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- Analysis of strategic plans of European Union in field of E-mobility
- Current situation in selected EU member states and expected development
- Recharging stations business models
- Economic effectiveness of public charging stations from the businesses point of view

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FACULTY OF ELECTRICAL ENGINEERING

DEPARTMENT OF ECONOMICS, MANAGEMENT AND HUMANITIES

MASTER THESIS

ANALYSIS OF DEVELOPMENT AND ECONOMIC EFFECTIVENESS OF E-MOBILITY

IAKOV BELSKIY

PRAGUE 2016

I hereby declare that this master’s thesis is the product of my own independent work and that I have clearly stated all information sources used in the thesis according to Methodological Instruction No. 1/2009 – “On maintaining ethical principles when working on a university final project, CTU in Prague“.

Date Signature

Keywords:
Electric car, electric vehicle, plug-in car, recharging station, investment model

Abbreviations:

AC – Alternative Current

ACEA – European Automobile Manufacturers' Association

BEV – Battery Electric Vehicle

CEN – European Committee for Standardization

CF – Cash Flow

CHAdeMO – Charge de Move – trade name of charging standard

CP – Charging Point

CS – Charging Station

DC – Direct Current

DCF – Discounted Cash Flow

EAMA – European Automobile Manufacturers' Association

EAT – Earnings After Tax

EBT – Earnings Before Tax

EDSO – European Distribution System Operators

ETSI – European Telecommunications Standards Institute

EU – European Union

EV – Electric Vehicle

EVSE – Electric Vehicle Supply Equipment

MIT – Massachusetts Institute of Technology

NAP CM – Czech National Action Plan for Clean Mobility

NPV – Net Present Value

OEM – Original Equipment Manufacturer

PHEV – Plug-in Hybrid Electric Vehicle

RCD – Residual-current Device

RES – Renewable Energy Sources

ROI – Return on Investment

SEVA – The Slovak Association for Electromobility

V2G – Vehicle-to-Grid

WACC – Weighted Average Cost of Capital

Content

Basic definitions:

- **The EV (electric vehicle) -** a motor vehicle equipped with a powertrain containing at least one non-peripheral electric machine as energy converter with an electric rechargeable energy storage system, which can be recharged externally. [34]
- **Battery electric vehicles (BEV) -** electrically chargeable vehicles with no other energy source than the battery. [13]
- **Range-extended electric vehicles (REEV) -** vehicles which use a battery as the main energy source, but use a combustion engine driven range-extender running on hydrocarbons, after the batteries are discharged. [13]
- **Hybrid electric vehicle (HEV) -** vehicle combines a conventional internal combustion engine propulsion system with an electric drive system rechargeable from an outlet, using the gasoline engine on longer trips if the electricity is not enough to cover all trips. [20]
- **Plug-in hybrid electric vehicles (PHEV) -** vehicles which use battery as the main energy source for daily trips, but can also run in common hybrid mode using the combustion engine running on hydrocarbons if necessary. [13]
- **Electric vehicle supply equipment (EVSE, charging station) -** device that comprises one or more storage points functioning independently. [26]
- **Recharging point** means an interface that is capable of charging one electric vehicle at a time or exchanging a battery of one electric vehicle at a time. [34]
- **Recharging point accessible to the public -** a recharging point which provides Union-wide non-discriminatory access to users, may include different terms of authentication, use and payment. [34]
- **Normal power recharging point -** a recharging point that allows for a transfer of electricity to an electric vehicle with a power less than or equal to 22 kW, excluding devices with a power less than or equal to 3.7 kW, which are installed in private households or the primary purpose of which is not recharging electric vehicles, and which are not accessible to the public. [34]
- **High power recharging point -** a recharging point that allows for a transfer of electricity to an electric vehicle with a power of more than 22 kW. [34]
- **AC charging station -** common charging station for alternating current to power up to 22 kW or high-power charging stations for alternating current to power over 22 kW). [26]
- **DC charging station -** high-power charging station to direct current. [26]

Introduction

Electric drive was and still is one of the most challenging issues in the car industry. History of its development takes more than two hundred years from the beginning of using electric batteries for the motors in the earlier 1800s till nowadays, when recharging stations are being widely implemented, making electric cars more and more common and used both in households and in business. [37]

At the present time more than 23 plug-in electric and 36 hybrid models are on the roads in different parts of the Earth. The popularity of electric vehicles is raising according to decrease of their price and rising gasoline ones. There are more than 234 thousands plug-in electric vehicles and 3.3 million hybrids only in US at the moment [37]

Electric cars are cheaper to operate, reduce population's dependency on oil and amount of collective carbon emissions. Recharging cars batteries at home means never going to a gas station. Also EV doesn't need maintenance like oil changes and emissions checks, instead of internal combustion cars. [32]

One of the remaining things lead to this industry development still environment question: usual one car in operation consumed about 8 liters of gasoline per 100 kilometers and oxygen emissions in the atmosphere are about 2.3 kilograms (kg) of CO_2 for every liter of gasoline used. Not directly harmful to our health, CO_2 emissions contribute to climate change as a most discussed global warming. [29]

Since politics of EU in last year's taking much more care about environment than ever and also changing in human vision of the future and technology development would determine all drivers to plug in rather than fill up. Millions of cars powered by batteries are plugged into an electric grid. That fact concerned with not only drivers money saving and gas emissions reducing, it would also supply the grid with a distributed, high-capacity electricity storages. That could allow to stable and make the grid more efficient in a way of storing generated during times of low demand energy and then use it at peak demand hours that allow reducing the home electricity costs. [36]

For me this topic is one of the less discovered due to completely undeveloped in my native region and in Russia in general. That's why I'm interested in getting knowledge in this field – I think that in the nearest future EV's question will start to widely implement in Russia, so far educated specialists working with European experience will have invaluable benefits on the labor market. Also spread of the EU experience will definitely make environmental situation on our planet better.

My work is based on analysis of information given by different sources such as books, journals publications, energy and car manufacturing companies papers, governmental legislations and various web-databases concerning E-mobility. Analysis of sources form the full picture of electric vehicles sphere current state as in EU in general as in individual countries such as Czech Republic, Austria, Germany, Slovakia and Ireland. Forecasting analysis also makes a vision of future conditions and creates an ability to make evaluations for the future. Such evaluations as economic effectiveness of public charging stations from the businesses point of view, which is a practical part of my research, is one of them.

To accomplish the task it's necessary to observe strategies of EV sphere development as in Europe as in Czech Republic especially, describe the current types of recharging stations are in use and implemented installation business models. To achieve the objectives computational, analytical, methods of logic, mathematical statistics, and others are used. The implementation of these methods and algorithms carried out principally through software system "Excel". In the final result the investment model of building up EVSE infrastructure for year 2020 should be accounted, with full NPV model, including all technical and economical features and obtaining service charge due to payback period.

1. ANALYSIS OF EUROPEAN UNION STRATEGIC PLANS IN FIELD OF E-MOBILITY

History of EV's is a history of oil industry, national security and global warming. Record-high oil prices have turned users towards vehicles with bigger level of efficiency in fuel using and governments to review EVs as a way to decrease their dependence on imported petroleum and to address climate change. [36]

1.1. POSITION OF EU COMMISSION

I decided to start the EU plans observation from the Europe Union Commission position as the most authoritative in my point of view structure in the whole Europe. The survey is based on directive of the European Parliament and the Council of the European Union 2014/94/EU of 22 October 2014 on the deployment of alternative fuels infrastructure. This Directive identifies general frameworks of actions for alternative fuels infrastructure in the EU for serving the dual purpose: minimizing dependence on oil and environmental impact of vehicles based on gasoline. It also establishes minimum requirements for alternative fuels infrastructure development, including recharging stations for electric vehicles which have to be implemented by Member States in according to their national policy frameworks.

According to Directive 2007/46/EC of the European Parliament and of the Council and Regulation (EU) No 168/2013 of the European Parliament and of the Council, electricity is the potential source of increasing the energy efficiency of transport and decreasing the air pollution by reducing the CO_2 emission and noise in areas with high population density. Electro-mobility is also a significant factor to reaching climate and energy goals of the Union for 2020. [34]

Since 2007, the European Union has sought to achieve the list of goals called "20-20-20 targets". It contains reducing greenhouse gas emissions by 20% compared to levels of 1990, producing 20% of the consumed in Europe energy by renewables, and consuming 20% less energy. All this points are planned to reach up by 2020. After that point EU plans to set intermediate results for 2030 to reduce greenhouse gas emissions by expected 85-90% by 2050. [16]

According to Directive 2009/28/EC all Member States must achieve 20% share of energy from renewables where 10% being used especially in the transport sector. Commission requires Member States to build till 31 December 2020 such amount of public accessible recharging points, that will correspond to the number of EVs expected to be on the roads in 2020 on their territory. The ratio 'one recharging point per 10 cars' was suggested, but is not compulsory. Charging technologies, types of cars and already existing recharging stations accessible to the public on their territory are also should be taken into account to install the appropriate quantity of recharging stations available at stations of public transport, airports, railways stations and ports terminals, but only if it is considered in Member States national policy frameworks. Recharging stations which are located in the public areas may include privately owned recharging points, devices that allow access to the public through registration cards or fees or recharging points of car-sharing schemes which allow access for third party users by means of subscription. [34]

In June 2000, European standardization bodies CEN, Cenelec and ETSI received a mandate concerned with electric vehicles charging. It was necessary for promotion the internal market of EVs with plugs and chargers that were under operation to prevent the imposition of market barriers. The Focus Group prepared a large report, but it didn't make any sense because the mandate's objective was to achieve interoperability, not the adoption of a single connector. As a result, two types of connectors have been assessed as appropriate for the Europe that create a choice possibility for the market that will depend on inner countries regulations. [10]

Distribution system operators that are also play important role should cooperate with another recharging point's operators and owners to help them with access and use of the information needed to developing of the system. In its turn Member States shall control that prices charged by the operators of recharging points available to the public are economically justified, clearly comparable, transparent and non-discriminatory. [34]

According to Directive 2012/27/EU of the European Parliament and of the Council Intelligent metering systems are enable real-time data to be produced which is needed to ensure the stability of the grid and to encourage rational use of recharging services. An intelligent metering system allows gathering accurate and transparent information about recharging services cost and availability, thus stimulating recharging at low electricity demand and prices periods. Using of this system helps to optimize recharging with benefits to both sides: as consumer with less costs on electricity, as electro grid with balanced daily power consumption. In case of technical and financial reasonability using of intelligent metering systems allow to stable the power system by recharging the EVs batteries from the grid during the time of low electricity demand. In the future it will also allow to electric vehicles give power from their batteries to the grid back at times of power deficit. [34]

EU politics in recharging point question leads to unification of it: under Article 44 of Directive 2009/72/EC Interface should include several socket outlets or vehicle connectors complies with the technical specifications set out in it that will allow multi standard recharging. However, if Member State already invested in another standardized technology, their choice shouldn't be determined by EU directives deals with EVs connectors and so on, but only in case of ability of these recharging stations to real work. [34]

The European Commission attributes the participating countries to establish standards for the development of industry and recharging stations that will be in the framework of national policies and would meet the objectives of the market development of alternative sources of fuel and energy. Cooperation with small and medium-sized enterprises as well as to exceed the bounds of its territory and cooperation with neighboring countries, giving them access to technology and expertise to introduce recharging stations, will allow the European Union to act as one company for the development of electric transport in Europe. [34]

As far as Electro-mobility is a fast growing industry legislation will provide further technological innovation development such as wireless charging or battery swapping. Coordination of all Member States policy's will guarantee the long-term stability that requires for investments in electric vehicles infrastructure and industries, as private as public. [34]

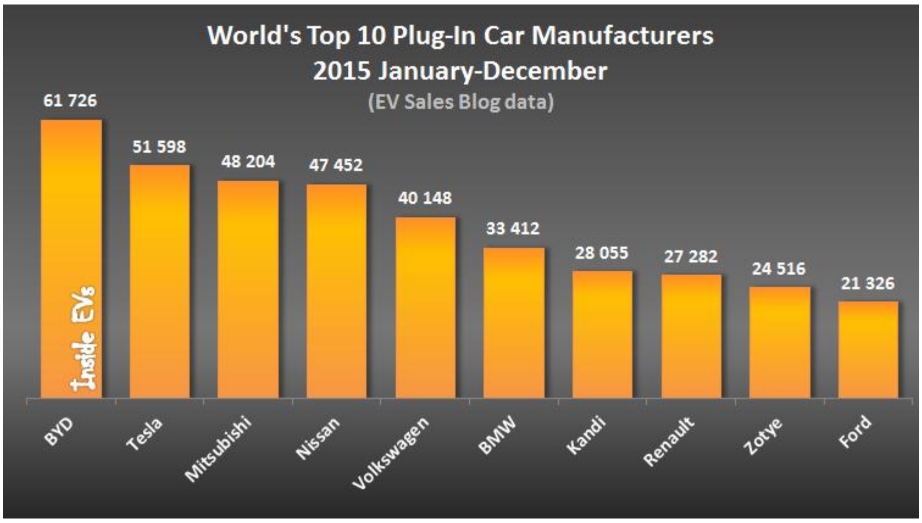
1.2. POSITION OF MAJOR STAKEHOLDERS

1.2.1. CAR MANUFACTURERS

Vehicle manufacturers are interested in development of EVs sector, as shown by large amount of investment and acquisitions during the past few years.

Only in 2014 about 320 000 of EVs/PHEVs in total amount were sold with an 80% rate of growth. Accumulative sales reached 740 000 vehicles by the end of 2014 and increased 1 million in 2015. But that sales still doesn't increase the share of even 1 percent of the global auto market, but represents that EVs and PHEVs are already came to stay. About 89 million units at beginning 2016 – that is the planned amount of the global vehicle sales. [21]

That's was numbers concerning general amount of EVs, if to be more detailed now over two dozen all-electric and plug-in hybrid electric vehicles are available on the market and at least two dozen additional models that are planned to be available in the next couple of years. The world's best-selling EV is still the Nissan Leaf, with over 165 000 units sold by March of 2015 since its release in late 2010. A new study found that the batteries have been very reliable, with 99.99%of the 35 000 Leafs sold in Europe still working perfectly. The Mitsubishi Outlander PHEV and the Tesla Model S are the second and third best-selling EVs today. [21]



Picture 1. World's top 10 plug-in car manufacturers 2015 [22]

Out of the over 50 000 **Tesla** Model S sold in 2015, Europe sales are estimated around 16 000 (15 800-16 200), which is nearly one third. Norway absorbs every fourth Tesla in Europe – 4 039 registrations. Two countries Norway and Denmark – represent nearly 42% of Tesla's sales in Europe, but only represent a small population portion of the region. A strong reason for this is that Norway has strong incentives to buy BEVs, while Denmark residents are encouraged to buy Tesla by entering a path of tax-incentives cuts. Including the third best performing country, the Netherlands (another plug-in friendly country), these three smaller countries account for 53% of the whole. [22]

Picture 2. Tesla Model S sales in Europe in 2015 [22]

During the 3rd quarter of 2015 Tesla produced 13 091 vehicles and said that a recent plant upgrade has vastly improved assembly capacity. They retooled final assembly line to increase the output by over 35%**,** completed and commissioned new paint shop, enabled new stamping equipment. Tesla still remains highly confident of average production and deliveries of 1 600 to 1 800 vehicles per week for Model S and Model X combined during 2016. [22]

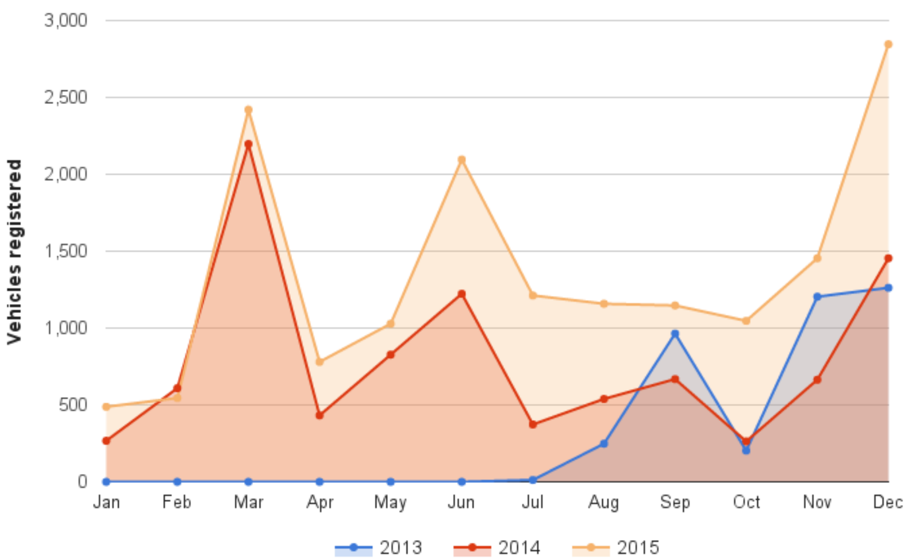


Figure 1. Tesla Model S registrations in Europe [22]

Tesla announced at the Geneva Motor Show that Europe remains a target region for the automaker and stated that high growth of service centers, stores and Superchargers are expected. The short term plan is to open 30 new service centers and stores across the continent. At October 13th, 2014, 73 Supercharging stations were operational in Europe. By the end of 2015 number expanded to about 225. From there the growth seems to slow, as 2016 would see the total growth decline to about 33% – to almost 280 stations in total. Additionally, the Supercharger network will be to a level at which most of the western part of Europe will be covered. Many of the new Superchargers allow for much easier travel into eastern Europe and the even more remote, such as Moscow (Russia), Turkey, Ukraine, Latvia, Estonia, etc. Also, the new stations fill out some empty coverage areas in their existing infrastructure; notably in southern Italy, northern Sweden Finland and Spain. By the end of 2016, Tesla expect users will be able to travel almost anywhere in Europe using only Superchargers. But its notable, that Tesla use specific charging standard which is not suitable for any other cars except Tesla. That makes rapidly increasing amount of Tesla chargers almost useless for majority of EV users. Tesla expects that combined sales in Europe and Asia will be almost twice as high as sales in North America. One of the reasons is the UK, where Tesla expects to gain some momentum. [22]

