the developer can opt for the preferred solution within a maximum of two months.

The technical connection permit represents the connection offer issued by the network operator and contains technical and economic details, connection conditions, grid reinforcement works (if needed), the connection fee, etc. A connection agreement will be issued and signed by both the charging station operator and the grid network operator based on the connection permit.

- *The connection certificate* – The connection permit remains valid throughout the construction phase. The connection certificate will replace it after finalising the construction and the commissioning of the charging station.

After finalising the construction works, the facilities for which a building permit had to be obtained must be registered in the Land Book.

The main challenge of obtaining the building permit lies in the fact that the process is very lengthy. A faster specific approval process for this type of construction may contribute to the more rapid roll-out of charging stations and potentially create more traction for international investors in the sector. Further improvement may derive from the digitalisation of the application process for the various approvals and certificates required throughout the process. An additional challenge is related to the fact that the general urbanistic plans do not contain specific details for these types of stations, which may lead to misunderstandings or differences in the way the relevant authorities of different municipalities approach the permitting process for this type of project.

4.5 Business models and market players

Driven by the trends observed in the electric vehicle market and the massive increase forecasted for the next decade, investments in charging solutions and related services become increasingly attractive for smaller entrepreneurs and big industry players. Some analysts estimate revenues from EV charging will surge and likely hit EUR 36bn in 2030 in Europe (Krug, 2021). Romania is still behind other countries in western Europe in terms of EV market development. However, various international and local players are already active on the market, offering different charging solutions and services.

According to Krug (2021), the charging market can be subdivided into the following revenue pools:

- *Hardware* – includes all revenues generated from manufacturing and selling charging equipment and payments related to the installation services such as planning, installing, and commissioning hardware on end-customer premises.

- *Asset ownership* (i.e., commercial operation) – includes the revenues generated from the sale of charging services by public and semi-public charging infrastructure owners.
- *Technical operation* – incorporates all revenues generated via operating private and public charging infrastructure and includes the charge point management software, technical service hotline, hardware maintenance and reparation and maintenance services in the field.
- *Electric Mobility Service Provider (EMSP)* – contains all revenues connected to enabling the access of the EV drivers to public charging infrastructure, such as transaction fees from the customers and roaming fees from the charging point operators.
- *Energy management* – refers to innovative charging services such as peak load shaving, PV integration, time-based tariffs and contributing to the balancing power to the electricity grid by pooling EVs connected to the grid.
- *Electricity & grid* – includes the sale of electric power and grid usage fees related to EV charging to end customers. These customers can be private households, companies, or operators of public charging infrastructure.

Krug also notes that these revenue streams are most often grouped, and the market participants are using business models that bundle several of these revenue streams. In general, he points out a tendency towards service integration (the "one-stop-shop" approach) with can be expected to accentuate in the years to come (Krug, 2021).

Figure 23 below illustrates different archetypes of business models by revenue stream clusters.

	Hardware	Asset ownership	Operation	Platform	Mobility Service	Energy management	Electricity & grid
1 Hardware providers	✓						
2 Software operators			✓	✓	✓	✓	
3 Full-service providers	✓		✓	✓	✓	✓	
4 Asset owners		✓					
5 Fully integrated	✓	✓	✓	✓	✓	✓	✓

Figure 23: Major business model archetypes for EV charging in Europe *(Source: own illustration based on Krug. 2021)*

In Romania, 40% of all public stations were managed at the end of 2020 by six network players (Nemes & Fundulea, 2021). According to the categorisation explained above, the most significant three players with a total share of 27% of all chargers are fully integrated charging services providers (business model 5 in Figure 23). These are:

- *Renovatio e-charge* – alongside their partner MOON, Renovatio owned at the end of 2020 ca. 15% of all charging stations at the national level. Over 80% of the charging stations were fast-charging stations (mostly 50 kW), and 1% offered an ultrafast charging capacity of 150 kW (Nemes & Fundulea, 2021). Renovatio is an international group of companies with a portfolio of renewable energy projects, specifically wind, solar and hydro. The group's activities essentially cover the renewable energy value chain, from project development to energy trading, through procurement, administration, management, and energy asset operation. Reneovatio has been present on the Romanian market since 2005, being one of the pioneers in the development of wind and photovoltaic projects (Source: www.renovatiotrading.ro). In 2016, Renovatio started installing EV charging stations in Romania, mainly in semi-public locations with retailer chains such as Kaufland. Currently, 2 out of 3 Kaufland branches in Romania are equipped by Renovatio with EV charging stations.
- *Enel X* – Enel X Romania is the energy services division of the Enel Group, which has installed and put into operation a network of 45 charging points in Bucharest and the surrounding areas (Nemes & Fundulea, 2021). Most of the charging points are two × 22 kW units called JuicePole, which allow drivers to recharge two electric vehicles simultaneously. Another charging station type offered by Enel X is the JuicePump version, with 50 kW DC, 22 kW or 43 kW AC. The charging points can be used at a fixed price per unit of consumption (kWh), or drivers can pay a subscription (that comes in two versions: Basic X or Premium X) which includes a certain number of kWh per month, a certain reservation fee for specific charging points and a fixed price per kWh. Drivers can find these charging points using the JuicePass application. They can see the entire network of over 50,000 public charging points currently existing in 18 European countries, using the interoperability partnership with IONITY and SMATRICS charging network operators (Source: www.enelx.com). Enel X has ambitious plans for the public charging infrastructure in Romania, including installing about 2,500 charging points in all country regions by 2023, with an

estimated total investment of approximately EUR 20mn (Source: www.interregeurope.EU).

