UNIVERZITA J. E. PURKYNĚ V ÚSTÍ NAD LABEM

Czech-Austrian Winter and Summer School

E-mobility in urban areas: comparison and lessons learned

Nika Martinović, Milan Klempay

Co-operating Universities

UNIVERZITA J. E. PURKYNĚ V ÚSTÍ NAD LABEM

Financial support by

Prague and Vienna, 2020

CONTENT

ABSTRACT

E-mobility with the combination of other inventions can represent a significant change in transportation as we know it today. In this paper, we want to present why we see potential in e-mobility in the cities. However, we would like to take one step ahead and look at the consequences of changing our cities transportation. For the e-mobility doubters, we will try to refute the most common myths about electric vehicles with the help of many types of research done in this area. We will also take a look at the particular applications of new era transportation in the capital cities of the Czech Republic and Austria.

1. INTRODUCTION

Ambitious targets of the European Union are challenging all 27 members for a greener future. After the so-called plan 20-20-20 we are now moving forward to the next decade objective. This includes a 40 % decrease in produced greenhouse gases compared to the 1990 data, 32 % share of renewables on consumed energy in each country, and 0,8% yearly savings of consumption per country. Although the new 40-27-27 2030 Energy Strategy goals don't specify targets for emission reduction in the transport sector, the increased share of renewables and energy efficiency supports more sustainability in it. The 2011 White Paper on Transport set challenging goals and targets for the decarbonizing transport sector. One of the main goals is to halve the use of conventional cars in urban areas by 2030 and ban their use completely from urban areas by 2050.

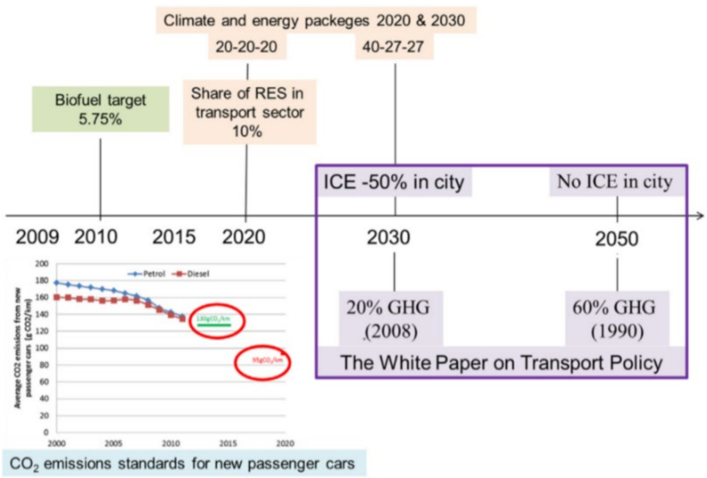


Figure 1 Development of EU targets regarding the reduction of GHG emissions in transport [1]

Nowadays, transportation, including international aviation is responsible for 25% of greenhouse gas emissions. E- mobility brings emission-free vision to this sector and a solution for reaching the targets. The path in succeeding is rather slow, as there are some problems in the development of the technology and penetration of the market. Also, e-mobility will lead to a significant reduction of GHG in the transport sector, only if the electricity itself is produced from renewable energy sources with a low carbon footprint.

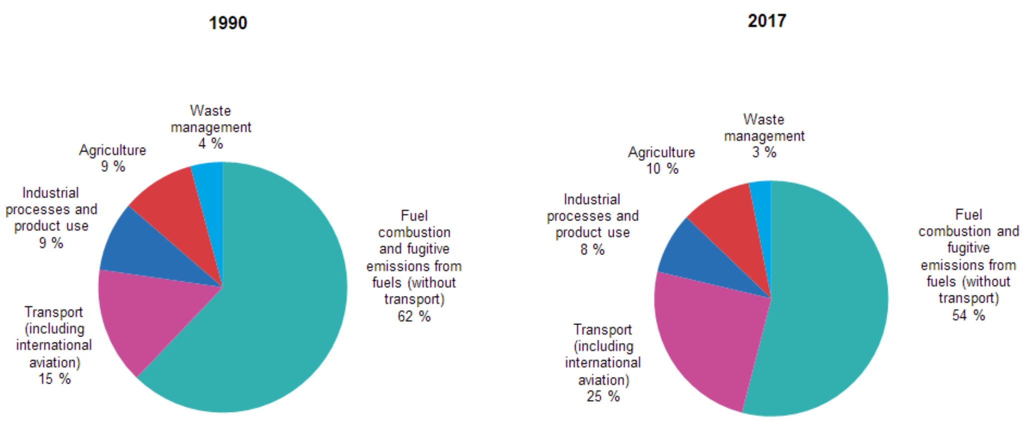


Figure 2 Greenhouse emissions analyzed by sector in EU-28 from 1990 to 2017 [2]

1.1. History of e-mobility

Electromobility is often considered as a modern trend, but to be precise, it's not an invention of our times, since first electricity-driven cars date more than 130 years before. Way back in 1867, and hence before the advent of the combustion engine, Werner von Siemens presented his electric generator based on the dynamo-electric principle at the World's Fair in Paris. The invention enabled a low-cost, flexible generation of electricity wherever it was needed and thus electrification in everyday life, industry – and vehicles. The first cars with an electric motor were presented at the end of the 19th century. [2]

In 1881, the French engineer Gustave Trouvé presented a world's first officially recognized electric vehicle: Three-wheel bike with two electric motors and lead batteries, which enabled a speed of 12 km/h and a range of 25km. The first Benz car with a combustion engine was not presented until 1886. Figure 4 shows the chronological order of the first three types of vehicles.