Picture 3. The Tesla Projected Supercharger Map For 2016. [22]

The Renault-Nissan Alliance announced that 302 000 all-electric cars were sold in the end of 2015. In Europe, Nissan's EV sales rose 14.3% in 2015 to nearly 20 000 vehicles. Renault's EV sales in Europe increased 49% to nearly 23 100 vehicles. Renault ZOE was the best-selling EV in Europe in 2015, accounting for nearly 19% of the market. Alliance announced plans to launch more than 10 vehicles with autonomous drive technology over the next four years globally. That is, 10 mainstream, mass-market and affordable cars, including the Nissan LEAF, which is most often used as the autonomous development prototype by Nissan. Autonomous driving will be developed step by step beginning in 2016. Autonomous drive is expected to help further reduce driver error, which is responsible for up to 90% of all fatalities. In 2018, Renault-Nissan will launch vehicles with "multiple-lane control," which can autonomously negotiate hazards and change lanes during highway driving. And in 2020 will be possible to see the launch of "intersection autonomy," which can navigate city intersections and heavy urban traffic without driver intervention. [22]

With the partner ENEL Nissan announced a smart grid trial in Europe using electric cars and a Vehicle to Grid system together. The goal is to create 'energy hubs' combining renewable energy and car battery as storage. Vehicle-to-Grid allows customers to take control of the type of energy they consume – avoiding peak tariffs and generating additional household income during peak times. Using a special two-way charger and energy management system developed by Nissan in partnership with ENEL, LEAF owners can connect to charge at low-demand, cheap tariff periods, with an option to then use the electricity stored in the vehicle's battery at home when costs are higher, or even feed back to the grid to generate additional household income. Consumers and businesses that join the trials with Nissan could count on receiving revenue when the car is plugged in. The trials will begin first in Denmark, Germany and the Netherlands. The Vehicle-to-Grid technology allows electric vehicles to be fully integrated into the electricity grid by also improving grid capability to handle renewable power and will make renewable sources even more diffused and affordable. In France for example, where there are 38 million vehicles and where the current electricity generation capacity is 130 GW, a future where all vehicles on the road are EVs/PHEV, the grid integration of the vehicles could generate a virtual power plant of up to 380 GW that's equal 3 times the national generation capacity of France. [22]

Battery-development firm Seeo, based in Hayward, California, which was acquired in August by German auto supplier Bosch, declare that their solid-state cells could be half the weight of those in the current Nissan Leaf — the leading battery electric car worldwide in terms of sales. The company also says its cells achieve 350 watt-hours per kilogram in the lab, but the real-world performance could be less. [30]

The Volkswagen Group has twelve brands from seven European countries, more than 440 000 employees at 72 locations in Europe. The Group is the largest industrial investor in many EU countries. Volkswagen has announced a major shift towards electrification. According the new Strategy 2025 for the

Group the company's brands will introduce about 20 additional models with electrical or plug-in hybrid drive trains by 2020. [22]

Also Volkswagen bought in 2014 a 5% stake in "Quantum Scape" - electronics firm in California deals with developing solid-state technology, which could multiply the list of forthcoming EVs by three. [30]

Car manufacturer Toyota says that cells that it has developed with double the energy density of today's alternatives could provide electric vehicles with a range of 480 kilometers on one charge. It has built prototype cells and even a small scooter powered by the batteries. Positive results have been reported for solid super-ionic electrolytes. But the company says that cell-energy density is still far below the potential, and production of the batteries is not expected to start until the early 2020s. [30]

For competitive reasons, many of the lab-stage battery companies are keen to emphasize the positive aspects of their research, but not all are forthcoming with sample cells or technical details. [30]

1.2.2. EURELECTRIC

EURELECTRIC (The Union of the Electricity Industry) - is the sector association which represents the common interests of the electricity industry at pan-European level, its affiliates and associates on several other continents. EURELECTRIC have currently more than 30 members represented the electricity industry in 32 European countries. Company's mission is to contribute to the development and competitiveness of the electricity industry, to provide effective representation for the industry in public affairs and to promote the role of a low-carbon electricity mix in the advancement of society. [12]

EURELECTRIC has allocated six Presidency Priority Projects among which electrification and decarbonisation. That provides proactive, agreed and effective work, taking into account developments at different levels as the European as well as international levels. One of the products of this work is a Position Paper Facilitating e-mobility. [12]

In accordance to this paper in the nearest future EVs will be the part of electricity smart grids and will play the role as the consumers as the electrical storages. In such way standardized communication protocol must be applied for interconnection the vehicle, charging infrastructure and the grid. That fact will enable load management that makes using of electricity generation especially renewables more efficiency and provides the distribution system operator with a power balancing tool in the way if EVs will be able to modulate the charging power on a wide range (1-22kW). [10]

Current market growth forecasts for EVs a wide degree of uncertainty and depends on a variety of factors, including government policies, purchasing costs and customer's willingness to buy the new cars.

A transition scenario would achieve a 10% electric vehicles share in terms of accumulated market shares in 2035. Figure below is achieved by following an "S-curve" development of market growth that saturates at 22% by the same year, representing the limit for market growth in annual sales in 2035. [11]

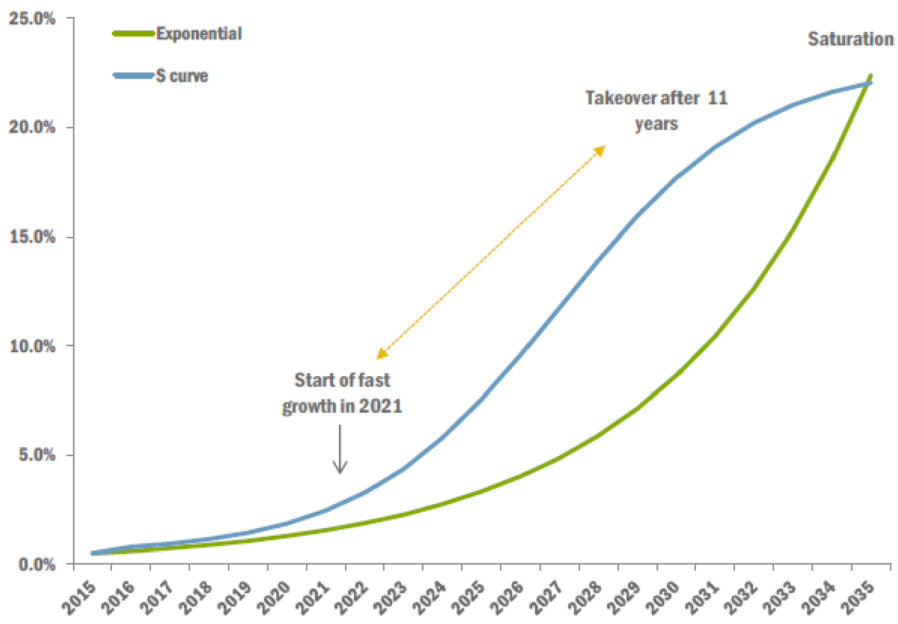


Figure 2. EV market uptake in a transition scenario (%)

(Theoretically approach S-curve vs exponential curve). [11]

Uptake of fast growth starting in 2021 is expectable, possibly because cars with higher battery capacity of more than 300 km would by then become available on the market at a cost-effective level of €/kWh. Figure 3 shows related developments for the e-mobility market uptake under three scenarios in terms of annual market shares: [11]

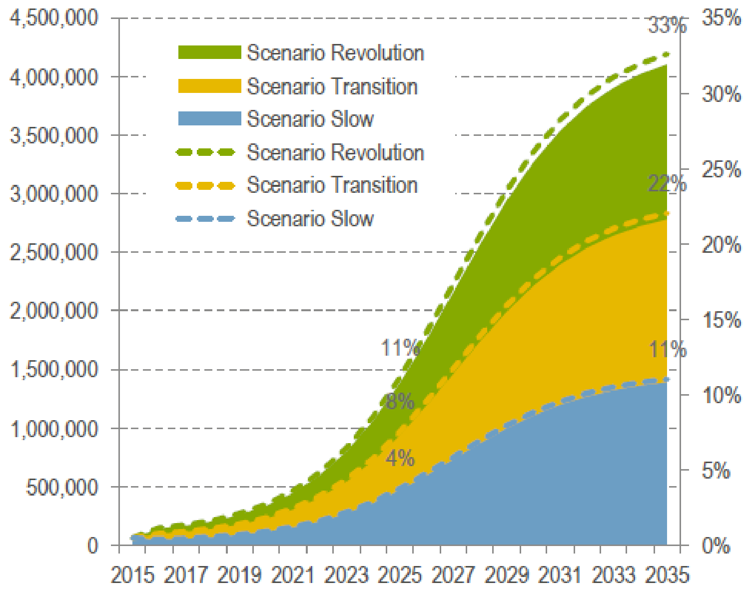


Figure 3. EV market uptake in the three scenarios [11]

Sales (Million) and Annual Market Share (%)

Table 1. Accumulated Sales (Million) and Market Share (%) [11]

EV Mill - %	Slow	Transition	Revolution
2025	1.9M - 0.8%	3.7M - 1.5%	5.5M - 2.2%
2035	12.7M - 5%	25.4M - 10%	37.5M -15%
2050	37.1M - 15%	74.2M - 29%	109.7M - 43%

According to EURELECTRIC position recharging stations should be located in such way to give customers opportunity to charge their vehicles without any obstacles at home or at the office, in a parking lot or at the shopping mall or supermarket, or at a dedicated high-power charging station on public roads. Three different locations categories can be defined: domestic areas, semi-public areas and public areas. Nowadays existing domestic sockets are not very functional and work with limited capabilities. In such way new charging infrastructure has to be installed in public and partly in semi-public locations with additional functionalities than indoor infrastructure. The variety of locations based on parking time and remaining range of the battery. But plug in during the parking makes the difference with internal combustion vehicles in the way of uselessness the refueling stops. [10]

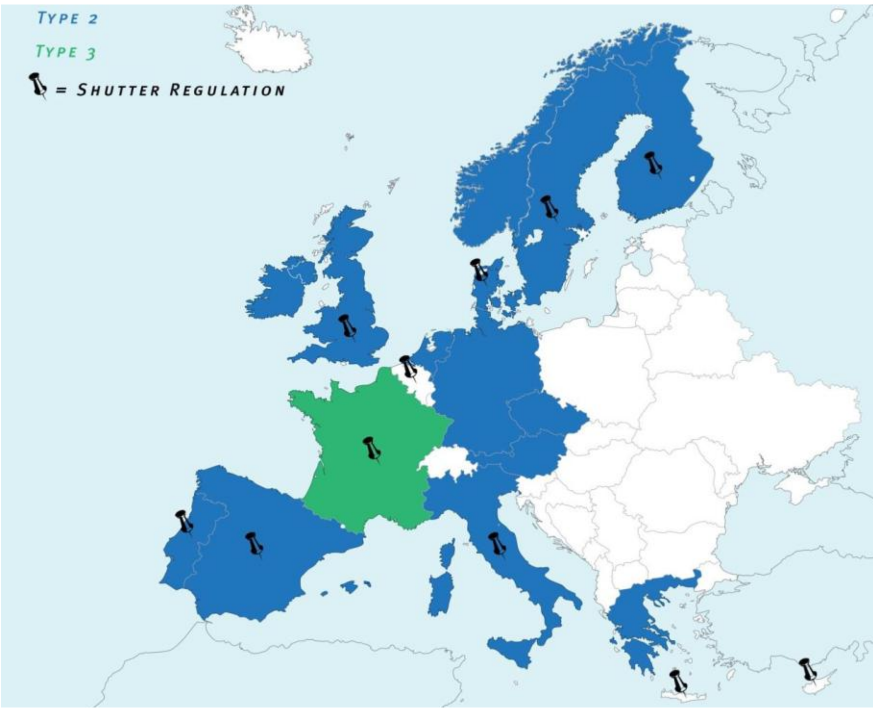
Home and office buildings already have domestic or industrial sockets with a connection to the electricity distribution grid that can be used for e-mobility purposes. In such locations EURELECTRIC defines the charging process as normal power charging (1-phase connection, $\leq$ 3.7kW). This minimum power level allows this connection to take place at any location, mostly in locations where the vehicle is supposed to be parked for a certain period of time. That will be enough to fully recharging due to its regularly appearance and not much amount of energy needed in such way. With the infrastructure already existing this and off-peak charging allows to avoid addition pressure on the grid. [10]

EURELECTRIC advised EVs owners to recharge mostly in domestic locations because of the difficulties in market development forecasting and smart charging hand in hand going. However, on possibility to local charging infrastructural differences between EU member states may influence. For example, possibilities to charge on private property are not common all over the Europe. Netherlands is the common example of such situation, so there public locations should be more used. [10]

As far as domestic and industrial sockets are not created for EV charging EURELECTRIC see the solution in standardized plugs that charge electric vehicles in Mode 1 and Mode 2 (detailed description of charging modes can be found in Appendix 1). That will lead to faster market penetration of EVs in smart home and building systems and taking part in power balancing through automated systems that consume, store, produce and re-distribute energy. [10]

To ensure customer convenience, the e-mobility socket should then be the same for all possible charging locations (domestic and publically accessible charging points), allowing electric vehicle drivers to charge their electric vehicle at any connection point without any adapters or extension-cables. [10]

The decision on a single AC connector in Europe is further complicated by differing national safety regulations for connecting household electrical loads to the distribution network. Some European countries explicitly require ordinary domestic sockets – which are usually under live voltage – to comply with shutters. Based on input from EURELECTRIC members, the map below shows which European countries have to comply with shutters in domestic settings. The map also shows which countries are installing which type of connector. Unmarked countries are awaiting European agreement before starting the roll-out of e-mobility infrastructure. [10]



Picture 4. AC connector type and countries with shutter regulations [10]

Based on this map it's possible to conclude that countries like Belgium or Switzerland are rather hesitant to start the roll-out of e-mobility infrastructure in the absence of an agreed European connector type. Other countries like Sweden, Greece and Finland have not yet deployed e-mobility infrastructure but intend to install the Type 2 connector once e-mobility infrastructure is installed. [10]

Based on an internal EURELECTRIC survey table below gives an indication of the number of dedicated e-mobility installations (Type 2 or Type 3) across Europe, including those already installed. The figures only include specific e-mobility infrastructure, not domestic and industrial connection points that could also be used for other purposes. The table only provides an indicative impression based on available information. [10]

Table 2. Installed AC connectors by country [10]

Type 2	Austria, Czech Republic, Denmark, Germany, Spain, Ireland, Italy, Netherlands, Portugal, UK
Type 3	France

Two conclusions can be drawn from the map and the table. First, European member states with a clear e-mobility target, such as Germany, France, Ireland, the Netherlands and Denmark, are – despite the absence of a European agreement – installing a significant amount of e-mobility infrastructure. Secondly, the absence of a European agreement is hampering the roll-out in European countries such as Belgium or Switzerland. Present situation is characterized by a lack of European coordination not only regarding the interoperability of the infrastructure, but also its availability. [10]

Current experience shows that retrofitting costs could range between €250 – when retrofitting is anticipated and it is only necessary to change the socket – and, in a worst case scenario, €3,000 per charging station. Economies of scale have to be encouraged to drive costs down. [10]

The major barriers for e-mobility are currently seen today in the: [11]

- cost of battery, in terms of €/kWh, and therefore the cost of the electric car in general, of which the battery represents a significant part (normally not lower than 25%);
- limited electric storage capacity that influences the car's range; and
- lack of charging infrastructure, including smart charging business models availability

There is a need to offer customers a high-power charging possibility that allows them to recharge the battery within a limited timeframe. A high-power connection would satisfy customer requirements for longer journeys, for instance by enabling relatively short recharging stops during longer motorway journeys. However, this charging method should not become the dominant way of charging electric vehicles, as electric vehicle customers would then probably not accept load management. Two technologies are at hand for high-power charging: DC off-board charging or AC on-board charging. DC off-board charging is more common today, due to the introduction of the first generation of Japanese electric cars on the European automotive market. Nevertheless, European automotive manufacturers have expressed their intention to launch a passenger car with an on-board charger which would be compatible with a high-power range AC supply arrangement. [10]

For the DC connection – with a maximum power level of 50kW – is currently the only available product on the market and is thus being rolled out in several European countries although it is not internationally standardized. The European automotive industry is however promoting the combined charging system with the Combo connector, which features a single inlet for AC and DC charging on the side of the vehicle and can potentially deliver high-power charging of up to 100kW in future. The Combo connector currently available on the market from the end of 2012. [10]

At the same time, the costs of batteries, a critical component of the overall cost of a car and range, are expected to experience a promising learning curve, with a significant decline in costs in the years to come. A battery pack of 39 KWh would see a reduction of 48%, reaching the value of 153 €/kWh in 2025 in the transition scenario. As for the range, there is a positive trend in battery technology, which could see their capacity increase between 36 kWh and 43 kWh in 2025 in a slow or revolutionary scenario respectively. The battery of an average vehicle is also estimated to achieve an energy density of 287 kWh/kg in 2025. [11]

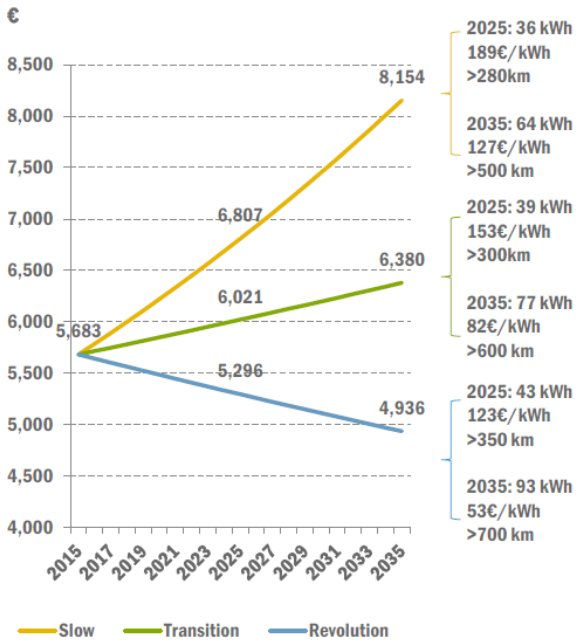


Figure 4. Development of battery costs (€) and capacity (kWh) in three scenarios [11]