- *E.On Drive* – at the end of 2020, E.On Drive was the owner of 35 charging stations in 16 counties in Romania (Nemes & Fundulea, 2021). E.ON is also part of the European project NEXT-E, having in scope to install fast-charging stations on gas stations in Romania. Enel X owns 252 charging stations in 6 different European countries. These are integrated into a monitoring and management system for loading sessions, providing non-stop scanning and resolving any incidents during charging remotely. Electric vehicle users can access and book stations directly on harta-statii.eondrive.ro or through the E.ON Drive mobile application (Source: www.interregeurope.EU).

It shall be noted that some business models appear not to be covered in Romania at the moment. On the one hand, no local charging equipment producers have been identified (business model 1 in Figure 23). Most of the international charging equipment brands are supplied to Romania mainly by local importers specialised in electrotechnical equipment supply and services or newly founded companies specialised in commercialising charging hardware. The hardware equipment business segment is estimated to generate ca. EUR 15.7bn one-time revenues in Europe by 2030 (Krug, 2021). The equipment producers will generate a significant portion of these revenues. By not being active in this business sector, Romania can miss a substantial business opportunity.

More importantly, no charging station operators (business model 4 in Figure 23) have been identified as asset owners. Typical asset owners on the western European markets are, among others, Ionity and Fastned, specialising in long-distance fast-charging solutions. Ionity and Fastned have been addressed for this analysis. While Ionity confirmed no plans to enter the Romanian market in the short run, Fastned did not respond to the request. The asset ownership segment is estimated to generate ca. EUR 2.9bn in revenues by 2030 (Krug, 2021). As the EV market grows, this business segment may become an attractive opportunity for international and local network operators in the medium term.

4.6 Economic assessment

One of the major issues when planning new charging infrastructure is a feasible business model, which creates value for both the charging stations owners and the EV drivers.

As shown in the previous section 4.2, long-distance fast charging is one area that potentially lacks sufficient coverage in Romania. This section presents three possible use cases for long-distance fast charging stations of 50 kW power and their economic performance in several scenarios.

Various factors have been identified to influence the economics of charging stations operation and investment. Figure 24 below illustrates a high-level overview of the different relevant income and cost items on which the analysis in this section will be constructed.

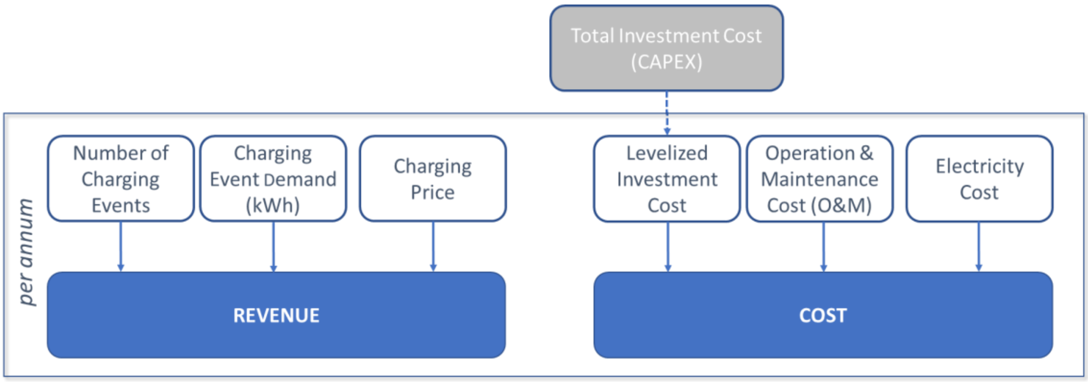


Figure 24: Overview of the main revenue and cost items *(Source: own illustration)*

After having identified the major cost and income determining parameters, the Annual Net Profit of the charging stations for each use case has been calculated and then compared to its Levelized Investment Cost to obtain a Return on Investment (ROI) figure as an indicator of profitability. Furthermore, several sensitivities on the Margin level and a number of charging events (N_{CE}) have been calculated.

It shall be noted that ROI represents only a short-term horizon assessment that gives a rough indication of whether a charging station can achieve profitability under various conditions. The ROI concept is a simple measure that does not require assumptions on the uncertain long-term cost and revenue dynamics.

The method for the ROI calculation and the equations applied have been explained in detail in 3, Description of the research method (equations 3, 4, 5, 6 and 7).

Further in this section, the assumptions made for estimating the value of each revenue and cost component necessary for the ROI calculation will be explained in detail.

- *Revenue*

The income generated by a charging station depends on the charging price, the energy demand per charging session and the total number of charging sessions.

Equation (3) explained in Chapter 3 has been applied to calculate the Total Annual Revenue.

The tariffs currently applied for DC charging by the major charging stations operators in Romania have been referred to estimate the charging price (CP).