1.2.3. EUROPEAN DISTRIBUTION SYSTEM OPERATORS

Distribution system operators are the managers and sometimes owners of energy distribution networks, under which operation are low, medium and high voltage levels transmission lines delivered large amount of electricity across long distance from points of generation (power plants) to the points of consumption like cities and industrial zones, where it transformed and distributed to the end-users. In this case overhead lines and underground cables are operated by EDSO. [16]

EDSO for Smart Grids is gathering leading Distribution System Operators, covering more than 70 percent of the EU points of electricity supply. [3] EDSO for Smart Grids fully supports the European Commission's and member states' initiatives that consider DSOs to play a key role in the development of e-mobility, ensuring the deployment of a technically and economically sustainable charging infrastructure for EVs. [10]

In order to translate 20-20-20 targets into live more and more new RES, which are predominantly variable in nature, are connected to the grid. That makes EDSO core mission in providing clean electricity especially for supply one of the cleanest transport slot as electric vehicles. [16]

According to the Electricity Directive (2009/72/EC) the DSO is "*responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system*", hence the DSO is also responsible for meeting the new demand that the EVs will bring. [15]

The DSOs will develop systems for EV charging control to avoid increasing peak demand. The future charging patterns are still fairly unknown, but as the number of EVs increases, experiences and statistics will allow for better prognoses. The number of charging spots will be much higher than the number of EVs and the reinforcement of the networks will take into account that all charging spots are not used at the same time. In the longer perspective, charging could create grid congestion (during the night) and sharp demand increases if the system is not accurately managed. Full flexibility of the charging processes has to be considered as a main target. If the charging process is systematically long, 8 hours or more, there will be less need for flexibility. Therefore it is at least initially, recommended to charge every night to reduce unnecessary system stress. [15]

The locations and types of charging spots – public and private, shared and single-user – are numerous. Also public charging spots should be installed as three phase level to allow for higher charging power, whereas private charging is usually single phase. From a security point of view, Mode 3 should be the standard for connecting vehicles to the grid. But DSOs must be in compliance with national and international standards and supportive of the updating of the existing rules, having a fully interoperable charging infrastructure as the final goal. [15]

The future smart energy systems have to be developed with new requirements for a large scale roll-out of electric vehicles. EDSO for Smart Grids is convinced that DSOs will play the key role here, bearing in mind that this new development directly and indirectly will affect the medium and low voltage grids from a technical and economic aspects: [15]

1) The charging process must be controlled according to time and power parameters, with the possibility to invert the charging power flow providing electricity to the private network (Vehicle-to-Home services), or to the grid (Vehicle-to-Grid);

2) Mode 3 is necessary for safety reasons and for allowing an accurate control of the charging load profile (time and power control).

3) Mode 3 should be designed to allow maximum flexibility regarding time and power regulation, and EVs should comply with this possibility;

4) Price signals cannot be the only solution for load control, since this may result in sharp increase or decrease in the electricity demand;

5) A public charging service operator has to give access to all mobility service providers;

6) There is a need for cost-benefit assessments to reach a reasonable cost for private EV charging;

7) The organization of EV load management should be an integrated part of the ordinary DSOs energy system management and control.

8) To give the EV car drivers the possibility to choose electricity supplier at every public charging spot, this has to be an official point of electricity supply equipped with a meter;

9) A communication infrastructure has to be developed to allow data exchange between energy market actors (customers, DSOs, TSOs, suppliers, aggregators) and EV charging service suppliers (e- mobility service providers and charging spot operators);

10) DSOs can harmonies the European charging infrastructure, providing seamless access for any EV to any CS and allow pan-European business development by all mobility service operators.

1.2.4. EUROPEAN AUTOMOBILE MANUFACTURERS ASSOCIATION

The European automotive industry is a key to the competitiveness and strength of Europe. The European Automobile Manufacturers Association represents the 15 Europe-based car, van, truck and bus makers, has close relations with the 29 national automobile manufacturers associations in Europe, and maintains a dialogue on international issues with automobile associations around the world. ACEA works with a variety of institutional, non-governmental, research and civil society partners - as well as with a number of industry associations with related interests. [13]

Most stakeholders assume a realistic market share for new electrically chargeable vehicles to be in the range of 2 to 8% by 2020 to 2025, based on today's market, depending on how quickly the various technological, infrastructure and socio-economic challenges can be addressed. Even as the electrically chargeable vehicle develops, the industry expects that for the foreseeable future the combustion engine will remain the dominant and most popular propulsion method. Over time this may change as consumers become used to the vehicles and as infrastructure develops. [13]

Electrically chargeable vehicles may promise many benefits for towns and cities, such as very low to zero tailpipe emissions and reduced noise. However, the source of the electricity used to charge electrically chargeable vehicles is crucial. While they may be clean at the point of use, their CO2 emissions may be created at the point of energy generation. In order to determine the calculation method for well-to-tank efficiency, there are several potential studies and methods. There is no single and agreed approach. [13]

Only once a large volume of electrically chargeable vehicles has reached the market, it is likely that some extra supply of electric energy will be needed. However, even broad introduction of electrically chargeable vehicles would not meet the limits of generating capacity. Assuming the future energy consumption of an electrically chargeable passenger car to be in the order of 100-120 Wh/km and assuming an average 10 000 km traveled per year, it follows that 1 million vehicles will require about 1 TWh of energy which is only a minor fraction of the annual electricity output of the EU (2006: 3 400 TWh). Smart charging can limit peak demand issues. With increasing number of electrically chargeable vehicles in coming future, there will be increased need for smart charging and a need for the balancing of demand and supply from the perspective of the energy generation and grid capacity. The final goal should be electrically chargeable vehicles powered by renewable energy. [13]

Smart charging can represent an opportunity for all the stakeholders involved: [11]

- Customers: satisfaction, reduced energy costs and ecological value;
- Power system: optimizing generation and grid capacity, cost efficiency by minimizing network reinforcement costs, facilitating renewables integration;
- Society: reducing local and global CO2 emissions and related costs, in addition to increasing energy efficiency and social welfare

Standardizing the connection between the electricity grid and electrically-chargeable vehicles is one of the main points to help e-mobility gain a viable market share. It provides predictability to investors, enables economies of scale, reduces costs for all stakeholders and is essential in increasing user acceptance. Presently a small electric car can cost double or even triple the price of a comparable conventional-engine car (can be checked on manufacturers´ respective web-sites). Not including purchasing expenses, the in-service cost of electric cars is, in principle and on a €/km basis, considerably cheaper than the comparable conventional engine vehicle. This is calculated by comparing current prices of electricity and petrol or diesel. [13]

The industry has stressed the need for a single harmonized plug system for the recharging of electric vehicles on both the vehicle and the infrastructure sides, and already agreed on a joint proposal for an EU-wide charging system. In September 2011, the automotive industry recommended the use of the Type 2/Type 2 Combo as the common plug in public infrastructure across Europe. On the vehicle side, all vehicles will have the same plug starting with new vehicle types as of 2017. [13]

However it is very concerned by the lack of progress in creating the framework to meet these goals. This was one of the key incentives for ACEA members to revise their position on electrically-chargeable vehicles and to lower their expectations for the future market share of these vehicles. ACEA now forecasts the future market penetration of EVs to be in the range of 2 to 8% for the next decade, with significant differences among manufacturers depending on their individual strategies. [13]

Standardization provides predictability to investors; it enables economies of scale, reduces costs for all stakeholders and is essential in increasing user acceptance. All relevant industries want to provide a simple and cross-border operational solution for European citizens. The signatory associations are promoting a solution that can push Europe a step further, providing a tool for a more competitive and successful e-mobility market in the EU. The necessary steps should be taken to implement this solution without further delay. From 2017, the solution should become standard for all new vehicle types in Europe. [13]

2. CURRENT SITUATION IN SELECTED EU MEMBER STATES AND EXPECTED DEVELOPMENT

2.1. STRATEGY OF CZECH REPUBLIC

One of legislative tasks of the Ministry of Industry and Trade under the State Energy Policy Review is the presentation of National Action Plan for Clean Mobility (CM NAP). CM NAP for the period 2015-2018 with a view to 2030 is based on the requirements of Directive 2014/94 / EU on the deployment of infrastructure for alternative fuels to adopt appropriate national policy framework for market development of alternative fuels in the transport sector and the relevant infrastructure. This task was also contained in the document "Transport Policy of the Czech Republic for the period 2014-2020 with a view to 2050", according to which the NAP CM had become one of the 12 follow-up strategy documents contributing to the implementation of transport policy objectives. CM NAP goals are also consistent with the National Environmental Policy which contains, among other things, 10% share of renewable energy in transport by 2020 while reducing emissions from traffic, which contribute to the overall reduction levels of air pollution in the country. [26]

In accordance with Directive 2014/94 / EU, the essential starting point for determining the desired number of public charging stations is anticipated number of vehicles running on electricity, which can be recharged from the infrastructure at the end of 2020. NAP CM is working in that direction with the assumption of 17 000 electric vehicles, (out of them 6 000 BEV and 11 000 PHEV). But nowadays development of electro mobility in the Czech Republic is still in its infancy due to several reasons [26]:

- The cost of electric vehicles, which operates on electricity compared to vehicles with internal combustion engine to conventional fuels.
- Lack of regulatory framework
- Economic reasons (electromobility is not yet fully commercial; the market is still in its formative stages).
- Limited range of vehicles (limited range of models in different segments of the mass sales related to the fact that the Czech market is not for the main players so attractive, and delays can be expected in comparison with Western Europe).
- Absence charging infrastructure (low density rechargeable networks)
- Prejudices and distrust users limited practical experience

Costs for securing supply in the area for a fast charging stations are, on average, estimated at 750 000 – 1 500 000 CZK. To build a sufficiently dense network assumes the need 500 to 1 000 sites throughout the country. [26]

Investing in charging infrastructure, however, is burdened with considerable risk and uncertainty. Especially in the beginning of a sufficient return on investment due to the small number of vehicles in the streets. The construction of charging stations gradually, but the development is very slow and is mainly limited by the volume of funds that are investors in venture capital so willing to invest. The risk level is determined by the following factors [26]:

- A significant part of the investment in charging infrastructure, especially for fast and ultra-fast charging is the cost of providing the necessary connectivity to power and construction works in the area. These costs are complicated by property rights relations, which is usually either the construction of trespassing (complication of law works) or investment in existing foreign facilities (the problem of technical improvements), with consequences in terms of accounting and taxation (tax deductibility thus expended funds depreciation period, the possibility of disposing of property etc.). The actual charging stations is movable property from the perspective of the operator is less risky, because it remains his property and can be (unlike investments in energy input) if necessary, moved to another location.
- The owner of the land or building is not usually the investor and operator of charging infrastructure and is not sufficiently motivated to allow the long-time operation of charging infrastructure on his premises. The problem is that the construction and operation of charging infrastructure - especially at an early stage – is not in the current term commercial, and so it is difficult to motivate landowners, for example, in the form attractive rent by the operator of a charging station or analogous compensation.

In terms of the number of charging stations, it is important to distinguish between the location (at one location more charging stations can be placed) and the type of station. The DC fast charging stations can recharge only one vehicle in DC mode, therefore represents one charging fast charging point. AC charging stations are typically equipped by two independent sockets, representing two AC charging points. With regard to the definition of "charging stations" in Directive 2014/94 / EU is a specific target has been defined based on the number of charging points. [26]

The place where it will be installed several charging stations (initially a smaller number, additional to be installing later), which on one hand increases the demand for consumption of electricity in the area, but on the other hand, simplifies the process of building and installing charging stations, including the necessary grid connection (majority of construction works is done at once, allowing further expansion of the site without additional construction work or in much smaller extent). [26]

Growing share of electric vehicles in the Czech Republic reduces the level of taxes collected from liquid fuels due to the substitution of these fuels for electricity. Given that the development of electromobility in the Czech Republic at the very beginning, these effects are still relatively low - in 2014 it was the cumulative shortfall in tax revenues at a level less than 5 500 000 CZK. Bigger value can be expected when there is a massive and commercial development of electromobility. A suitable method of solution will be designed in response to market developments within the updated NAP CM 2020 would reduce the value selection excise duty could reach 250 000 000 CZK. [26]

To calculate the environmental benefits of electromobility a comprehensive analysis of the entire chain, so-called. "Well-to-Wheel" analysis ("from mining to the wheels") is usually used. Its concept is based on the fact that the environmental impact of the operation of a car consists of two basic parts - fuel production and operation of its own. Followed were three key pollutants - CO_2, CO and NO_x . Electric vehicles are completely emission-free operation of the vehicle ("Tank to Wheel"), in terms of fuel is a key fuel mix used in electricity production (this part is emission-free in a situation where electricity is produced from renewable sources). [26]

Increasing number of alternative fuel vehicles will help the Czech Republic to reduce transport emissions. Private cars annually produce nearly 10 000 tons of $CO_{2,}$ which represents about 55% of emissions in transport. Road public passenger transport, including public transport buses and road freight transport emit additional more than 6 600 tons of $CO_{2,}$ which together with cars represents more than 90% of CO_2 emissions in transport. Road vehicles are the main contributor to emissions in the transport sector with a share exceeding 80%. [26]

Summarizing the strategy and analysis of NAP CM next plan in form or the list of basic goals and expectations in clean mobility can be generated [26]:

Period 2020

- ✓ The usual electric range 150-200 km / recharge;
- ✓ Charging infrastructure is covered cities with more than 100 000 inhabitants, all regional cities and highway routes. More than 25% of the Czech population will be commercially available electric charge;
- ✓ Quick charging at public stations is a dominant way;
- ✓ Electrobuses begin to implement in public transport;
- ✓ Annual sales at the end of the period will reach about 17 000 pieces of electric vehicles, and overall will operate 6 000 BEV vehicles and 11 000 PHEV;
- ✓ In relation to Directive 2014/94 / EU on the deployment of infrastructure for alternative fuels 1 300 public charging points (500 DC charging stations and 800 charging points AC) will be reached.

Period 2021 - 2025

- ✓ The usual electric range to over 200 km / recharge;
- ✓ Further expansion of charging infrastructure into smaller cities with more than 10,000 inhabitants;
- ✓ Annual sales at the end of the period will reach about 25 000 pieces of electric vehicles and generally 35 000 BEV vehicles and 66 000 PHEV will be in operation.

Period 2026 - 2030

- ✓ Implementation of dynamic tariffs for recharging electric vehicles;
- ✓ Continues to increase penetration charging infrastructure;
- ✓ Annual sales at the end of the period will reach about 44 000 pieces electric vehicles and generally will be in operation about 250 000 vehicles.

Period after 2030

- ✓ Charging infrastructure will be so widespread, as is currently pumping station on petroleum products;
- ✓ Electromobility will be perceived as the standard technology;
- ✓ Annual sales will gradually rise to about 50 000 pieces of electric vehicles and the total number of vehicles in operation will rise to 400 000.

2.2. COMPARISON WITH STRATEGIES OF EU MEMBER COUNTRIES

In Europe, for instance, Denmark, the UK, Ireland, France and Portugal are currently creating favorable conditions for the rapid introduction of electromobility by means of tax measures and flat-rate funding models. The leading electric vehicle manufacturers concentrate on markets with sufficient basic conditions (safeguarded in the medium term): Renault Nissan will deliver at least 100 000 electric vehicles (mass-production vehicles, Renault Fluence ZE) to Israel from 2011. Similar plans exist – partially as government agreements - with Denmark and Portugal (as well as France). [37]

Next chapters will represent situation with EVs and charging infrastructure in different countries due to closest geographical position to Czech Republic (Germany, Austria, Slovakia) and due to extremely developed chargers infrastructure (Ireland).

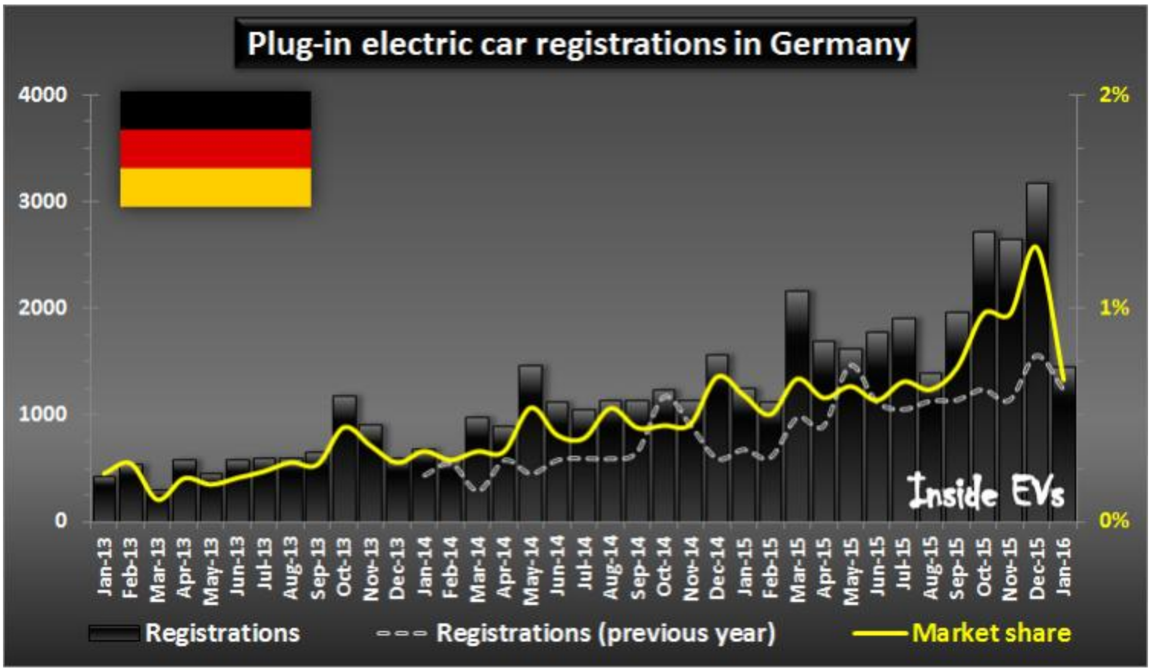
2.2.1. GERMANY

Electromobility constitutes a key building block in achieving Germany's new energy policy aims and can accelerate the integration of renewable energies. Electric vehicles have the potential to serve as decentralized energy storage devices – thus making an important contribution to stabilizing the distribution grid. Capable of accumulating energy, they can be charged at times when more renewable energy is available than is being used. Experts estimate that 85% of the times, electric cars are charged either at home or at work – at times when the car would be parked for long periods anyway. [33]

Electric engines will be the defining face of future mobility. This will be the only way of achieving Germany’s and Europe’s climate protection goals in the field of traffic and transportation. Due to the high proportion of nuclear energy and the rapidly growing amount of renewable energies in today’s E.ON electricity mix, an electric car with a consumption of 15 kilowatt hours per 100 kilometers will only generate 75 grams of CO_2 per kilometer. This places the vehicle substantially below the limit of 120 grams per kilometer for a car manufacturer's fleet consumption that will be prescribed by the EU from 2012. [6]

The German Federal Government set the ambitious target of putting one million electric vehicles on the road by 2020, possibly reaching over five million by 2030 that is the bold aim of Germany's National Electromobility Development Plan. By 2050, most urban traffic will be able to do without fossil fuels. This will also entail installing suitable infrastructure for charging the vehicles. [20]

Government plans to make one billion euros available for research into the topic of eMobility. Germany's company car tax has also been amended. Experts expect the market to grow dynamically in the next few years. On paper, 24k EVs were sold in Germany 2015 year. By 2017, the number is expected to increase five-fold, to 500 000 vehicles, and by 2020, to double again to one million. Cars with a plug-in hybrid motor are expected to account for around 55% of the vehicle fleet, with the remaining 45% consisting of purely electric vehicles. [33]



Picture 5. Plug-in electric car registrations in Germany [22]

The National Electromobility Development Plan initially set aside more than EUR 500 million in incentives for the development of vehicles, energy storage devices and infrastructure. The government has prepared a traffic guideline statement outlining the uniform sign-posting of parking places (particularly charging stations in public traffic areas) which allows local authorities to implement existing legislation more easily. [20]

Nowadays in the communities of Stuhr and Weyhe near Bremen, some 30 households are taking part in a model program: they have been equipped with photovoltaic units, modern heating and cooling appliances, EVs and intelligent electricity meters. Company E.ON is also fitting the electricity networks in both communities with cutting-edge control technology to turn them into intelligent local grids: self-regulating transformers will automatically counteract any fluctuations in voltage caused by the feed-in of solar power. The project uses this ambitious technology for the first time in conjunction with low-voltage networks, and it enables research to be carried out on a power network under conditions which are likely to be prevalent in 10 years' time. [6]

Another “experiment” - the “e-mobility showcase” program will run for three years and will receive € 180 million in subsidies from the German government's energy and climate fund for the showcase regions. The four regions, which were chosen in a competition, are Baden-Württemberg, Bavaria-Saxony, Berlin-Brandenburg and Lower Saxony. In large-scale regional demonstration and pilot projects, electromobility is being tested at the interface between energy system, vehicle and traffic system. Apart from the fleet trials and real-time balancing tests with green electricity and batteries for electricity storage, E.ON’s e-mobility team (an international privately-owned energy supplier based in Düsseldorf, one of the world's leading companies within the renewables segment which focusing on renewables, energy networks and customer solutions) will particularly focus on fast charging: in the Berlin region a number of charging stations developed by different manufacturers with a high DC charging capacity will be installed and field-tested. The main objective of these showcase projects is to give potential users and the general public in Germany a chance to experience e-mobility. In all, some 7 000 electric vehicles will be used. Along the A9 motorway leading from Munich to Leipzig via Nuremberg, DC fast-charge stations have been installed enabling drivers to quickly recharge their electric vehicles. A total of eight such stations have been set up no more than 90km apart. The project is being carried out by E.ON together with Siemens and BMW. The DC fast-charge stations have the new CCS plug that has become standard across Europe. [6]

According to a study by the German Association of Energy and Water Industries, there was a total of approximately 4 800 public charging points by mid-2014, around 100 of which were DC fast charging points. The majority provide AC charging up to 22 kilowatts using Type 2 connectors. Around 60 charging points currently offer both DC charging using Combo 2 connectors and AC charging with Type 2 connectors. The required basic public charging infrastructure has been built Consequently, approximately 900 new charging points have been built since December 2012, equivalent to an increase of about 23%. As can be seen in Figure 5, this means that the growth in the number of charging points has slowed significantly compared to previous years. Following an initial spate of charging point creation by the energy industry, the growth in electric vehicle numbers is now comfortably outstripping the growth in charging infrastructure. [19]

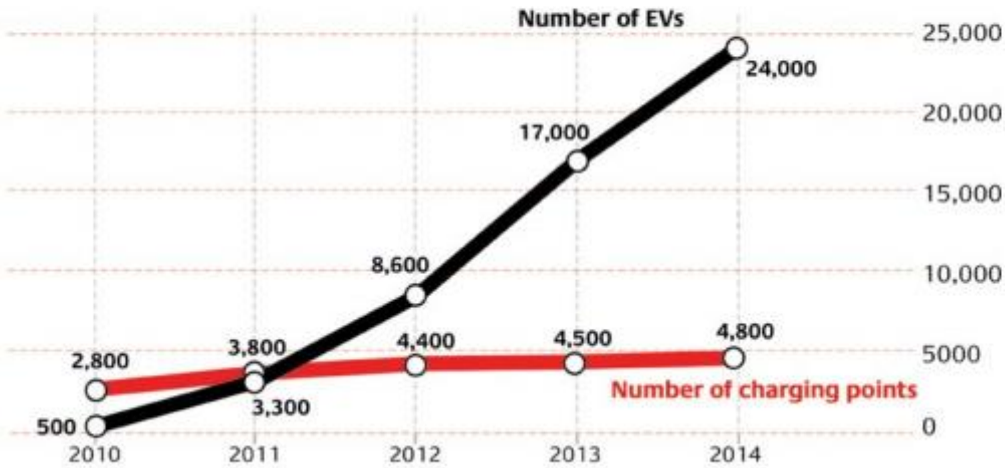


Figure 5. Public charging infrastructure in Germany 2010-2014 [19]

In 2020, 85% of the required charging infrastructure will be in the private domain, a further ten percent will be in the semi-public domain and only five percent of the total charging infrastructure – 70 000 AC charging points – in the public domain. In the same scenario, it is forecast that 7 100 fast charging points will be required. [19]

2.2.2. AUSTRIA

An important basis for the sustained success of electromobility is the interplay of all necessary components. First and foremost are those of electricity production and supply from renewable resources. Two thirds of Austria's electricity production is based upon renewable energy carriers, especially hydropower. By 2015, some 900 GWh of electricity from renewable sources will be added to this in Austria through the power plant projects already in operation. The e-mobility requirement can therewith be more than covered by 2020. This offers optimal prerequisites for an environmentally friendly "revolution" of the traffic system. The energy and communication interfaces to the supply grids must be standardized, especially when it is a matter of taking into account that e-vehicles in future have to fulfill a double role as a means of transport and mobile energy reservoir. According the Umweltbundesamt study, the degree of electricity required in non-commercial traffic will amount to 9 TWh by 2050. This will thus result in a fossil fuel saving of just under 32 TWh. The electricity used for electromobility is equally able to cause emissions during its production. [38]

Electric cars will account for 75 % of the entire fleet by 2050. A greater increase in new registrations of electric vehicles is expected from 2020 onwards, whereby a share of 50 % will have already been reached in 2025. In the car and light-duty commercial vehicle segment, it is anticipated that the only new vehicle registrations will be those for electric vehicles. [38]

VERBUND is Austria's leading electricity company and one of the largest producers of electricity from hydropower in Europe that generate more than 90% of electricity from hydropower, supplemented by thermal power and wind power. The Verbund-initiated platform "Austrian Mobile Power» started in summer 2009, in which the major Austrian technology companies collaborate in order to create a basis for a quick implementation of electromobility in Austria. In a project called EmporA all partners from the fields of automotive industry, infrastructure technology, energy supply and science are all working on the development of an integrated system solution for electromobility. Sponsoring the EmporA project represents an important contribution to achieving the platform members' ambitious goal of investing 50 million Euro for the introduction of electromobility in Austria by 2020. [38]

With the founding of "VERBUND-Mobile Power Region GmbH", Verbund – together with the regional association "Naturpark Almenland" – is launching a model region unique in Austria for the establishment of electromobility. In the process, the development of electromobility in the region not only comprises the twelve Almenland municipalities and the public institutions, but also private commercial enterprises and – in particular - the local tourism operations. In this way, visitors to the region will be able to experience the scope of electromobility - beginning with a pollutant-free bus and "hiking shuttle" service and the use of electric scooters, bikes or also electric motorbikes right through to the operation of networked electric vehicles in the Almenland municipalities. Funding models are also to provide support for the region's inhabitants in the purchase of electric vehicles. It is intended that some 600 electric vehicles will ultimately be in use in the Almenland and that they will deliver a constant evaluation of important findings for the suitability of electromobility in daily use. [38]

With the progressive expansion of electromobility in Almenland, more than 3000 tons of carbon dioxide (CO2) are to be avoided in the project period alone. However, this target can only be achieved if the electromobility is powered via renewable energy sources. In the final stage, more than 600 electric vehicles will implement the idea of soft mobility and thereby provide important research results for the pan-Austrian development of electromobility. The target is the CO_2-neutral Almenland region. [38]

A current, VERBUND-initiated study of the Federal Environment Agency has revealed the fact that more than 200 000 e-vehicles are to be expected for Austria by 2020. This shows that the 100 000 e-vehicles that the Austrian Mobile Power Platform had originally forecasted for 2020 may even be doubled. Based on Charge Everywhere concept from 230 000 to 575 000 charging points for the infrastructure should be implemented. By 2020 it can already contribute to achieving the Austrian energy and climate goals and reduce CO_2 emissions in car traffic by 80 % by 2050. [38]

2.2.3. SLOVAKIA

The development of electric vehicles and charging infrastructure is progressing very slowly in Slovakia. One of the key reasons is that expansion of electric vehicles is hampered by the lacking financial support. Due to this political uncertainty investors are unwilling to take risks. [24]

The strategic target in the transport sector to 2020 is to achieve a 10% share of RES in fuel consumption. An advisory working group was created by the Ministry of Economy named the Slovak Platform for e-mobility and is charged with developing and supporting electromobility in terms of the implementation and operation of a comprehensive and integrated system for the actual use of electric vehicles, evaluating the benefits of electric vehicles for the national economy in terms of environmental impacts, job growth and state revenues, an increase in the competitive benefits to the Slovak economy, mapping the situation involving electric vehicles in selected European Union member states, analysis and recommendations from strategic documents of the European Union and draft policy to support electromobility in Slovakia including support for managing the electricity system. The Strategy for the Development of Electromobility in the Slovak Republic was completed in 2013. [27]

The use of intelligent networks and electromobility is related to the decentralisation of generation whereas it can be expected that batteries in vehicles could provide up to 20% of the capacity for future potential use in the system during charging and discharging over the long term. Two types of supply will occur in this situation: from generation through the system to the batteries in vehicles during charging and if necessary the flow from the batteries to the system during their discharging. The deployment of more small and decentralized power sources to the network will then be supported. The objective is to balance the system so that generation equals consumption. Multiple systems are being developed for charging batteries along three main lines: [27]

- Exchanging discharged batteries for charged ones in special charging stations (requires the unification of batteries but is very fast and such stations have a much higher chance of contributing to maintaining balance);
- Charging batteries in electric vehicles: quick charging stations or slow chargers within significant increases in consumption that are stable for long hours. Night-time charging of batteries has a favorable impact on increasing household utilization of excess generation capacity at night, primarily produced by nuclear power plants.
- Charging batteries in electric buses using stationary traction lines installed in cities with such systems for mass public transport.

The Economy Ministry recommends several systemic tools for support of the electric mobility development. These include stimulation of the growth of the sale of e-cars and plug-in vehicles, so-called green procurement, support of science, research, development and innovations, support of development of the network of charging stations as well as an information campaign. In terms of the support of the sale of electric and plug-in vehicles indicates a possibility of forgiveness of some costs, but the strategy does not elaborate what costs could be forgiven during acquisition of an electric car. [25]

The Slovak Association for Electromobility published a paper titled “Background of the proposal for an electromobility development strategy in the Slovak Republic” in March 2013 that was subsequently adopted by the Ministry of Economy. The adopted strategy seeks to identify the potential for electromobility in Slovakia. It is primarily aimed at increasing competitiveness, fostering innovation, and creating new jobs. The project “Central European Green Corridors” supports the development of electromobility and the pilot deployment of 115 high power-recharging points in Central Europe, including 21 in Slovakia. [24]

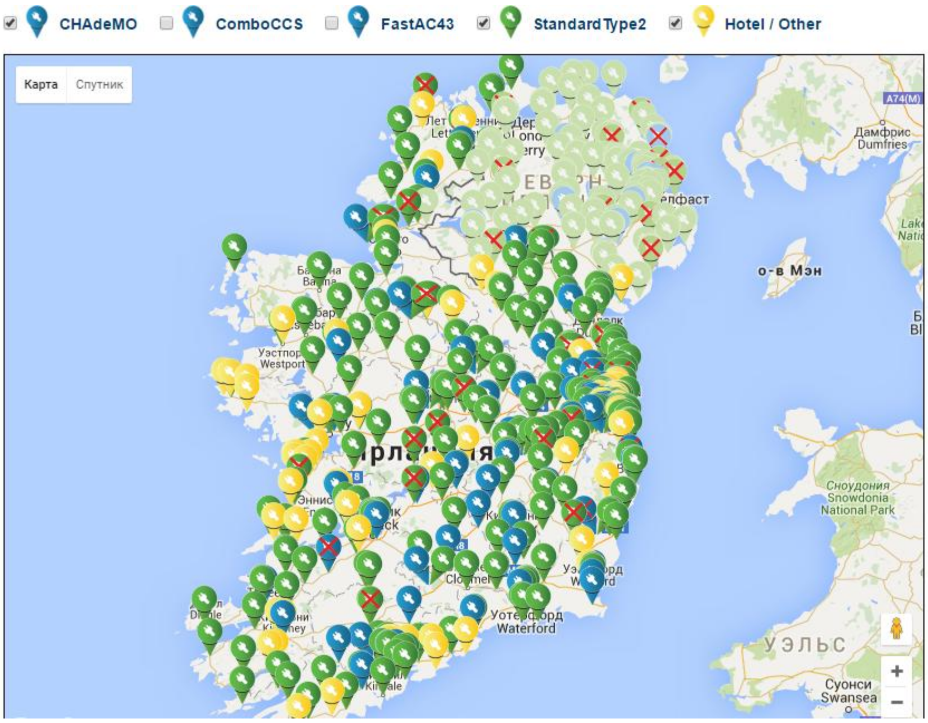
There were more than 170 electric cars and up to 100 hybrid and plug-in hybrid vehicles driving Slovak roads based on the data of the Slovak Automotive Industry (ZAP) on September 2015. It relatively small if to take into account that out of three carmakers in Slovakia only Volkswagen manufactures e-cars and cars with the hybrid drive and last year they manufactured 6 000 such vehicles. [25]

For now especially the high price of electric cars, about €25,000 per vehicle, is cited as the biggest obstacle for a higher usage of electric cars in Slovakia - though the cost of charging of such cars is low compared with classic motor fuels. At present there are about 50 charging stations, and an e-car can technically travel across the country with little trouble. [25]

The Strategy for Support of Electromobility on September 9 2015 forecasts that between 600 and 4 000 electric cars and plug-in hybrid vehicles will take to Slovak roads in 2016 and 2017. Their number should increase to between 10 000 and 25 000 in 2020. By that time Austria and Germany should have 250 000 and 1 million such cars should drive, respectively. [25]

2.2.4. IRELAND

There are currently 1 200 public charge points available across the island of Ireland. This includes over 300 public charge points in Northern Ireland. These are found in convenient on-street locations, in car-parks, popular retail and leisure venues, as well as at key transport hubs nationwide. All charge points are accessed via a single charge point access card. That’s exactly good amount of charging points if to take into account that in July 2015 was announced 1 000 EV’s registered on the Irish roads. The charging time for standard charge points depends on the model of vehicle and how full the car battery is when it is plugged in. [8]



Picture 6. Charge points available across the island of Ireland [8]

Out from mentioned before amount of charging stations Network of over 70 fast chargers in the Republic of Ireland plus additional 15 public fast chargers in Northern Ireland, primarily installed at service stations to facilitate longer journeys between major towns and cities are currently operate in Ireland. On average, a fast charge point can charge an electric vehicle up to 80% in as little as 25 minutes. These charge points form part of the Rapid Charge Network project which is co-funded by the European Union via the Trans European Transport Network and represents a substantial partnership investment of over €7 million. The project links the EV charging networks in Ireland and Britain with Europe via 1 100km of major UK and Irish roads which also link with major ports and airports. [8]

So widespread of charging points were gained thanks to the state and industry support. It's possible to derive these benefits into two groups: [8]

1. Benefits of Electric Vehicles for Customers:
   - €5 000 Government grant towards the purchase of an electric vehicle
   - €120 motor tax band for electric vehicle
   - Free home charge point for the first 2 000 purchasers of new electric vehicles
   - Nationwide charge point infrastructure

2. Benefits of Electric Vehicles for Businesses
   - Accelerated capital allowance scheme permitting write off of capital investment within one year
   - Government incentive of a €5 000 grant per vehicle
   - Reduction in company carbon footprint