Table 11: DC charging tariffs in Romania *(Source: own table)*

	Renovatio e-charge	**Enel X**	**E.On Drive**
DC Charging	2.49 RON/kWh	1.79 -1.89* RON/kWh	1.99 - 2.22 RON/kWh

*) Tariff plans without a subscription fee

The average charging price for DC is 2.1 RON / kWh, representing the equivalent of EUR 0.42 / kWh (1 EUR = 4.95 RON on 31 Dec. 2021). This tariff will be considered in the base case of the current calculation.

EV users are assumed to charge their battery as much as possible, so the average charging event demand is considered to be 20 kWh. This assumption is based on the estimation made for most of the reference cases cited (Table 12) and is also confirmed by Fastned data, whereby in Q3 2021, the average charging speed of the equipment across the Fastned network has been 51 kWh and the average charging per session 19 kWh (Fastned, 2021).

Using a 50-kW power charging station, the charging time is expected to be ca. 24 minutes (20 kWh / 50 kW). Therefore in 24 hours, a maxim of 60 charging events can be achieved.

The number of charging events cannot be estimated as it can widely vary depending on multiple factors such as EV users charging behaviour, the location of the charging station and actual traffic figures, the penetration of EVs on the Romanian market at a particular moment. Therefore, several scenarios will be calculated for different possible numbers of charging events to determine the approximate utilisation degree starting from which the investment in a 50-kW charging station can become economic. A maximum of 10 charging sessions per day has been considered per charging point.

- *Electricity Cost*

The database of Eurostat and the Romanian National Authority for Regulating the Energy Sector (ANRE) has been looked into to retrieve the cost of the electricity sold. While Eurostat shows more extended records, ANRE shows more details of different electricity price clusters for different non-household consumers categories and appears more accurate. Out of the latest ANRE report (ANRE, 2021), the electricity prices for universal service consumers have been chosen as they have been appreciated to be the most appropriate price cluster for medium size consumers such as charging stations and also appear to be the more conservative choice (ca. 8% higher the competitive prices applicable for large non-household consumers). The prices include transport, distribution, and balancing costs. Their evolution between January 2020 and October 2021 is illustrated in Figure 25 with and without taxes. The original prices in RON have been converted to EUR using the quarterly exchange rates extracted from the National Romanian Bank (BNR) database.

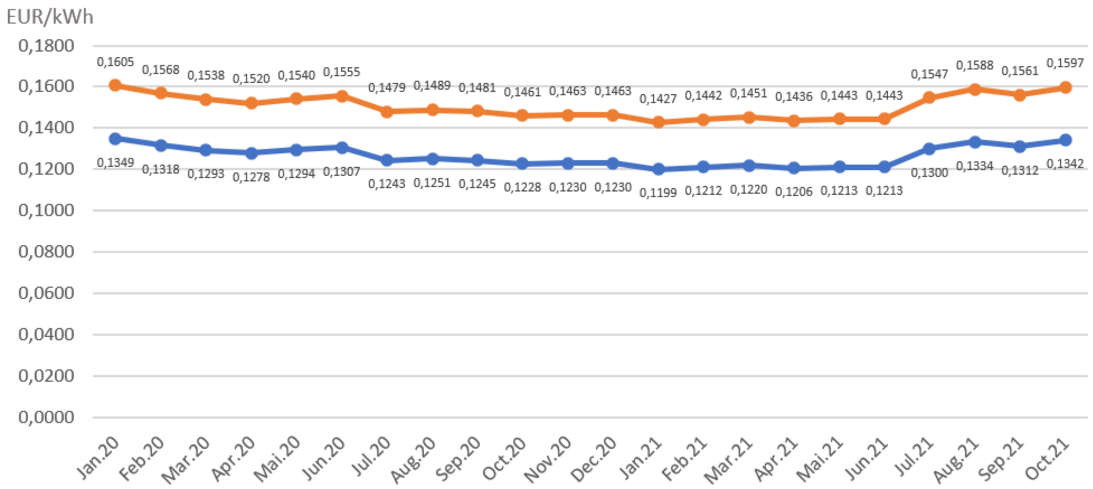


Figure 25: Electricity prices for non-household consumers in EUR equivalent per kWh
(Source: own illustration based on data from ANRE and BNR)

After a slight downturn during the COVID crises, the electricity prices have recovered toward the end of 2021 to a level very similar to the beginning of 2020. According to the ANRE website, it shall be noted that as of January 2022, the electricity prices substantially increased. However, given the lack of data and visibility on the further evolution of the electricity prices, for this analysis, the electricity cost (C_{el}) will be considered 0.16 EUR/kWh (Oct 2021 level) in the base case. Further sensitivity cases on higher electricity prices and their potential impact on the profit margin have been calculated.

By deducting the cost of electricity sold (C_{el}) from the charging price (CP), the profit Margin has been determined. Given that no reliable long-term projections for electricity prices and charging tariffs are available, the calculation was based on the assumption that the initial profit Margin remains constant and fluctuations in the electricity prices are passed through to the customers offering a partial natural hedge against the market dynamics (Fastned, 2021).