Due to this policy Ireland have wild range of EV's available on the market, such as AUDI A-3 e-Tron, BMW i3, BMW i8, Mitsubishi i-MiEV, Mitsubishi Outlander PHEV, Nissan e-NV200, Nissan LEAF, Renault Fluence Z.E., Renault Kangoo Z.E., Renault Twizzy, Renault ZOE, Tesla Model S, Volkswagen e-Golf, Volvo V60. But the premium Tesla's electric vehicles will costs over €73 500. Tesla has no plans to open a dealership with a service center in Ireland. With Tesla's typical range of 400 km per charge, the company doubles the range of any electric cars currently available in Ireland. [22]

Table 3. Countries strategies analysis outcome

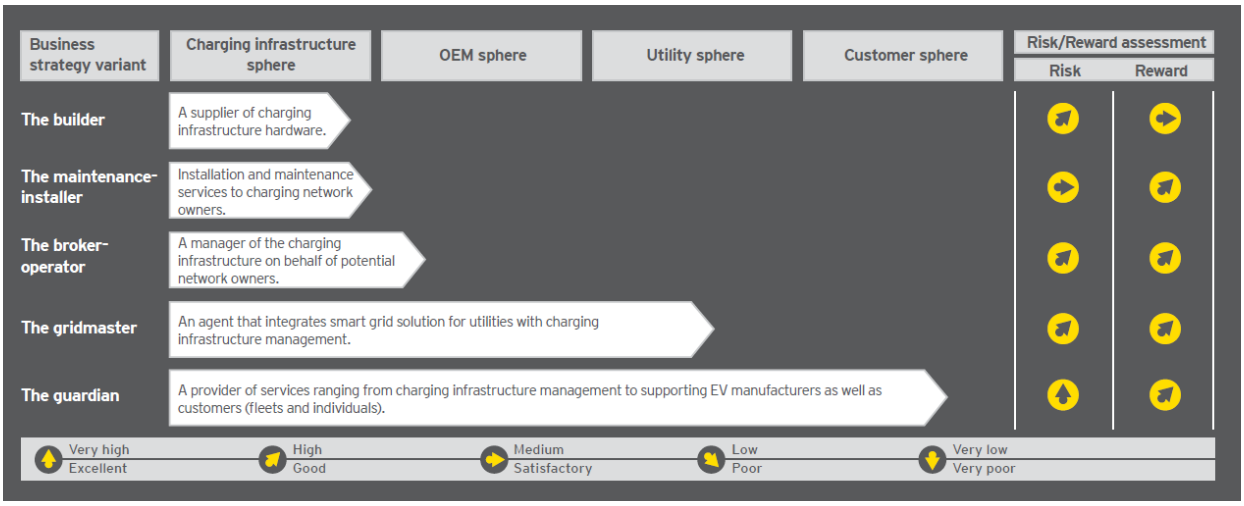
	Czech Republic	Germany	Austria	Slovakia	Ireland
Area, km^2[31]	78 867	357 022	83 871	49 035	70 273 84 421
Population, thousands. [31]	10 186 000	82 599 000	8 361 000	5 390 000	6 399 105
Actual quantity of cars on streets	1 000 EVs	50 000 EVs	4 200 EVs	170 EVs	1 000 EVs
Expected quantity of cars on streets by 2020	6 000 BEV + 11 000 PHEV	one million	250 000 EVs	10 000 – 25 000 BEV+PHEV	200 000 EVs [4]
Actual quantity of recharging stations	90-100 (20 DC)	4 800 charging points (100 DC fast charging)	1 463 (up to 22 kw) 87 (22-45 kw) 153 (from 45 kw) [9]	50 charging stations	1 200 public charge points (85 fast chargers)
expected by 2020 quantity of recharging stations by 2020	500 DC charging stations + 800 AC charging points	70 000 AC charging points + 7 100 fast charging points	230 000 – 575 000 charging points	50 + 21 high power-recharging points	25 000 public charging points [14]

This table represents how different the situation across EU is. Even in similar by population or area countries situation vary a lot. Such example I see in Czech Republic – Austria pair, where area almost the same, but amount of EVs under operation 4 times differ. In chapter 4.1 of this work calculations of average expected amount of EVs for each country and for EU as average made based on this table can be found.

3. RECHARGING STATIONS BUSINESS MODELS

The growth of the EV charging infrastructure is set to be an exciting chapter in the vehicle electrification process. Market strategies differ significantly between Asia, North America and Europe, and those differences may harden into different regional standards, slowing growth for all. [7]

The charging infrastructure that necessary to stimulate widespread adoption of increasingly available EVs in the marketplace remains to be built. Ernst & Young's Global Automotive Center have identified 143 companies worldwide that deals with EV charging infrastructure. Company closely analyzed them and chose 18 distinct business activities that were grouped to develop five potential business strategy variants. These business strategies are at different levels of complexity within the value chain and consequently, bring different risks and rewards to the participants. [7]



Picture 7. Recharging stations infrastructure representation [7]

Some companies operate in several of them at once, or even active in all of them, such as the company Better Place. Most companies advertise that they offer solutions for a wide range of customers — from utilities to car rentals, to hotels and home users – but lack a differentiated package and convincing revenue model. Charging station companies in the upper end of the value chain propose services that could be claimed by other, more natural players. [7]

If to focus on customer, the most common charging configuration is likely to be chargers at both home and work. However, several other potential customers such as hotels and restaurants, car rental/sharing, fleet managers and gas stations are identified. The basic elements of the emerging EV charging value chain are clear: [7]

- It must transfer energy from an outlet to a vehicle.
- It must track information of the energy provider and the energy recipient.
- It must include a payment system easy for the consumer to understand and easy for the energy distributor to integrate within pre-existing billing systems.
- It must meet government regulations and carmaker requirements.

Around the customer sphere, which is the private or business user of EVs three spheres ere revolved: [7]

- The charging infrastructure sphere comprises all services ranging from manufacturing the charging stations to setting up the physical infrastructure and managing the delivery of energy through the network of charging stations.
- The utility sphere involves activities ranging from generating and distributing energy to billing the end-user for consumption.
- The OEM sphere comprises all activities associated with the vehicle, ranging from selling to maintenance, operating and up to the end of its life cycle.

3.1. DESCRIPTION OF VARIOUS BUSINESS MODELS

According to the Ernst & Young's Global Automotive Center research based on multiple internal interviews in total 143 companies the five business strategies were derived: [7]

- The builder - a supplier of infrastructure hardware.
- The maintenance-installer - an installer and operator of charging stations.
- The broker-operator - a supplier of charging stations who acts as a middleman to the power markets.
- The gridmaster - a smart grid operator or agent who uses the idle capacity of parked car batteries to smooth overall power loads.
- The guardian - a provider of support and maintenance for the vehicles who won't necessarily own or operate charging stations.

The most common market entrant into the EV charging landscape is from the power supply equipment manufacturing sector. Companies that manufacture and/or market power supplies, converters, inverters and chargers are included in this list of 78 manufacturers. 26 out of them come from the power supply equipment manufacturing sector, and 9 companies from the manufacturing sector for components for electrical power supply, such as cables, switches and plugs. Together, they represent 45% of market entrants in EV charging station manufacturing. [7]

The table below represents the outcome of activities analyses of EV charging value chain that includes 18 distinct activities dispensed according to five business strategies:

Table 4. Charging station activity set [7]

	builder	maintenance-installer	broker-operator	gridmaster	guardian
1. Unbranded charging station manufacturer	✓				
2. Branded charging station manufacturer	✓				
3. Charging station retailing	✓	✓			
4.Maintenance and servicing of charging stations		✓			
5. Installation		✓			
6. Vehicle performance diagnostic for OEMs			✓		
7. In-vehicle charging infrastructure information for EV drivers			✓		
8.Mobile/Web-based customer portal			✓		
9. Smart grid interface			✓		
10. Smart charging			✓		
11. Billing capability			✓		
12. Metering capability			✓		
13. Charging station network management software			✓		
14. Smart energy grid management				✓	
15. Fleet management tools					✓
16.Engineering services					✓
17. Peripheral services: EV owners related					✓
18. Peripheral services: battery related					✓

3.1.1. BUSINESS STRATEGY ONE: THE BUILDER

This player would simply create the infrastructure hardware necessary for charging batteries in an urban, residential or corporate setting. The operations of both the vehicles and the electrical companies would be beyond its scope — like an internet modem developer. [7]

Any infrastructure involving high-voltage connections are highly regulated, which means that the technology itself could not be used as a barrier to entry with two possible exceptions: if regulatory certification for safety reason limits new entrants, or if another player in the value chain, such as a vehicle OEM or a power company, supporting a particular candidate as an industry standard can lock out other players. Tangible demand for charging devices is expected in the next three to five years - in this case the right partnership with an OEM or city administration may prove very profitable. Builders will have few opportunities for differentiation outside specific regional voltage requirements. True advantages are more likely to grow out of alliances with OEMs, but this is a rapidly diminishing opportunity. [7]

Companies operating this business strategy may choose to own, outsource or even have a panel of branded – unbranded charging station manufacturers. The unbranded charging station market can be attractive if the device is to be constantly updated with leading-edge technology and design. As the example potential alternative technologies such as induction charging can replace need for standard charging stations. Business strategies that based exclusively on hardware charging stations are not likely goes in hand with the changes in the market. Players in this area will need an important strategic partner to succeed, but high exposure to supply chain may cause a supplier to become a competitor. [7]

In collaboration with city administrations, charging stations may be set up near metro and public transportation stations, integrating EVs into the municipal transportation scheme. The builder looking for a specific customer target niche and customize its offering based on explicit needs it might have. In this case devices could be customized for particular specialty niches. For example, rather than concentrate on permanent facilities, some entrants might develop portable charging stations that EV owners could take with them, reducing the need for permanent infrastructure. [7]

Companies active in this sector will face also the commodity challenge: low cost/high volume but will also have to renovate their product to stay in business, which is to be capital intensive. Higher capital expenditure will be a heavy burden for independent players with low market capitalization and selling charging stations as such will limit the target audience significantly in the middle term because several users will require more than a device to satisfy their needs, they will need network connection, billing capability and so on. [7]

3.1.2. BUSINESS STRATEGY TWO: THE MAINTENANCE-INSTALLER

This company would install and then manage the operational reliability of charging stations. This a little similar to the filling stations of today, but the special nature of battery charging such as hours needed to charging process will likely demand a very different kind of infrastructure, perhaps integrated into parking lots. This market niche is also likely to disappear for some target markets (for instance home charging), as utilities may decide to put it into their service package. [7]

For home installation, the low maintenance that such facilities will require and the lack of differentiation would likely limit the possibilities to build customer loyalty. Home chargers that can be installed with fewer additional electrical upgrades than other charging solutions have strong potential moving forward. This is very differ from owners of public/semi-public charging networks, because maintenance contracts are significantly more important for them as downtime will result in lost revenues. Strategic combination of installation device with a green energy supply or off-peak energy management support may attract consumers who are into environment. For instance, some stations may generate power from green energy sources built inside the home, such as photovoltaic panels. It is difficult to imagine EV consumer ownership without a home EVSE. [7]

The maintenance-installer is best positioned to help accelerate standardization. It should carefully navigate the risk associated with the lack of standardization in order to manage inventories while providing ready services. [7]

The maintenance-installer will find it hard to expand geographically. It will have to comply with installation regulations and service requirements that are likely to vary significantly by region, at least until the market are established. The growing need to educate buyers may open up new business opportunities surrounding the business of the maintenance-installer. While retailing, installing or servicing charging device, supporting utilities in energy saving campaigns may, for instance, generate new business. The value of maintenance contracts may increase over the years as the number of charging stations in operation is likely to expand in the future. [7]

3.1.3. BUSINESS STRATEGY THREE: THE BROKER-OPERATOR

This company would manage the energy use, the costs of that energy and the amount that needs to be billed to the customer. The company would be in a position to extract better terms with both the utility and the consumer, or at the very least, create analytics that could add value to power companies. This additional data could also be used to create bundled offerings based on a household's complete energy consumption profile. [7]

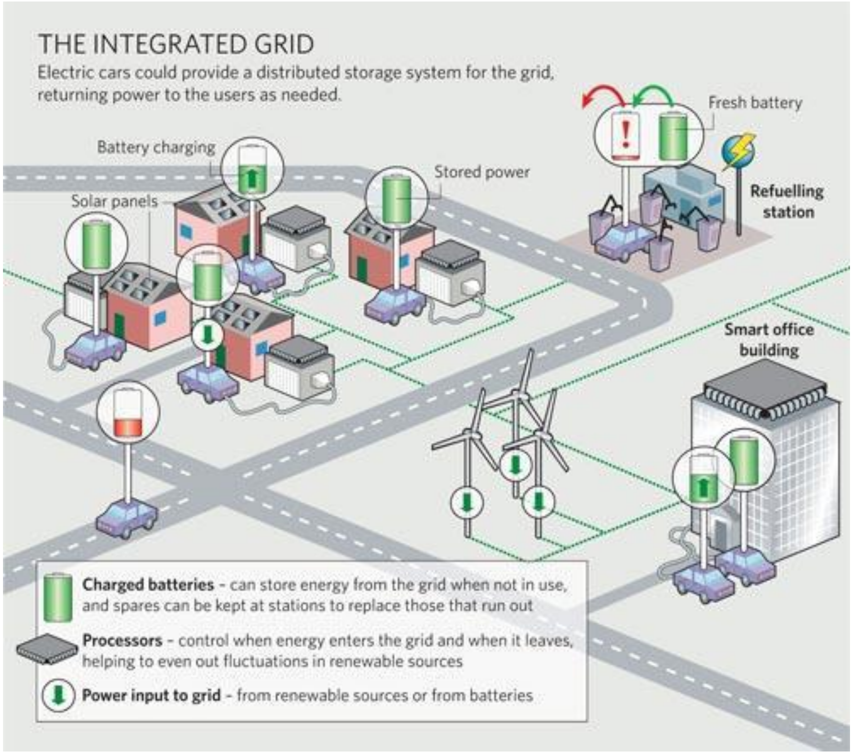
The key competence owned by the broker-operator is the ability to involve billing to the charging process. One of the broker-operator's strengths and value in the market will therefore be to help identify and quantify the value of a potential charging infrastructure project. [7]

The broker-operator has a wide array of service to be packaged for an extensive range of customers. It will find it hard to cover all business highlighted under his activity set; success will depend on strong alliances with energy companies, many of which tend toward non-entrepreneurial cultures. The diagnostic capabilities of the broker-operator may also be useful to insurance companies and other data-centric businesses. Also the broker-operator should be able to help understand how to monetize the opportunities at hand, thereby strengthening its role in the value chain. [7]

Potential buyers are likely to expect several services to be free. Buyers need to have a network connection in place to purchase charging station without data management processor. Currently, it is hard to imagine that potential EV charging station buyers can see a compelling reason to enter this business which requires significant investment in systems and communications tools so its need to educate buyer. [7]

3.1.4. BUSINESS STRATEGY FOUR: THE GRIDMASTER

This market player provides energy storage and generation solutions. Beyond monitoring the charging process, the gridmaster would use the batteries of parked cars as a resource. One of the most difficult aspects of electric energy production is that most energy is generated for immediate use, not for use at a later date. As a result, generators producing energy must be able to handle the highest peak load times even if most of these pikes are infrequent. Renewable energy has this problem as well in that the amount of energy created by the most popular renewables such as solar or wind, not always in synchronize with usage peaks. A gridmaster would help solve these problems by making the entire network more efficient, using these parked car batteries to first store and then draw down energy to help smooth load requirements. Trading “green” energy credits to support EV charging with renewable sources will be an attractive complement for the gridmaster once this market establishes. The role at the utility level may help secure business immediately. [7]



Picture 8. The integrated grid [36]

Given the lack of understanding of market demand companies focusing on a smart grid deployment will need to work closely with companies that can help make smart grid adoption more affordable and immediately appealing to utilities. To create an EV charging infrastructure and build a smart grid might multiply the value of each but will also increase the magnitude of investment and managerial effort required. Standard-setting could create a barrier to entry in this sector. [7]

3.1.5. BUSINESS STRATEGY FIVE: THE GUARDIAN

The guardian extends its service offering to the owner of the EV (business or private), in addition to other stakeholders in the EV charging ecosystem. At this stage, the key differentiators from other business strategies are the value-added services that may be peripheral to the charging infrastructure, but are critical in the overall EV ecosystem. The guardian has a more strategic role in the management of the charging network, and therefore have a greater risks compared to the broker operator. [7]

No other strategy deals with so many different industries as the guardian's one, which will deal the OEM, telecom, software and even insurance industries. Controlling the record of the EV's operation and the data flows, the value of the guardian could combine the usefulness of building control systems and buyer loyalty cards with the potential to be a kind of "app store" for users. [7]

The guardian can customize the vehicle and energy access package based on the customer – business or private. Identifying cost reduction opportunities for potential customers, then proposing adequate implementation integrated in a charging network could also be good business complement. The guardian can consider offering selected EV owners specific services such as vehicle leasing, subscription-based energy access packages. [7]

Unlike other business strategies, the guardian can help establish regional and/or national standards for the charging infrastructure, and manage a network of gridmasters and broker-operators. The guardian could also offer peripheral services related to the EV's batteries, such as operating a network of swapping stations and/or recycling centers. [7]

4. ECONOMIC EFFECTIVENESS OF PUBLIC CHARGING STATIONS FROM THE BUSINESSES POINT OF VIEW

The goal of my practical part is to make a business model for a company investing in a business of recharging stations installation and operation. The final point is to obtain the value of annual payment by customers in order to get the access to the service, also called as ‘flat fee’ or ‘usage card’ which allows charging electric vehicles on recharging stations owned by company.

To form and calculate economic model first of all it’s necessary to form the list of assumptions which will create the framework of my model. Also it will helps to restrict the model to avoid taking into account several factors that will affect calculations complexity. Thereby I define assumptions listed below:

a) Calculations will be made for city with 500 000 citizens located in central Europe
b) City is absolutely isolated from the external world - no EV’s goes inside no out
c) City population and EVs quantity are constant for all period of evaluations
d) Evaluations will be made based on 2020 EV’s forecasts with nowadays prices
e) Technologies and efficiency of CS’s are frozen – no influence on future conditions
f) Company is already operated so it’s no need to calculate office expenses as investments

4.1. CHARGING STATIONS QUONTITY CALCULATIONS

Based on assumptions it’s possible to calculate amount of charging stations are necessary to be installed to cover all customers charging needs and do not to avoid overloads.