Considering a charging price (CP) of EUR 0.42 / kWh and the electricity price assumed to be EUR 0.16 /kWh, the resulting base case gross margin per kWh is EUR 0.26. The profitability calculation will consider several additional scenarios for the gross margin: a pessimistic case with EUR 0,16 / kWh gross margin, an optimistic case with EUR 0.36 / kWh gross margin, as well as a case calculated based on the weighted average gross margin of an actual case of EUR 0.46 / kWh (Fastned, 2021).

- *Capital Expenses (CAPEX) and the Levelized Investment Cost*

To estimate the average investment costs to be used for this analysis, the information provided by several case studies has been referred to. The summary of the CAPEX estimates and the data sources are shown in Table 12 below.

Table 12: Total CAPEX for 50 kW DC charging stations, in EUR *(Source: own table based on various data sources)*

	Reference A [1]	**Reference B** [2]	**Reference C** [3]	**Reference D** [4]	**Reference E** [5]
Hardware	33,000	25,950-45,500	27,150	30,000	40,000 – 75,000
Lifetime	8 y	15 y	7.5 y	7- 15 y	10 -15y
Connection	4,000	n.a.	n.a.	44 400	15,000 (+35,000*)
Construction	5,000	n.a.	n.a.	4 500	
TOTAL	**42,000**	**25,950 – 45,500**	**27,150**	**78,900**	**55,000 - 90,000 (+35,000*)**

As can be observed, most of the case studies assume similar costs for the hardware. These are estimated to be in the range of EUR 25,000 to EUR 45,000, with only one exception where the cost of the equipment is estimated to be higher (Reference E, up to EUR 75,000). Some of the cited case studies appear to disregard the costs related to the connection and civic works. However, these are mentioned by Reference cases A, D, and E and are estimated to be between EUR 9,000 and EUR 15,000 in total. In Reference case D, the connection costs are estimated to be much higher. These are probably triggered by the installation of a transformer station, like Reference E. The transformer station is mentioned as a separate item with the related costs estimated to be ca. EUR 35,000.

[1] Markkula et al., 2013
[2] Kreyenberg, 2016: 63
[3] Madina et al., 2015
[4] De Jong, 2016 (Curbside case)
[5] Schroeder & Traber, 2011 / *) transformer costs if applicable

For this analysis, an average of EUR 35,000 for the hardware costs (including the installation) and EUR 12,000 for the connection and civic works has been considered, totalling EUR 47,000 investment costs. The equipment cost estimation may be regarded as conservative given that the sources cited are dated 2011-2016. These costs can be expected to have decreased over the past few years as more producers have entered the market and the technology has become more standardised.

An additional use case has been calculated, considering the costs related to the transformer station of EUR 35,000 as part of the initial investment costs (Case 2 below).

It shall be noted that the costs estimated above do not include the investment related to major civic works which would be required for the construction of a stand-alone green field long-distance charging station. De Jong (2016) estimates these costs to be approximately EUR 150,000. However, in such a case, a higher number of charging points would be installed, and therefore the additional costs would proportionally affect the price per charging unit. For instance, in the Fastned network, there were on average 3.8 charging points per station in Q3 2021 and 6 charging points at their top 5 charging stations, according to the Trading Update report from October 2021 (Fastned, 2021). This would mean that a maximum of EUR 40,000 additional civic work costs would be allocated to each charging point's total individual investment costs. Case 3 assumes a long-distance charging station with four 50 kW charging points and considers the additional investment costs for the underlying infrastructure.

Regarding the lifetime of the hardware, the sources cited estimate it to be between 7 and 15 years. For this analysis, 10 years have been considered the most likely duration of the equipment lifetime. Considering an interest of 6% and a project lifetime of 10 years, The Levelized Investment Costs calculated according to equation (7) explained in 3 results to be EUR 6,389 for each hardware unit.

The lifetime of the infrastructure constructed for stand-alone long-distance stations is estimated by de Jong (2016) to be 15 years. The Levelized Investment Cost for the infrastructure costs in Case 3 has been calculated separately to account for the longer lifetime.

- *Operating Expenses (OPEX)*

The same reference cases used for the CAPEX estimation have been used to estimate the operation and maintenance costs as OPEX component to be used for the calculation. A summary of the references is presented in Table 13 below.

Table 13: Yearly operation and maintenance costs of 50 kW DC power charging stations *(Source: own table based on various data sources)*

	Reference A [6]	**Reference B** [7]	**Reference C** [8]	**Reference D** [9]	**Reference E** [10]
Fix Costs EUR p.a.	5,600	1,808 – 5,670	3,075	12,000	4,000
Percentage of Equipment Costs*	17%	7%-12%	11%	40%	5%-10%

**) without transformers, infrastructure costs for stand-alone charging stations. rents.*

Most of the sources analysed to estimate the costs related to the operation of 50 kW charging stations to be between 7% and 17% of the initial investment costs associated with the hardware, with only one exception where they are estimated to be ca. 40% of the initial investment costs (Reference D). This extreme case has not been considered in calculating the average as it is not representative. Based on the other reference cases, the average has been calculated to be ca. 10% of the hardware costs per annum and has been applied for the calculations in this analysis. The base for the calculation is the equipment cost instead of total initial investment costs, as maintenance works are usually related to the equipment and not to the other elements such as civic constructions and connections.

Based on the assumptions made for each parameter, the Return on Investment has been calculated for three different use scenarios by applying the equations detailed in 3. The underlying input parameters and the equations used have been summarised in Table 14 below. The calculated ROI for all demand scenarios will be shown in Figure 26, Figure 27, and Figure *28* for each use case separately.

[6] Markkula et al., 2013
[7] Kreyenberg, 2016: 63
[8] Madina et al., 2015
[9] De Jong, 2016
[10] Schroeder & Traber, 2011

Table 14: Key parameters and equations used for the ROI calculation in 3 different use cases *(Source: own table)*

	Case 1 *1 x 50 kW*	**Case 2** *1 x 50 kW + Transformer*	**Case 3** *4 x 50 kW + Transformer + Infrastructure*
Charging Price (CP), *Base Case*	EUR 0.42 / kWh		
Number of Charging Events (N_{CE})	1 to 10 daily (x 365 days)		
Charging Event Demand (D_{CE})	20 kWh		
$TR = CP \cdot N_{CE} \cdot D_{CE}$ (3)			
Cost of electricity (C_{el}), Base Case	0.16 EUR/kWh		
Margin ($CP - C_{el}$) - Base Case - Pessimistic Case - Optimistic Case - Actual Case (Fastned)	 EUR 0.26 / kWh EUR 0.16 / kWh EUR 0.36 / kWh EUR 0.46 / kWh*		
$GP = TR - TC_{el} = (CP - C_{el}) \cdot N_{CE} \cdot D_{CE}$ (4)			
Total Investment Cost (CAPEX)	EUR 47,000	EUR 82,000	EUR 373,000
Investment Horizon (n)	*10 y*	*10 y*	*10 y / 15 y*
Interest rate (i)	*6%*		
$LIC = \frac{CAPEX}{\frac{(1+i)^n - 1}{(1+i)^n \cdot i}}$ (7)			
O&M Costs	EUR 3,500	EUR 3,500	EUR 14,000
Other Revenue (OR) - Test case: advertising &restaurant - Test case: investment subsidy	 EUR 8,000 EU 38,000	 EUR 12,700 EUR 38,000	 - 4xEUR 38,000
$NP = GP - OPEX - OC - T - I + OR$ (5)			
$ROI = \left(\frac{NP}{IC} - 1\right) \cdot 100$ (6)			

*) Q3 2021 Trading Update, Fastned (2021);
**) OPEX includes O&M and Levelized Investment Cost (LIC, eq. Amortisation + Interest); Other Costs (OC) and Taxes (T) are considered 0 for this calculation

Use Case 1 assumes a single 50 kW charging station located in a semi-public space, like in the parking space of a retailer, hotel, or restaurant. Given the high power of the charging technology, such equipment would be best suited in a location in the vicinity of the motorway. No complex infrastructure investment is assumed to be needed, only essential works like the foundation of the charger, protection bars and signage. Also, the connection works are considered to be based on the pre-existing structure of the hosting facility with no additional costs required for a transformer station. The ROI calculation has been performed for different numbers of charging events (N_{CE}) of between 1 and 10 per day.

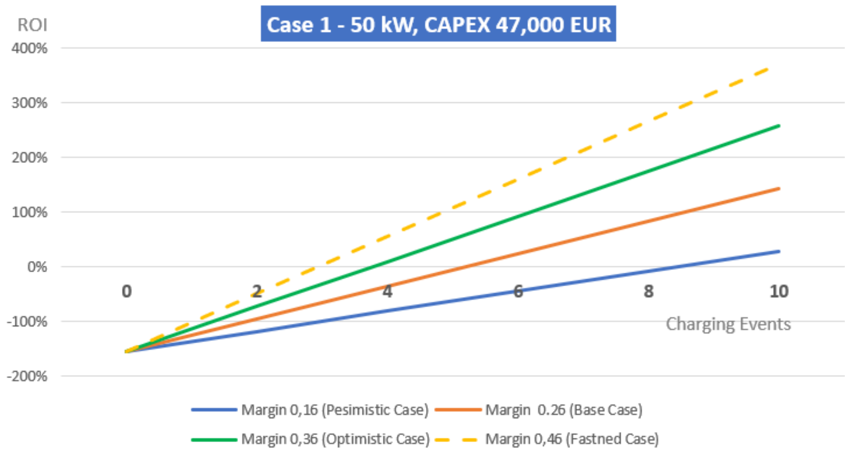


Figure 26: Case 1 – estimated return on investment for a 50 kW charging station *(Source: own illustration)*

As shown in Figure *26*, in the base case, min. 5 daily charging events on average are required for the investment to generate sufficient revenue to cover the total yearly costs and start generating profits (ROI>0%). At a higher Margin, a lower number of 3.5 - 4 charging events would be sufficient for the investment to become profitable. In the long run or in hot traffic locations where the daily average charging events exceed 9, a lower profit margin of EUR 0.16 / kW may also be considered.