In this case I decided to start with amount of EV’s to be expected in EU for 2020 based on previous discussions. Based on Table 3 I obtained average expected EV per person in 6 different locations simply derived value of expected in year 2020 amount of EV’s by current population in this locations. Then multiplied this amount by amount of my city population and get expected quantity of cars operated in the city. For EU “average expected EV per person” value was taken as average from other countries values.

Table 5. EV’s expected amount calculation

Location	Average expected EV per person	EV’s expected in 2020 for 0.5 mil population city
1. EU	0,015419516	7 710
2. Czech republic	0,001668957	835
3. Germany	0,012106684	6 054
4. Austria	0,02990073	14 951
5. Slovakia	0,003246753	1 624
6. Ireland	0,031254371	15 628

For the following calculations value of 7 710 EV’s will be used as a background.

In order to find quantity of charging stations required to fulfill the city demand in charging let's find the "total daily electricity should be charged "value:

Table 6. Daily charging

Position	Value	Source
Average consumption of EV per 100 km	18 kWh	Based on consultation with CEZ
Average daily mileage	50 km	
Number of kWh to charge daily	9 kWh	$\frac{50\text{km}}{100\text{km}} \times 18\text{kWh}$
Share of public charging	20%	Based on consultation with CEZ
Daily charge at public	1,8 kWh	$9\text{kWh} \times 20\%$
Total daily charging at public	13 878 kWh	7 710 EV's × 1.8 kWh

Here "Share of public charging" means that 80% of energy EV users charge at home with the help of their own home-chargers, which are not taken into account in this model.

Now it's possible to deal with types of CS and their specifications. AC charger "Charging Post Smart Series -CCL-PT3" by company Circontrol perfectly fits my conditions and are already operated by number of operators within EU, including CEZ Group. Detailed specification of "Charging Post Smart Series – CCL - PT3" can be found in Appendix 3.

For DC fast charging case I choose the "Terra multi-standard DC charging station 53 CJG" produced by company ABB. Stations of this type are also already operated in number of EU countries, including Czech Republic and support all EV's charging standards. The "Terra 53 CJG" is suitable for use at car dealerships, petrol stations and busy urban areas. Detailed specification of "Terra multi-standard DC charging station 53 CJG" can be found in Appendix 4.

4.1.1. DIRECT CURRENT STATIONS

As far as charging is a fast developing sphere installation of pure AC stations is meaningless due to gradual aging of this technology and future inability to obtain charging of increasing capacity of batteries in a proper time frames. That's why in the first case only DC stations will be implemented.

Due to specification in Appendix 4 maximum output power of one DC station is 50 kW. That's mean that to cover 13 878 kWh/day consumption it's required to install 12 DC stations. But it can be possible only if station operate 24 hours/day, that's doesn't feet our conditions: public stations are used during the day only, in the night EV's charge at home. So, based on consultation with CEZ I assume that every station are under operation only 20% of the day, that's mean 4.8 hours. In this case 58 DC stations are required.

4.1.2. COMBINATION OF AC AND DC STATIONS

Originally, benefit of DC CS is that all types of car can be charged there at nominal conditions, in my case with 50 kWh. But amount of electricity consumed by EV with AC station based on features of batteries inside the car, that's create limitations for usage AC stations by customers. That's why in this chapter I will calculate AC stations with 16Amp and 400V outputs, which give 6.4 kW power and suits to majority of EV's. And type of DC stations remains the same.

Percentage ratio between AC and DC stations will be 70% DC and 30% AC based on consultation with CEZ. In this case with taking into account 20% daily operation time we obtain 136 AC charging points that's mean 68 AC stations (each station have 2 plugs possible to operate at the same time – Appendix 4) and 41 DC charging points that's mean 41 DC stations (each station can charge only 1 car – Appendix 4) which will cover 4163,4 kWh/day and 9714,6 kWh/day respectively.

At this point possible to plot a graph represents combinations of amount DC and AC stations in order to cover customers' needs in charging.

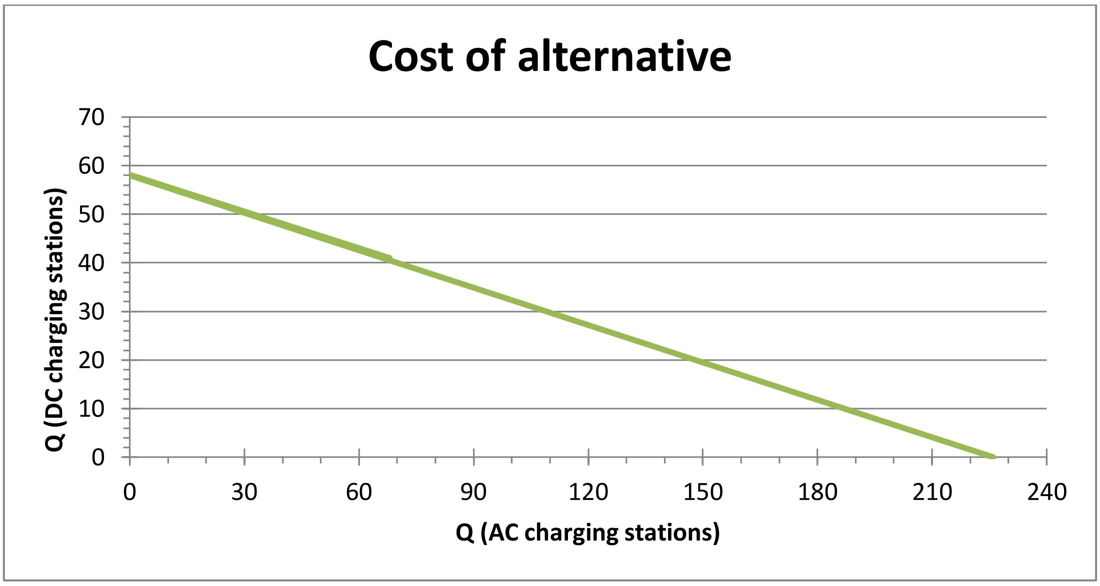


Figure 6. Possible AC-DC combinations

4.2. BUSINESS MODEL AC+DC

In order to reach the goal of the calculations and obtain the price of service its necessary to make NPV model based on several inputs:

4.2.1. INVESTMENTS

Invested value are consist of 2 parts: cost of recharging stations themselves (equipment) plus all expenses concerning installation such as cost of cables, ground and cable work, connection, installation service price and transportation.

Table 7. Investment calculations

Position		Value	Source
DC stations	Equipment price	750 000 CZK	Based on consultation with CEZ
	Required amount	41	Chapter 4.1.2
	Total cost	1 137 750,00 EUR	750 000 CZK × 41 × e, where e = 0.037 – exchange rate
	Lifetime equipment	10 years	Based on consultation with CEZ
	Installation price	300 000 CZK/station	Based on consultation with CEZ
	Installation cost	455 100 EUR	300 000 CZK × 41 × e, where e = 0.037 – exchange rate
	Lifetime installation	40 years	Based on consultation with CEZ
AC stations	Equipment price (station itself)	150 000 CZK	Based on consultation with CEZ
	Required amount	68	Chapter 4.1.2
	Total cost	377 400,00 EUR	150 000 CZK × 68 × e, where e = 0.037 – exchange rate
	Lifetime equipment	10 years	Based on consultation with CEZ
	Installation price	100 000 CZK/station	Based on consultation with CEZ
	Installation cost	251 600 EUR	100 000 CZK × 68 × e, where e = 0.037 – exchange rate
	Lifetime installation	40 years	Based on consultation with CEZ
Total	Investments (equipment)	1 515 150 EUR	1 137 750,00 EUR + 377 400,00 EUR
	Depreciation equipment	151 515 EUR/year	$\frac{1\ 515\ 150 \text{ EUR}}{10 \text{ year}}$
	Investments (installation)	706 700 EUR	455 100 EUR + 251 600 EUR
	Depreciation installation	17 667,50 EUR/year	$\frac{706\ 700 \text{ EUR}}{40 \text{ year}}$

Difference in installation cost between AC and DC stations can be explained as DC CS requires higher input power. That's mean that charger has to be connected to the part of the grid, that has a necessary reserved capacity, which might be longer, requiring more expensive ground works. Also in case there are several chargers built on one site, Distribution Company may require connection to high voltage grid, which requires additional costs as well

4.2.2. VARIABLE COST

Due to my model, stations will be installed at parking sides in public areas such as shop centers, stations, concert arenas and simple street parking. In this case I calculate the value of costs for parking places land leasing due to condition that every charging point must have one parking place. In order to simplify calculations value of land lease fee taken as constant and equal to all of them.

Not only annual service charge will be paid by costumers – they also will pay for amount of consumed electricity during charging according to tariff.

Table 8. Variable cost calculations

Expenses	**Position**	**Value**	**Source**
Electricity	Electricity consumed by customers/day	13 878 kWh/day	Table 6
	Electricity consumed by customers/year	5 065 470 kWh/year	13 878 kWh/day × 365 days
	Electricity price	0,1227 EUR/kWh	$\frac{1\,400\,000\ \text{CZK/month} \times 12\text{month} \times e}{5\,065\,311{,}10\ \ \text{kWh/year}}$, Where e = 0.037 – exchange rate, 1 400 000 CZK/month obtained from www.pre.cz for 5 065 311,10 kWh/year consumption including distribution, fixed, variable and operators fees
	Total cost of electricity consumed by customers/year	621 533,17 EUR/year	5 065 470 kWh/year × 0,1227 EUR/kWh
	Efficiency of charging station	94%	Appendix 4.
	Input electricity	5 388 797,87 kWh/year	$\frac{5\,065\,470\ \ \text{kWh/year}}{94\%} \times 100\%$
	Total cost of input electricity	661 205,50 EUR/year	5 388 797,87 kWh/year × 0,1227 EUR/kWh

IT operation	Annual payment for IT system operation	1 000 000 CZK/year	Based on consultation with CEZ
	Total annual payment for IT system operation	37 000 EUR/year	1 000 000 CZK/year × e, where e = 0.037 – exchange rate
Office operation	Total office costs, including personal, technical equipment and services	6 703 010 CZK/year	Appendix 5
	Total annual office costs, including personal, technical equipment and services	248 011,37 EUR/year	6 703 010 CZK/year × e, where e = 0.037 – exchange rate
Maintenance	INV equipment	1 515 150 EUR	Table 7
	Total annual expenses on equipment maintenance	15151,50 EUR/year	1 515 150 EUR × 1%, where 1% taken based on consultation with CEZ
Land leasing for stations installation	Parking places per DC charging station	1	Chapter 4.1.2
	Amount of DC	41	Chapter 4.1.2
	Parking places per AC charging station	2	Chapter 4.1.2
	Amount of AC	68	Chapter 4.1.2
	Amount of parking places	177 parking places	41 stations × 1 parking places + + 68 stations × 2 parking places
	Land lease	1 000 CZK/place/month	Based on consultation with CEZ
	Land lease	444 EUR/place/year	1 000 CZK/place/month × 12 month × e, where e = 0.037 – exchange rate
	Total for land leasing	78 588 EUR/year	177 parking places × 444 EUR/place/year

The Maintenance cost will be applied in NPV model from 4th year, based on the assumption that maintenance for three years will be covered by producer as part of the warranty period (can be agreed for different period, 3-year warranty was chosen).

4.2.3. NPV MODEL

The last point before forming full NPV model is calculations of Weighted Average Cost of Capital (WACC). For this purpose I implemented few more values:

Table 9. WACC calculations

Name	Description	Value	Source
Discount rate r_e (cost of equity)	the interest rate used in DCF analysis to determine the present value of future cash flows (include the risk or uncertainty of future cash flows) [23]	15%	Based on presumption, will be defined during sensitivity analysis
% of own money E/INV	Share of own funds in total investments	15%	Based on presumption, will be defined during sensitivity analysis
Bank interest r_d (cost of debt)	The percentage that the bank expects to receive from a loan issued	1%	http://www.sazebnik-kb.cz
Income TAX	a tax that governments impose on financial income generated by all entities within their jurisdiction	19%	Act No. 586/1992 Coll. On Income Taxes by Czech National Council
WACC	is the average of the costs of types of financing, each of which is weighted by its proportionate use in a given situation. Shows how much interest a company owes for each dollar it finances. [23]	2,94%	$\frac{E}{INV} r_e + (1 - \frac{E}{INV}) r_d (1 - TAX)$ 15% × 15% + (1– 15%) × 1% × (1 – 20%)
Cost escalation	an increase in the price of goods [23]	0,50%	Based on presumption, will be defined during sensitivity analysis

As was mentioned in Table 7 lifetime of equipment equal 10 years and lifetime of installation is 40years. Unfortunately, at the moment I can’t be sure that this technology will be exist after 40 years, so all calculations will be made for 10 years – in the end of 10th year all equipment will be sold out with the 75% price (10 years of usage out of 40): that fact will be influence on depreciation value and value of revenues received in 10th year.

Concerning price of service, that is a main point of calculations, it will be valued as 100 EUR/year as fixed payment by every customer and will be calculated as revenues. Amount of 100 taken based on presumption in purpose to compare in proper way “only DC” and “AC + DC” cases.

Also its necessary to mention that in revenues besides service fee income include income of payments for electricity by customers due to electricity consumed during the charging.

In the table 10 are summarized all initial values that will be used in future calculations.

Table 10. NPV table values for the 1st year

Position		Value	Source
Investments	INV in equipment	1 515 150 EUR	Table 7
	INV in installation	706 700 EUR	Table 7
Fixed cost	Depreciation	169 182,50 EUR/year	Depreciation equipment + + Depreciation installation 151 515 EUR/year + 17 667,50 EUR/year [Table 7]
Variable costs	Input electricity	661 205,50 EUR/year	Table 8
	IT system operation	37 000 EUR/year	Table 8
	Office costs	248 011,37 EUR/year	Table 8
	Maintenance	15 151,50 EUR/year (excluded in 1st, 2nd and 3rd years)	Table 8
	Land leasing	78 588 EUR/year	Table 8
	Total variable cost	1 024 804,87 EUR for 1st, 2nd and 3rd years 1 039 956,37 EUR/year starts from 4th	
Revenues	Cost of Input electricity + Price of service × Quantity of EV's	1 392 533,17 EUR	661 205,50 EUR/year + 100EUR/year × 7 710 EV's [Table 8, 5]
EBT	Revenues – Fixed cost – Total variable cost	198 545.80 EUR	1 392 533,17 EUR/year – 169 182,50 EUR/year – 1 024 804.87 EUR/year [Table 10]
TAX	EBT × Income TAX	37 723.70 EUR	198 545.80 EUR × 19% [Table 10, 9]
EAT	EBT - TAX	160 822.10 EUR	198 5.80 EUR - 37 723.70 EUR
CF	Revenues – Investment – Variable cost – TAX	-1 891 845,40 EUR	1 392 533,17 EUR – 1 515 150 EUR – 706 700 EUR – 1 024 804,87 EUR/year – 37 723.70 EUR [Table 10]
DCF	$CF \times (1+WACC)^{-year}$		
NPV	$\sum_{t=0}^{10} DCF$		

Taking into account cost escalation all variable costs should be multiplied by $(1 + 0.50\%)^{year-1}$

Table 11. NPV model

Years		0	1	2	3	4	5	6	7	8	9	10
Fixed costs	INV equipment (charging stations)	1 515 150,00										
	INV ground work + installation	706 700,00										
	Depreciation		169 182,50	169 182,50	169 182,50	169 182,50	169 182,50	169 182,50	169 182,50	169 182,50	169 182,50	699 207,50
Variable costs	Electricity		661 205,50	664 511,53	667 834,08	671 173,25	674 529,12	677 901,77	681 291,28	684 697,73	688 121,22	691 561,83
	IT operation		37 000,00	37 185,00	37 370,93	37 557,78	37 745,57	37 934,30	38 123,97	38 314,59	38 506,16	38 698,69
	Office operation		248 011,37	249 251,43	250 497,68	251 750,17	253 008,92	254 273,97	255 545,34	256 823,06	258 107,18	259 397,72
	Maintenance		-	-	-	15 379,91	15 456,81	15 534,09	15 611,76	15 689,82	15 768,27	15 847,11
	Land leasing		78 588,00	78 980,94	79 375,84	79 772,72	80 171,59	80 572,45	80 975,31	81 380,18	81 787,09	82 196,02
Revenues			1 392 533,17	1 399 495,83	1 406 493,31	1 413 525,78	1 420 593,41	1 427 696,38	1 434 834,86	1 442 009,03	1 449 219,08	1 986 490,17
EBT			198 545,80	200 384,44	202 232,28	188 709,44	190 498,90	192 297,31	194 104,71	195 921,14	197 746,66	199 581,31
TAX			37 723,70	38 073,04	38 424,13	35 854,79	36 194,79	36 536,49	36 879,89	37 225,02	37 571,87	37 920,45
EAT			160 822,10	162 311,40	163 808,14	152 854,65	154 304,11	155 760,82	157 224,81	158 696,12	160 174,79	161 660,86
CF		- 2 221 850,00	330 004,60	331 493,90	332 990,64	322 037,15	323 486,61	324 943,32	326 407,31	327 878,62	329 357,29	860 868,36
DCF		- 2 221 850,00	320 584,23	312 838,26	305 280,12	286 810,22	279 876,95	273 111,88	266 510,93	260 070,10	253 785,48	644 404,24
NPV (function)		981 422,42										
NPV (DCF)		981 422,42										

For better understanding of the project profitability I calculated IRR using inner Excels function and obtained 10% value. It represents a discount rate which makes NPV equal to zero with the price of service 100 EUR/year.