This result shows that for as long as the average number of charging events remains below 5, investments of this type are loss-making, or higher margins are required. The number of charging events may vary widely depending on where the respective charger is placed. However, given the current maturity stage of the Romanian EV market, it can be generally assumed that the profitability threshold for stand-alone charging stations (no subsidies considered) can be reached within ca. five years. According to the figures reported by Fastned in Nederland, the average number of charging sessions per day has increased from 1.3 in 2015 to 5.7 per charging point in Q3 2021 (Fastned, 2021). For reference, in Nederland in 2015, there were already 9,368 BEVs registered compared to 5,566 in Romania in 2020. Given the growth pace of the Romanian EV market recorded in the last years (see section 4.1) and the exceptional success of the acquisition subsidy scheme for EVs in 2021 (see section 4.3), it can be assumed that the total feet of EVs in Romania will reach at least similar levels to Nederland's within a comparable timeframe and thereby also the utilisation rates for the charging infrastructure can be expected to increase accordingly.

Case 2 analyses the profitability of an investment similar to Case 1; the only difference derives from the additional CAPEX required for a transformer station. The total investment cost thereby becomes EUR 82,000.

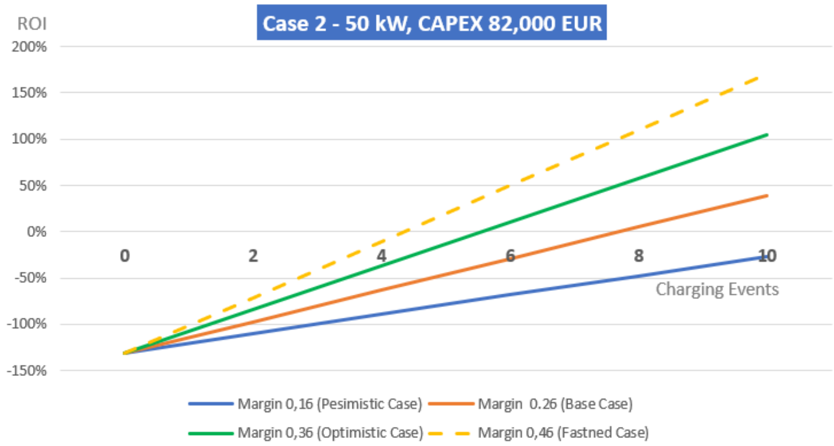


Figure 27: Case 2 – Estimated return on investment for a 50 kW charging station with transformer station *(Source: own illustration)*

Figure 27 shows that the additional CAPEX requirement significantly affects the station's profitability. As such, in the base case, the number of minimum average charging events required for the Total Annual Revenue to exceed the total costs increases from 5 in Case 1 to almost 8 in Case 2. Also, in case a higher Margin of EUR 0.36 / kWh would be applied, the investment would only become profitable if the number of average charging events exceeds 6.

According to Madina et al. (2015), the charging station operator (CSO) can compensate for the low occupancy rates in the initial years by obtaining additional income from advertising at the charging station's location. “Furthermore, due to the expected charging time (20 kWh/50 kW=24 min), highway charging can be a good alternative for CSOs who own a restaurant. At an average 1.50 EUR additional income from the restaurant (…), the required CS usage can be further reduced”.

Based on this idea, both Case 1 and Case 2 assumptions have been updated to include additional cross-selling revenues from either advertising or restaurants (Other Revenues) in the base case. The results demonstrate that with EUR 8,000 additional cross-selling revenue per year, Case 1 becomes profitable at only 1 charging event daily. Similarly, in Case 2, one charging event daily would suffice if an additional EUR 12,700 would be generated yearly from other sources. Charging stations operators may consider cross-selling revenues at their location to overcome losses in the ramp-up years.

Furthermore, investment subsidies can also play a significant role in overcoming the initial low traffic years. For instance, with a EUR 38,000 investment subsidy (AFM program, see section 4.3.), Case 1 would become economically viable at only 1.5 daily charging events on average. Case 2 would need below five daily charging sessions to reach profitability.

Use Case 3 assumes a long-distance charging station with 4 DC chargers of 50 kW. In addition to the costs described previously for each hardware unit, an initial investment of an estimated EUR 150,000 has been considered. The latter mainly consists of expenses associated with civic works such as building accessways, parking, signage, protection fence, carports, and other construction costs. Also, in this case, a transformer station will be required. Thus, an additional EUR 35,000 will be considered part of the investment costs. The total investment costs for the charging station are EUR 373,000. The results of the calculation are illustrated in Figure 28.

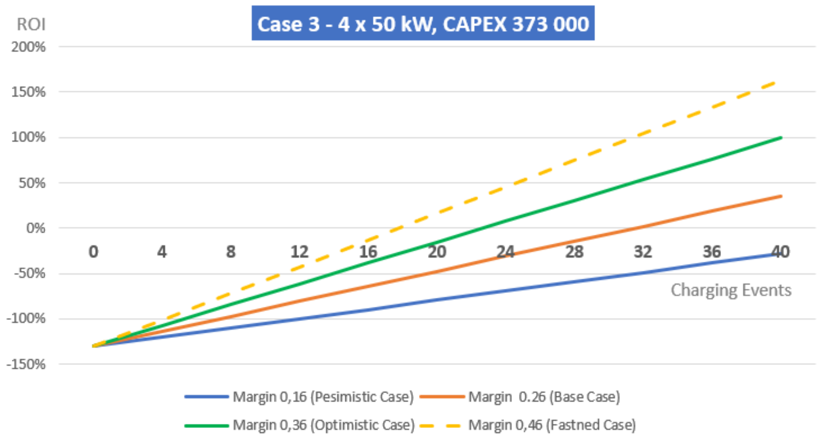


Figure 28: Case 3 – Estimated return on investment for a charging station with four 50 kW charging points *(Source: own illustration)*

Due to the high investment costs related to the infrastructure, the necessary number of charging events per charging point needs to increase to at least 8 (32 in total) to reach positive return values. The actual case of Fastned proves that this occupancy level is still challenging to reach. According to the calculation, in the Fastned case, a minimum of 18 charging events daily are needed to achieve positive results. However, Fastned, despite the remarkable maturity of the EV market in the Netherlands, only exceeded the threshold of on average 18-charging events daily in Q1 2021. At the end of 2020, the average number of charging events per station was 15.9 (Fastned, 2021). As mentioned, in terms of EV fleet, Romania just reached the 2015 level of Nederland in 2021. By making this direct association, it can be concluded that greenfield long-distance charging stations in Romania cannot be expected to be economically viable before 2028-2030 without other sources of income or subsidy support. It shall be noted that this calculation only considers the gross profit margin reported by Fastned without considering other relevant assumptions. Therefore, the Fastned case does not reflect the actual profitability profile of the Fastned chargers.

Investment subsidies for this type of projects will play a vital role during the EV market ramp-up period. For instance, with a EUR 38,000 investment subsidy for each charging unit, the number of average charging events required to reach breakeven in Case 3 reduces to 5 per charger (20 in total).

Sufficient fast-charging infrastructure is vital in overcoming range anxiety and increasing EVs acceptability among drivers. Government support and subsidies will have a crucial role in helping businesses overcome the EV market rump-up period and ensuring a rightly paced roll-out of the long-distance charging solutions.

5. Conclusion

Charging infrastructure proved to be a significant impediment in the development of the EV market already over a century ago and has been flagged as an essential barrier also by recent studies. Therefore, an appropriate and even deployment of the charging infrastructure throughout the EU countries represent one of the critical enablers of an accelerated EV adoption required to meet the 2050 decarbonisation targets.

The market share of EVs in the EU will be ca. 16% by 2030 and in Romania between 5% and 10%, with between 350,000 and 700,000 EVs estimated to be on the roads by that time (Mathieu, 2020) (PNRR, 2021). These projections are very modest considering the Fit-for-55 target of reaching carbon neutrality by 2050 in the transport sector. Thus, more ambitious immediate targets and policies will be required to ensure that the current market forecast for 2030 will be exceeded and that Romania is set on the right path to CO2 neutrality in the transport sector.

To support the acceleration of the EV market development, an appropriate number of public charging points needs to be deployed by 2030. According to some projections, 12,000 charging points will need to become available in Romania by that time (Mathieu, 2020) from 502 in 2020 (EAFO, 2022). These targets bring several challenges and opportunities for decision-makers and market players.

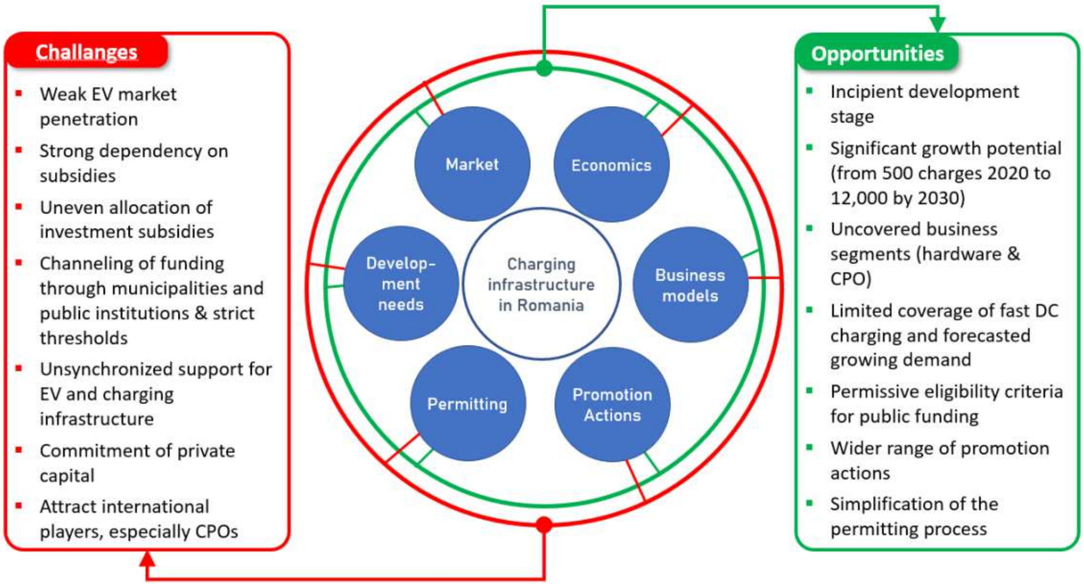


Figure 29: Summary of identified challenges and opportunities related to the deployment of public charging infrastructure in Romania *(Source: own illustration)*

To ensure the accelerated roll-out of the charging infrastructure, massive capital investment in this sector will be required. The private sector will need significant support from either EU or local administrations in form of subsidies and support actions. Currently, the promotion schemes focus primarily on fiscal and tax measures to encourage customers to acquire EVs. While this is vital in promoting the development of the EV market, the promotion measures focusing on the deployment of the charging infrastructure must not be neglected. An integrated policy approach to boost both the EV market segment and the charging infrastructure deployment in a synchronised manner could be beneficial and create synergies for both segments.