Using Excels data analyzing function "What if" by making NPV equal to zero I obtained the service price 82,0230 EUR/year, which is a start price that makes project profitable. IRR in this case will be 2.94%

4.3. BUSINESS MODEL DC

Now business model of "Only DC stations" case can be calculated based on example of chapter 4.2.

4.3.1. INVESTMENTS DC

Table 12. Investment calculations (DC)

Position	Value	Source
Equipment price	750 000 CZK	Based on consultation with CEZ
Required amount	58	Chapter 4.1.1
Total INV equipment	1 609 500,00 EUR	750 000 CZK × 58 × e, where e = 0.037 – exchange rate
Lifetime equipment	10 years	Based on consultation with CEZ
Installation price	300 000 CZK/station	Based on consultation with CEZ
Total INV installation	643 800 EUR	300 000 CZK × 58 × e, where e = 0.037 – exchange rate
Lifetime installation	40 years	Based on consultation with CEZ
Depreciation equipment	160 950 EUR/year	$\frac{1\ 609\ 500{,}00\ \text{EUR}}{10\ \text{year}}$
Depreciation installation	16 095 EUR/year	$\frac{643\ 800\ \text{EUR}}{40\ \text{year}}$

4.3.2. VARIABLE COST DC

Table 13. Variable cost calculations (DC)

Expenses	Position	Value	Source
Electricity	Electricity consumed by customers/day	13 878 kWh/day	Table 6
	Electricity consumed by customers/year	5 065 470 kWh/year	13 878 kWh/day × 365 days
	Electricity price	0,1227 EUR/kWh	$\frac{1\,400\,000\ CZK/month \times 12 month \times e}{5\,065\,311{,}10\ \ kWh/year}$, Where e = 0.037 – exchange rate, 1 400 000 CZK/month obtained from www.pre.cz for 5 065 311,10 kWh/year consumption including distribution, fixed, variable and operators fees
	Total cost of electricity consumed by customers/year	621 533,17 EUR/year	5 065 470 kWh/year × 0,1227 EUR/kWh
	Efficiency of charging station	94%	Appendix 4.
	Input electricity	5 388 797,87 kWh/year	$\frac{5\,065\,470\ \ kWh/year}{94\%} \times 100\%$
	Total cost of input electricity	661 205,50 EUR/year	5 388 797,87 kWh/year × 0,1227 EUR/kWh
IT operation	Annual payment for IT system operation	700 000 CZK/year	Based on consultation with CEZ
	Total annual payment for IT system operation	25 900 EUR/year	700 000 CZK/year × e, where e = 0.037 – exchange rate
Office operation	Total office costs, including personal, technical equipment and services	6 703 010 CZK/year	Appendix 5
	Total annual office costs, including personal, technical equipment and service	248 011,37 EUR/year	6 703 010 CZK/year × e, where e = 0.037 – exchange rate

Maintenance	INV equipment	1 609 500 EUR	Table12
	Total annual expenses on equipment maintenance	16 095 EUR/year	1 609 500 EUR × 1%, where 1% taken based on consultation with CEZ
Land leasing for stations installation	Parking places per DC charging station	1	Chapter 4.1.2
	Amount of DC	58	Chapter 4.1.1
	Amount of parking places	58 parking places	58 stations × 1 parking places
	Land lease	1 000 CZK/place/month	Based on consultation with CEZ
	Land lease	444 EUR/place/year	1 000 CZK/place/month × 12 month × e, where e = 0.037 – exchange rate
	Total for land leasing	25 752 EUR/year	58 parking places × 444 EUR/place/year

Maintenance cost will be applied in NPV model starts only from 4th year as in previous model.

4.3.3. NPV DC MODEL

WACC and cost escalation values are remains the same and they are 2.94% and 0.50% respectively.

Table 14. NPV table values for the 1st year (DC)

Position		Value	Source
Investments	INV in equipment	1 609 500 EUR	Table 12
	INV in installation	643 800 EUR	Table 12
Fixed cost	Depreciation	177 045 EUR/year	Depreciation equipment + + Depreciation installation 160 950 EUR/year + 16 095 EUR/year [Table 12]
Variable costs	Input electricity	661 205,50 EUR/year	Table 13
	IT system operation	25 900 EUR/year	Table 13
	Office costs	248 011,37 EUR/year	Table 13
	Maintenance	16 095 EUR/year (excluded in 1st, 2nd and 3rd years)	Table 13
	Land leasing	25 752 EUR/year	Table 13
	Total variable cost	960 868.87 EUR for 1st, 2nd and 3rd years 976 963.87 EUR/year starts from 4th	
Revenues	Cost of Input electricity + Price of service × Quantity of EV's	1 392 533,17 EUR	661 205,50 EUR/year + 100EUR/year × 7 710 EV's [Table 8, 5]
EBT	Revenues – Fixed cost – Total variable cost	254 619.3 EUR	1 392 533,17 EUR/year – 177 045 EUR/year – 960 868.87 EUR/year [Table 14]
TAX	EBT × Income TAX	48 377.67 EUR	254 619.3 EUR × 19% [Table 14, 9]
EAT	EBT - TAX	206 241.63 EUR	254 619.3 EUR – 48 377.67 EUR
CF	Revenues – Investment – Variable cost – TAX	-1 870 013.37 EUR	1 392 533,17 EUR – 1 609 500 EUR – 643 800 EUR – 960 868.87 EUR/year – 48 377.67 EUR [Table 14]
DCF	$CF \times (1+WACC)^{-year}$		
NPV	$\sum_{t=0}^{10} DCF$		

Taking into account cost escalation all variable costs should be multiplied by $(1 + 0.50\%)^{year-1}$

Table 15. Full NPV model DC

	Years	0	1	2	3	4	5	6	7	8	9	10
Fixed costs	**INV equipment (charging stations)**	1 609 500,00										
	INV ground work + installation	643 800,00										
	Depreciation		177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	659 895,00
Variable costs	**Electricity**		661 205,50	664 511,53	667 834,08	671 173,25	674 529,12	677 901,77	681 291,28	684 697,73	688 121,22	691 561,83
	IT operation		25 900,00	26 029,50	26 159,65	26 290,45	26 421,90	26 554,01	26 686,78	26 820,21	26 954,31	27 089,08
	Office operation		248 011,37	249 251,43	250 497,68	251 750,17	253 008,92	254 273,97	255 545,34	256 823,06	258 107,18	259 397,72
	Maintenance					16 337,63	16 419,32	16 501,42	16 583,93	16 666,85	16 750,18	16 833,93
	Land leasing		25 752,00	25 880,76	26 010,16	26 140,21	26 270,92	26 402,27	26 534,28	26 666,95	26 800,29	26 934,29
Revenues			1 392 533,17	1 399 495,83	1 406 493,31	1 413 525,78	1 420 593,41	1 427 696,38	1 434 834,86	1 442 009,03	1 449 219,08	1 939 315,17
EBT			254 619,30	256 777,62	258 946,73	244 789,06	246 898,23	249 017,95	251 148,26	253 289,23	255 440,90	257 603,33
TAX			48 377,67	48 787,75	49 199,88	46 509,92	46 910,66	47 313,41	47 718,17	48 124,95	48 533,77	48 944,63
EAT			206 241,63	207 989,87	209 746,86	198 279,14	199 987,57	201 704,54	203 430,09	205 164,27	206 907,13	208 658,70
CF		-2 253 300,00	383 286,63	385 034,87	386 791,86	375 324,14	377 032,57	378 749,54	380 475,09	382 209,27	383 952,13	868 553,70
DCF		- 2 253 300,00	372 345,27	363 366,09	354 604,15	334 268,27	326 204,30	318 335,52	310 657,17	303 164,63	295 853,40	650 157.11
NPV (function)		1 375 655,91										
NPV (DCF)		1 375 655,91										

IRR In this case equals 12.601% . It represents a discount rate which makes NPV equal to zero with the price of service 100 EUR/year.

Using Excels data analyzing function “What if” by making NPV equal to zero I obtained the service price 74.80 EUR/year, which is a start price that makes project profitable. IRR in this case will be 2.939%

4.4. SENCITIVITY ANALYSIS

Based on calculations in chapters 4.2.3 and 4.3.3 I found out that NPV in case of “Only DC chargers” 40% bigger then NPV in case “AC+DC chargers”. And minimal required price of service therefore 9.66% lower. It gives me all rights to make a conclusion concerning implementation of “Only DC” case as more profitable and cheap for customers.

As far as inputs used in calculations are not constant and can vary due to different reasons I decided to make a sensitivity analysis in few variations of inputs changings in order to show how they will react on model stability and directly on NPV with price of service value. Analysis made for model recalculated with price of service 74.80 EUR/year obtained in the end of previous chapter. In this case model can be represented by next table

Table 16. Final NPV calculations

	Years	0	1	2	3	4	5	6	7	8	9	10
Fixed costs	INV equipment (charging stations)	1 609 500,00										
	INV ground work + installation	643 800,00										
	Depreciation		177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	177 045,00	659 895,00
Variable costs	Electricity		661 205,50	664 511,53	667 834,08	671 173,25	674 529,12	677 901,77	681 291,28	684 697,73	688 121,22	691 561,83
	IT operation		25 900,00	26 029,50	26 159,65	26 290,45	26 421,90	26 554,01	26 686,78	26 820,21	26 954,31	27 089,08
	Office operation		248 011,37	249 251,43	250 497,68	251 750,17	253 008,92	254 273,97	255 545,34	256 823,06	258 107,18	259 397,72
	Maintenance					16 337,63	16 419,32	16 501,42	16 583,93	16 666,85	16 750,18	16 833,93
	Land leasing		25 752,00	25 880,76	26 010,16	26 140,21	26 270,92	26 402,27	26 534,28	26 666,95	26 800,29	26 934,29
	Revenues		1 198 253,90	1 204 245,17	1 210 266,39	1 216 317,73	1 222 399,31	1 228 511,31	1 234 653,87	1 240 827,14	1 247 031,27	1 736 116,43
	EBT		60 340,03	61 526,95	62 719,81	47 581,00	48 704,13	49 832,88	50 967,27	52 107,33	53 253,09	54 404,58
	TAX		11 464,61	11 690,12	11 916,76	9 040,39	9 253,79	9 468,25	9 683,78	9 900,39	10 118,09	10 336,87
	EAT		48 875,42	49 836,83	50 803,05	38 540,61	39 450,35	40 364,63	41 283,49	42 206,94	43 135,00	44 067,71
	CF	-2 253 300,00	225 920,42	226 881,83	227 848,05	215 585,61	216 495,35	217 409,63	218 328,49	219 251,94	220 180,00	703 962,71
	DCF	- 2 253 300,00	219 471,26	214 113,50	208 887,19	192 003,19	187 309,32	182 730,81	178 264,78	173 908,48	169 659,18	526 952,30
	NPV (function)	0,00										
	NPV (DCF)	0,00										

Table 17. Escalation/ bank interest chart

Escalation %	Bank Interest, %						
	0	1	2	3	4	5	6
0	58 111,95	-33 289,80	-119 545,59	-201 000,67	-277 974,21	-350 761,44	-419 635,61
0,5	93 048,44	0	-87 807,38	-170 725,29	-249 078,73	-323 168,35	-393 272,44
1,0	128 904,84	34 160,54	-55 244,57	-139 668,60	-219 442,61	-294 872,84	-366 242,77
1,5	165 705,21	69 214,51	-21 835,74	-107 810,41	-189 046,78	-265 856,89	-338 529,57
2,0	203 474,20	105 185,14	12 441,01	-75 130,03	-157 871,72	-236 102,06	-310 115,43
2,5	242 237,04	142 096,22	47 608,11	-41 606,31	-125 897,45	-205 589,48	-280 982,49
3,0	282 019,55	179 972,08	83 688,53	-7 217,57	-93 103,50	-174 299,81	-251 112,51
3,5	322 848,17	218 837,66	120 705,77	28 058,37	-59 468,95	-142 213,31	-220 486,81
4,0	364 749,98	258 718,47	158 683,90	64 244,20	- 24 972,36	-109 309,72	-189 086,27
4,5	407 752,67	299 640,61	197 647,53	101 363,16	10 408,18	-75 568,36	-156 891,34
5,0	451 884,60	341 630,82	237 621,87	139 439,01	46 695,11	-40 968,03	-123 882,01
5,5	497 174,78	384 716,44	278 632,69	178 496,08	83 911,39	-5 487,06	-90 037,79
6,0	543 652,92	428 925,46	320 706,39	218 559,26	122 080,50	30 896,72	-55 337,76

Slots marked by orange color represent combinations which lead to negative NPV and therefore inappropriate (at least for chosen price). Table shows that smaller bank interest means higher NPV, and higher escalation means higher NPV. In general, NPV is higher, the greater the escalation over bank interest.

Table 18. Escalation/ discount rate chart

Escalation %	Discount Rate, %						
	0	0,05	0,10	0,15	0,20	0,25	0,30
0	286 501,61	172 959,95	66 539,17	-33 289,80	-127 011,90	-215 071,92	- 297 878,18
0,050	325 562,02	209 968,70	101 627,60	0	-95 407,88	-185 048,98	-269 339,09
0,010	365 666,38	247 959,53	137 640,49	34 160,54	-62 983,23	- 154 252,18	-240 069,84
0,015	406 842,22	286 958,27	174 602,03	69 214,51	-29 716,66	- 122 661,54	-210 051,65
0,020	449 117,77	326 991,32	212 536,99	105 185,14	4 413,62	- 90 256,59	-179 265,28
0,025	492 521,92	368 085,76	251 470,74	142 096,22	39 429,94	- 57 016,39	- 147 691,06
0,030	537 084,24	410 269,29	291 429,23	179 972,08	75 355,13	-22 919,47	-115 308,85
0,035	582 835,01	453 570,27	332 439,06	218 837,66	112 212,59	12 056,10	- 82 098,02
0,040	629 805,26	498 017,74	374 527,44	258 718,47	150 026,25	47 932,79	-48 037,49
0,045	678 026,70	543 641,44	417 722,20	299 640,61	188 820,59	84 733,60	- 13 105,66
0,050	727 531,85	590 471,77	462 051,87	341 630,82	228 620,69	122 482,04	22 719,55
0,055	778 353,94	638 539,88	507 545,60	384 716,44	269 452,20	161 202,19	59 460,77
0,060	830 527,02	687 877,64	554 233,27	428 925,46	311 341,36	200 918,67	97 141,09

Slots marked by orange color represent combinations which lead to negative NPV and therefore inappropriate (at least for chosen price). Table shows that lower discount rate means higher NPV, and bigger escalation means bigger NPV, as in previous table. In general, NPV is bigger, the greater the escalation over discount rate.

Table 19. Electricity price/Price of service chart

Electricity price EUR/kWh	Price of service, EUR/year					
	60,00	75,00	90,00	105,00	120,00	135,00
0,0227	- 579 125,43	239 771,03	1 058 667,48	1 877 563,93	2 696 460,38	3 515 356,84
0,1227	- 808 067,97	10 828,49	829 724,94	1 648 621,39	2 467 517,84	3 286 414,30
0,2227	- 1 037 010,51	- 218 114,05	600 782,40	1 419 678,85	2 238 575,30	3 057 471,76
0,3227	- 1 265 953,05	- 447 056,59	371 839,86	1 190 736,31	2 009 632,76	2 828 529,22
0,4227	- 1 494 895,59	- 675 999,13	142 897,32	961 793,77	1 780 690,22	2 599 586,68
0,5227	- 1 723 838,13	- 904 941,67	- 86 045,22	732 851,23	1 551 747,68	2 370 644,14
0,6227	- 1 952 780,67	- 1 133 884,21	- 314 987,76	503 908,69	1 322 805,14	2 141 701,60
0,7227	- 2 181 723,21	- 1 362 826,75	- 543 930,30	274 966,15	1 093 862,60	1 912 759,06
0,8227	- 2 410 665,75	- 1 591 769,29	- 772 872,84	46 023,61	864 920,06	1 683 816,52

Increase in electricity price decreases NPV despite the fact that electricity consumption is covered by customers. That's because of efficiency of charging stations – power losses are covered by company. Increase in the price of service leads to increase of NPV, because there is a direct relation with Revenues without any expenses based on it.

Table 20. Influence of users quantity on NPV and price of service

Country	Amount of users	NPV	Obtained minimal price of service
Czech Republic	835	- 3 641 390,36 EUR	690,68 EUR
Slovakia	1 624	- 3 223 491,16 EUR	355,12 EUR
Germany	6 054	- 877 111,63 EUR	95,26 EUR
EU	7 710	0 EUR	74,8 EUR
Austria	14 951	3 835 244,74 EUR	38,57 EUR
Ireland	15 628	4 193 822,39 EUR	36,9 EUR

Table 20 was constructed for situation, when forecast of EV's amount wrong and real amount of cars operated on streets changed up or down. Original calculations in this project were made for the average amount of users for EU and in this table possible to see what if development will be as one has to be expected in another countries. Besides, amount of constructed charging stations remains the same. Obtained price illustrates the charge from one user in order to obtain zero NPV. Situation with increasing of users amount seems positive, however overcrowded of stations can be happen, because in even small increase of users amount condition of 20% station operation time will not be full-filled.

And what if company decided to build up such amount of stations based on forecast of another country? In this way I obtained next table (was calculated for price 100 EUR/year):

Table 21. Influence of users quantity on chargers Amount, NPV and price of service

Country	Amount of users	Chargers (only DC case)	NPV	IRR	Obtained minimal price of service
Czech Republic	835	7	-1 603 563,08	-	371.22 EUR
Slovakia	1 624	13	-1 266 381,14	-	210.13 EUR
Germany	6 054	46	648 903,57 EUR	8.856 %	84.86 EUR
EU	7 710	58	1 375 655,91 EUR	12,60 %	74,8 EUR
Austria	14 951	113	4 472 199,36 EUR	18.428 %	57.76 EUR
Ireland	15 628	118	4 766 281,43 EUR	18.718 %	46.93 EUR

Such results may be explained by the fact that expenses such as IT and Office operation are constant and their value doesn’t affected by amount of charging stations and users increasing. Conversely, these costs are evenly derived among users that will decrease the price of service in case of increasing amount of users. That’s why if to compare EU and Austria increasing amount of users and stations on 94% and 95% respectively leads to decreasing of service charge on 30%.