Furthermore, the public funding programs for charging infrastructure have several limitations:

- *Allocation*: the current procedures for public funds' allocation at the national level run mainly through local municipalities and public institutions. This may negatively impact the roll-out of individual projects, discourage private investors, and put the creation of a competitive environment at risk. Furthermore, the funds' allocation will likely occur through time-consuming bureaucratic procedures involving lengthy and complex bidding undertakings. This, in addition to the cumbersome permitting process and stretched economics during the ramp-up period, may lead to limited interest of the local and international private players to enter the Romanian market.

- *Thresholds*: Connecting Europe Facility allows private companies to apply for funding, yet it imposes minimum thresholds for single applications (EUR 1mn) and sets minimum charging powers (150 kW and 350 kW power stations only). Therefore, only large companies with access to an extensive network of locations and a strong balance sheet to cover the minimum 10% equity requirement can qualify for this program. In addition, 150 kW and 350 kW charging stations are expected to have minimal applicability on the Romanian market in the short term.
- *Scope*: ElectricUp government program appears accessible to wider range of applicants among the small and medium enterprises. However, it primarily targets companies that can host a photovoltaic system. Charging station operators could benefit from this program as a one-time subsidy but does not constitute substantial support if seen as part of a more complex roll-out plan at different locations.

Romanian regulators shall consider more permissive eligibility criteria for allocating public funds to access a wider pool of interested investors. With the current incentives framework and the modest penetration degree of the EVs on the vehicles market, Romania presents little attractiveness for international operators and local entrepreneurs. As shown in this analysis, with a EUR 38,000 investment subsidy granted through the AFM program as an example, a 50-kW charging station would become economical with only 1.5-2 daily charging events on average compared to 5 charging events needed without. Thus, investments subsidies can play a significant role in supporting investors overcome the EV market ramp-up period and thereby solving the “chicken-or-egg” dilemma of the sector.

Finally, another way to create traction for investors is to simplify the permitting and approval process. The main challenge related to obtaining the building permit for new charging stations lies in the fact that the process is very lengthy. A faster specific approval process for this type of projects may contribute to charging stations' faster roll-out. Further improvements may derive from the digitalisation of the application process for the various approvals and certificates required. An additional challenge is related to the fact that the general urbanistic plans do not contain specific details for this type of infrastructure, which may lead to misunderstandings or differences in the way the relevant authorities of different municipalities approach the permitting process for this type of projects.

As the market evolves and the number of EVs increases, financial incentives for EVs’ acquisitions will become unsustainable and may prove insufficient for the next development stage. Future policies should focus more on other related segments, which may have a more significant impact and indirectly reach out to different customer categories. R&D subsidies could improve battery technology, inherently lower acquisition prices for EVs, and improve range. Investments in education could increase awareness and understanding of the benefits of the transition to electric mobility and could thus contribute to a higher social acceptance.

In terms of business potential, it shall be noted that specific business models appear not to be covered in Romania at the moment. On the one hand, no local charging equipment producers have been identified. Most international brands are available in Romania, supplied mainly by local importers. The charging hardware business segment is estimated to generate ca. EUR 15.7bn one-time revenues in Europe by 2030 (Krug, 2021), a significant portion of which will be rendered in the production segment of the value chain. By not being active in this sector, Romania misses an important business opportunity. Furthermore, no charging station operators specialising in long-distance fast-charging solutions have been identified. The asset ownership segment is estimated to generate ca. EUR 2.9bn in revenues by 2030 (Krug, 2021). As the EV market grows in Romania, this business area may become an attractive opportunity for international and local network operators in the medium term.

To conclude, the charging infrastructure sector in Romania finds itself in a very early development stage compared to other European countries. This brings along fundamental challenges and opportunities. Whether the gap versus more developed markets can be closed and the targets set for 2030 can be achieved depends in part on how decision-makers will overcome several key challenges such as subsidies allocation, simplification of the permitting process and the creation of a favourable business environment to attract private capital and secure necessary investment volumes.

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List of abbreviations

AC	Alternating Current
AFID	Alternative Fuels Infrastructure Directive
AFM	Environmental Fund Administration
BEV	Battery Electric Vehicle
CAPEX	Capital expenses
CEF-AFIF	Connecting Europe Facility, Alternative Fuels Infrastructure Facility
CPO	Charge point operator
CSO	Charging station operator
DC	Direct Current
EMSP	E-mobility service provider
EV	Electric Vehicle
EU	European Union
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gases
HEV	Hybrid Electric Vehicle
ICEV	Internal Combustion Engine Vehicle
mn	Million
OPEX	Operating Expenses
PHEV	Plug-in Hybrid Electric Vehicle
PNRR	Planul National de Redresare si Rezilienta
ROI	Return on Investment
RQ	Research question
RFID	Radio Frequency Identification

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