In general this table represents evaluations for 6 different countries in short and gives information about how exactly the result of my practical part would looked like if another territory was taken as basic.

Conclusion

In accordance with the task of my Master thesis work I analyzed current situation and strategic plans concerning future development of electromobility and charging infrastructure in European Union along with member states such as Czech Republic, Germany, Austria, Slovakia and Ireland. Analyzed countries had been selected based on neighborhood with Czech Republic, while the last one was taken for comparison, as having the most developed charging infrastructure in Europe at the moment which accounted as 1200 charging points per 1000 EVs. As the result of my observations I found that at the moment Slovakia has the less developed charging infrastructure, basically due to less amount of registered EVs. Germany possessed as a country with biggest plans in the issue of charging infrastructure implementation – German government expect 1 million EVs on the roads by 2020 and 77 100 recharging points which will cover all needs of those cars. According to suggestions of European commission by 2020 one recharging point is expected to correspond with 10 cars. Such ratio already reached by all observed in theory part of my work countries.

Governments support EV's industry includes tax exemptions or deductions policies which increase the interest for new customers to EVs. However in the future it's expected that this approach will be reviewed due fiscal reasons (tax revenue losses) especially from petroleum excise taxes imposed on liquid fuels, representing the stable revenue of central budgets, that will be replaced by electricity.

Forecasting analysis also creates a vision of future conditions and an ability to make evaluations for the future. In the final result I accounted the investment model of building up EVSE infrastructure for year 2020 for a city with 7 100 EVs' that was based on average of forecasted person/EV ratios for observed countries. In this work I created full NPV model, including all technical and economical features for two cases: implementing of infrastructure that consists only of DC fast chargers, and combination of AC and DC stations. The last one in the result represents itself as less profitable due to NPV 40% lower than in case of only DC stations. I think that my calculations really represent the best option in economic term as far as AC charging due to rapid developing of technologies may became old and not efficient technology in few years (being too slow). However, implementation of only DC chargers in practice might be not optimal solution in selected public areas such as shopping centers, as far as their utilization might create problems for users – responsibility to return to parking after 30 minutes and move car away to avoid the blocking of the charger for the use of another EVs. In this case combination of 2 types of charging stations makes sense, but still the DC public charging model only represents a valid option based on assumption that people can charge slowly at home and fast in public places.

The point of my calculations was obtaining the price of service which each customer will pay annually in order to have access to charging in the form of a flat fee. I obtained value equal 74.80 EUR/year which guarantee zero NPV if all inputs will be constant. As far as economic situation is always changing it is not possible to be absolutely sure in future conditions of the market and probability of realistic forecasts. For such case I made sensitivity analysis of my project. It represents NPV dependences on discount rate, bank interest, escalation level, level of price on electricity and amount of EV's users in a city based on assumption that forecast of another country will be implemented in calculations.

Obtained price 74.80 EUR/year along with average annual cost of consumed electricity during the charging in amount of 80.61 EUR/year gives me 155.41 EUR/year payments for public charging. Of course this amount is not a total – calculations based on assumption that share of public charging is 20% that's mean that total annual payment will be around 477.85 EUR/year if the electricity tariff for both household and business will be the same. If to compare this amount with average price for petrol car it will be 2 277.6 EUR/year for a car driving 50 kilometers daily with petrol price 1.04 EUR/liter and 12 liter/100 kilometers fuel consumption. That figure fully represents how cheaper EV operation really is compared to combustion engine cars. And even with increasing of service charge (which was also accounted as constant, but in the future can be ranged for different tariffs due to users needs) in a purpose to make my project more profitable situation will not turns into petrol cars.

I think it is also necessary to discuss weak points of my model, as far its s study project and several assumptions were made in order to avoid overcrowded calculations. The first it's a calculation of installation costs – in real life installation cannot be constant value due to variable level of work in every location of charging stations implementation. Even length of cables and volume of groundwork can significantly change the total installation cost value. The same situation I see in electricity pricing which can differ according to different tariffs applying to my company based on annual consumption. Electricity connection fee can be also relatively high. In case of building two 50 kW chargers on a site, for example, 100kW connection in order to cover required power to be sure that both can charge on full power can cost a lot.

Land leasing is the second most controversial item of expenditures. In my calculations it was taken as constant value for all stations, but it cannot be so if somebody decided to rent parking places in different parts of a city. First of all price difference based on location of parking relatively city center, presence of security staff and so on. The biggest issue, of course, is that parking owner will be interested to increase the parking rent as far as project will start to be commercial. Real company can reach agreement on a preferential period until the infrastructure start to really work and have stable profits.

If to talk about technical issues not taken into account during calculations I will mention power operational losses which take place regardless whether someone is charging or not – lights, screen backlighting, internet connection. Share of these losses is small, but it anyway affects on final price of the service.

My opinion is that my calculations fully represent the real economic situation which recharging stations installers and operators meet and can be used as a background in real projects after correction of mentioned week points. I fulfilled all requirements according the task clearly analyzed the theory and made practical calculations in a proper way with obtaining the result connecting with real situation on the market.

Appendix 1. EV CHARGING STANDARDS

The charging mode describes the safety communication protocol between EV and charging station. These standards are identical worldwide. Different Charging Modes are defined for various applications and charging requirements. [17]

Mode 1: Home charging by using standard power outlet with a simple extension cord, without any safety measures. [2]

Key features: [3]

- Standard non-specific for EVs electrical network connector
- Slow AC charging.
- The installation must be protected with circuit breakers and earth leakage protection elements.
- Maximum 16 A per phase (3.7 kW - 11kW).

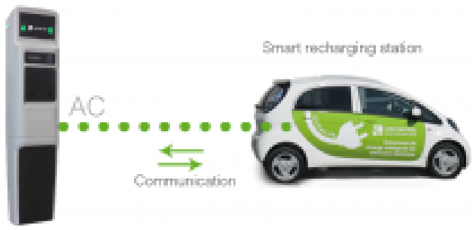
Mode 2: Home charging from a standard power outlet, but with a special in-cable EVSE, usually supplied with an EV from the manufacturer. Mode-2 cables provide a moderate level of safety and are the minimum standard today for charging an EV. This cable provides in-cable over-current and over-temperature protection, protective Earth detection (from wall socket). Power will only flow to the vehicle if next requirements will be full filled: [2]

- Protective Earth is valid
- No error condition exists (over-current, over-temperature, etc.)
- Vehicle has been plugged-in
- Vehicle has requested power

Key features: [3]

- Slow AC charging.
- The installation must be protected with circuit breakers and earth leakage protection elements.
- Maximum 32 A per phase (3.4 kW - 22kW).
- Special cable with an intermediate electronic device, with a control and protection pilot function.

Mode 3: Wired-in AC charging station with Mode 2 identical safety protocol, allowing a higher power level than Mode 2 either in public places or at home. [2]



Picture A1-1. Mode 3 Charging standard [3]

Key features: [3]

- Electrical network connector, specific for EVs.
- Slow or semi-fast charging in single or three-phase installations.
- Protection elements included in the special infrastructure for EVs.
- Maximum 64 A per phase (14.8 kW - 43 kW).
- Direct connection of the EV to the charging unit.

Mode 4: Wired-in DC charging station, either in public places or at home. In DC charging stations, the charger is part of the charging station, not part of the car. [2]

Picture A1-2. Mode 4 Charging standard [3]

Key features: [3]

- Electrical network connector, specific for EVs.
- Quick DC charging.
- Charging station, exclusively used for EVs.
- Maximum 400 A per phase (50 kW - 150 kW)
- Control and protection elements installed in the infrastructure.

The EV Market is currently adopting Mode 3 and 4 for Street and Fast Charging were vehicles can be charged with up to 63A 3 Phase current. Mode 1 and 2 for domestic use, it is expected to be replaced by more sophisticated and intelligent equipment in the future. [17]

Appendix 2. TYPES OF CHARGING CONNECTORS

The type of a charging station (or vehicle inlet) describes the actual connector being used. [2]

The EV charging process is regulated by the IEC 61851 and IEC 62196 international standards. These standards define the different charging modes and the type of connection required to charge EVs. [3]

Picture A2-1. Types of connectors [39]

Here below are described types of connectors mentioned in the work.

Type 1: The connector/inlet pair used in the US and Japan. As the U.S. and Japan do not have a three-phase power grid, this standard is limited to single-phase and lower power output than Type 2. For Type 1 the charging cable is permanently fixed to the charging station. Type 1 charging station on the other hand can only charge Type 1 cars, as the cable is fixed to the station and the usage of adapters is prohibited. [2]

Key features: [3]

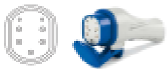
- SAE J1772 Regulation.
- 5 pins (L1, L2/N, PE, CP, CS).
- Maximum 230Vac 32A single-phase (7.3kW).

Type 2: The connector/inlet and plug/socket pairs used in Europe, also called “Mennekes” after the company first proposing this standard. Type 2 supports both single-phase and 3-phase charging at higher power rates than Type 1. For Type 2 charging stations, the charging cable is detachable, so station can charge both, Type 1 cars and Type 2 cars with the correct charging cables. [2]

Key features: [3]

- 7 pins (L1, L2, L3, N, PE, CP, PP).
- Maximum 400Vac 63A three-phase (43kW).

Type 3: France and Italy were campaigning for yet another connector/inlet and plug/socket solution, which has "shuttered contacts" - contacts that are 4 physically covered by a non-conductive cover when not in use. Proponents of Type1 or Type 2 (both non-shuttered) point out that these are safe without shutters, as current can only flow when an EV connection has been detected. [2]



Picture A2-2. Type 3 connector [3]

Key features: [3]

- 7 pins (L1, L2, L3, N, PE, CP, PP).
- Maximum 400Vac 32A three-phase (21kW).

It is expected that Type 2 will be the standard in all countries with 3-phase power grids, which countries without them will adopt Type 1. [2]

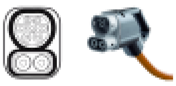
Type CHAdeMO: DC connector, name came from "Charge de Move" and became trade name of charging method.

Picture A2-3. Type CHAdeMO connector [3]

Key features: [3]

- Indirect connection between the EV and DC supply point.
- Control and protection elements installed in the infrastructure.

Type Combo 2 (CSC - Combined Charging System): DC connector of the combined AC/DC plug-in charging system. The inlet of the plug-in connector can also be used for AC voltage charging with a type 2 AC plug. One inlet is required on the vehicle side for AC and DC charging. [3]



Picture A2-4. Type Combo 2 (CSC) connector [3]

Appendix 3. AC charging station specification [3]

Charging Post Smart Series -CCL-PT3 provides a durable and modular enclosure with the robustness necessary to support hard climatic conditions along the streets. Equipped with latest technology in terms of communication and safety devices allows charge electrical vehicle in an easy and protected way includes advanced communication capabilities to monitor and setup remotely as well as RFID reader.

Charging Post Smart Series Technical Features:

- ✓ Backlight LCD display
- ✓ Kwh consumption in real time
- ✓ Indicators: “Available”, “Reserved”, “Not available”
- ✓ Instructions for use displayed on the screen.
- ✓ User ID
- ✓ Compatible with Mode 3 IEC 61851-1 (Certified).
- ✓ Type I, Type II or Schuko connectors, in compliance with
- ✓ the IEC 62196-2 regulations.
- ✓ IK10 Vandal-proof polyurethane casing.
- ✓ Protection degree : IP54 and anti-graffiti finish.
- ✓ RFID Identification and pre-payment.
- ✓ Mechanical locking of the Type 2 and Schuko socket.
- ✓ Self-resetting circuit breaker and earth leakage protection.
- ✓ Built-in Ethernet and RS-485 communication systems, 3G (optional).
- ✓ Connected to SCADA control software.
- ✓ Remote control and monitoring of the unit.
- ✓ Integration with third-party software (OCPP,XML).
- ✓ Custom painting and logos.

Picture A3. Charging Post Smart Series -CCL-PT3

Table A3. Charging Post Smart Series -CCL-PT3 specification

	Type	CCL-PT3
	Code	490083
	Number of sockets	2
Input	AC power supply	3P + N + PE
	AC Voltage	400V AC +/- 10%
	Nominal input current* * Adjustable power limit control	64 A
	Nominal input power	42 kW
	Required power supply capacity	44,2 kVA
	Frequency	50 / 60 Hz
Output	Maximum output power	21 kW (Socket A) 21 kW (Socket B)
	Maximum output current* * Adjustable power limit control	32 A (Socket A) 32 A (Socket B)
	AC output voltage	400 V AC 3P + N
Charge system	Socket A	Mode 3 (IEC 61851) Type 2 (UNE EN 62196-2) lock system
	Socket B	Mode 3 (IEC 61851) Type 2 (UNE EN 62196-2) lock system
Electrical protections	Overcurrent protections	MCB
	Safety protection	RCD 30mA auto recovery (class A)
Energy meter	Accuracy class in active energy	Class 1 - EN50470-3
	Accuracy class in reactive energy	Class 2 - EN62053-23
Meter standards		EN62052-11, EN62053-21, EN62053-23, EN61010-1
Network connection	Ethernet	10/100BaseTX (TCP-IP)
	Bus	RS-485 (Modbus)
General	Enclosure rating	IP 54 / IK 10
	Enclosure material	Polyurethane casing
	Socket protection	Vandal metal doors
	Operating temperature	-30 to + 45 °C (Heater system included)
	Operating humidity	To 95% RH Non-condensing
	RFID system	ISO / IEC14443A / B
	Display	LCD Backlight double line text
	Rear Light beacon	Three color led status
	Power limit control	Mode 3 PWM control according ISO/IEC 61851-1
	Interface protocol	OCCP / XML
	Net weight	65 Kg
Optional devices	Wireless Communication	3G / GPRS
	RCD Protection	RCD class B
	Overvoltage protection	"Transient surge protector Type 2 (EN 61643-11)"

Appendix 4. DC charging station specification [1]

The Terra multi-standard DC charging station 53 CJG (50 kW fast charging station) combines industry standardization with fast charging technology to support all current and next generation vehicles. Its multi-protocol design allows for easy tailoring to support CCS and CHAdeMO 1.0 for DC fast charging, as well as the EN61851-1 standard for AC charging (type 2, mode 3). Typical charging times range between 15 and 30 minutes.

Charger comes with Internet based Connected services to allow customers to easily connect their chargers to different software systems like back-offices, payment platforms or smart grid energy systems. This allows for remote assistance, tailored diagnostic trouble shooting and repair, and remote updates and upgrades. A reliable, secure, cost efficient and future proof connectivity solution based on open industry interfaces.

Picture A4-1. DC charging station 53 CJG

Outlet specifications	C (default)	J (option)	G (option)
Charging standard	CCS	CHAdeMO	Type 2 cable
Maximum output power	50 kW	50 kW	43 kW
Output voltage range	50 - 500 V_{DC}	50 - 500 V_{DC}	400 V +/- 10%
Maximum output current	125 A_{DC}	125 A_{DC}	63 A
Connection standard	EN61851-23 / DIN 70121	CHAdeMO 1.0	EN61851-1:2010
Connector/socket type	Combo-2	CHAdeMO / JEVS G105	IEC62196 mode-3 type-2
Cable length	3,9 m	3,9 m	3,9 m
Compatible car brands	BMW, Volkswagen, GM, Porsche, Audi	Nissan, Mitsubishi, Peugeot, Citroen, Kia	Renault, Daimler, Tesla, Smart, Mercedes

Picture A4-2. Outlet specifications of DC charging station 53 CJG

Main features:

- CCS standard DC fast charging 30 to 80% of a 24 kW battery in 15 minutes
- Future proof connection via open industry standards
- Flexible interfacing with added value systems
- Remote uptime monitoring and assistance
- Remote updates and upgrades
- Easy to use 8” daylight readable touch screen display
- Graphic visualization of charging progress
- RFID authorization
- Aesthetic all weather stainless steel enclosure
- Low operational noise

Key optional features:

- CHAdeMO 1.0 DC fast charging expansion package
- AC fast charging 43 kW connector
- Simultaneous AC and DC charging
- Input power limiting software to avoid expensive grid upgrades
- Web modules for statistics and access management
- Integration with back-offices, payment platforms and smart grid energy systems
- Customized branding possibilities

Table A4. General specifications of 53 CJG

General specifications	
Environment	Indoor / outdoor
Operating temperature	-10 ºC to +50 ºC (Option: -35 ºC to +50 ºC)
Storage temperature	-40 ºC to +70 ºC
Compliance and safety	CE / Option: CHAdeMO
Input AC power connection	3P + N + PE
Input voltage range	400 VAC +/-10% (50 Hz or 60 Hz)
Max. rated input current & power	143 A, 98 kVA
Power factor (full load)	> 0.96
Efficiency	94% at nominal output power
RFID system	ISO/IEC14443A/B, ISO/IEC15693, FeliCa™ 1, NFC reader mode, LEGIC Prime & Advant
Network connection	GSM / CDMA / 3G modem, 10/100 Base-T Ethernet
Protection	IP54
Dimensions (D x W x H)	760 mm x 525 mm x 1900 mm
Mass	400 kg

Appendix 5. Office costs calculation

Annual office costs, including personal, technical equipment and services according to information received from CEZ. These calculations were used in 4.2.2 for obtaining Total office costs in EUR/year for implementing into NPV model as variable cost.

Table A5. Office costs

Personal expenditures (team)	1 x Director	2 000 000 CZK/year
	1 x Senior Consultant	1 500 000 CZK/year
	2 x Junior Consultant	1 000 000 CZK/year
Technical equipment	Web domain + e-mail	3 630 CZK/year
	Web management	7 260 CZK/year
	Internet	72 600 CZK/year
Services	Rent of offices for 4 people, incl. office equipment	580 800 CZK/year
	PR and media	500 000 CZK/year
	Accounting	38 720 CZK/year
Total	Personal expenditures (team)	5 500 000 CZK/year
	Technical equipment	83 490 CZK/year
	Services	1 119 520 CZK/year
	Total office costs, including personal, technical equipment and services	6 703 010 CZK/year

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