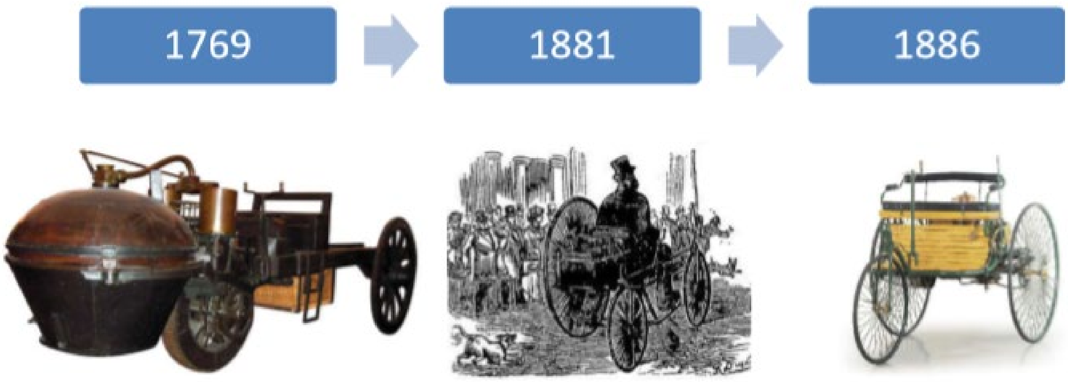


Figure 3 Trouvé created the second type of mechanical drive 112 years after Nicholas Cugnot's first three-wheel steam car in 1769; five years later Carl Benz with his three-wheel Benz patent motor car Number 1 with combustion engine as the third type of drive.

Belgian Camille Jenatzy even set a record in 1899 (29. April 1899 in Archères, Paris) as the first road vehicle of any kind to go faster than 100 km/h, precisely 105,8 km/h, (the picture on Figure 5).

From the end of the 19th century, trains and trams were supplied with energy by overhead lines or power rails. As figures from the year 1900 show, e-cars were still widespread at the start of the 20th century: 22 percent of vehicles on U.S. roads had a combustion engine, 40 percent were steam-driven, and 38 percent were electrically powered. The combustion engine had a disadvantage back then: Vehicles had to be cranked up at considerable effort to get started. Gasoline drives did not begin to displace other types of powertrain until 1911 when the electric starter was invented.[3] After 1920, petrol-driven vehicles began to dominate in the US because of the development of more comprehensive road infrastructure. They were also seen as superior to electric cars because they could travel faster and further. Anyhow, petrol-driven vehicles have been under the process of electrification ever since. During the 20th century, electronic components and sub-systems have replaced non-electronic counterparts in fuel injection systems, engine ignition, and engine management (Figure 5). One could thus argue that the drivetrain is the last remaining non-electronic element and that its electrification appears to be predestined, given the apparent path-dependency of road vehicles.[4]

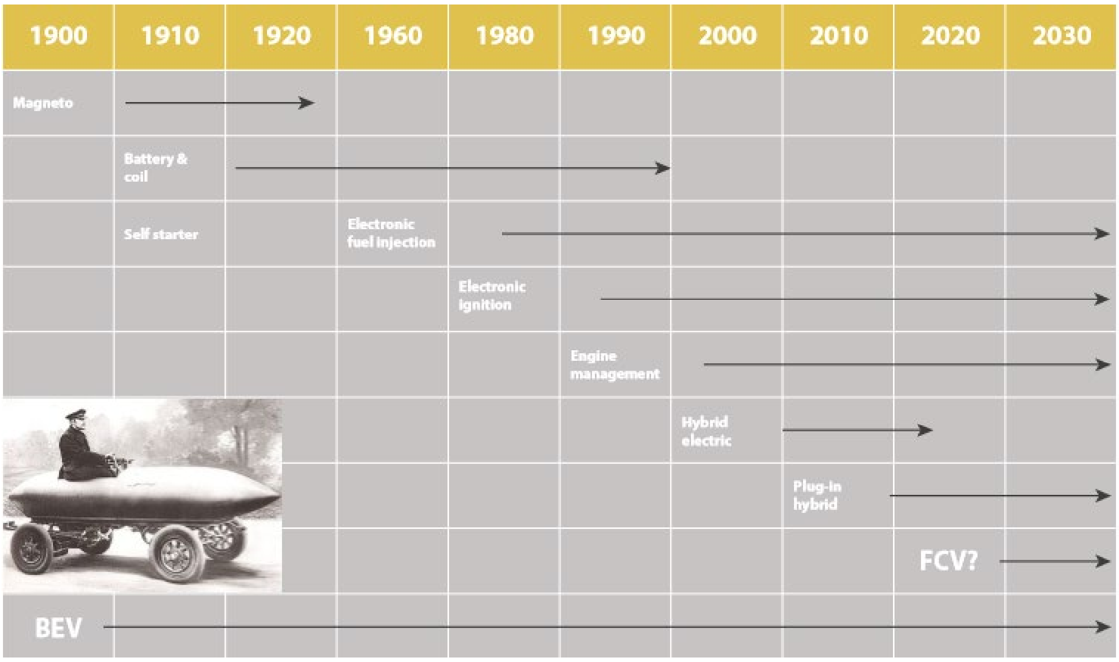


Figure 4 The electrification of road vehicles in a historical perspective [5]

Although having the longest pats, electric vehicles had almost downgraded to a niche existence, but they never completely disappeared. "Modern" electromobility was launched in 1997, with a hybrid model that came on the market in the shape of the Toyota Prius. In 2008, a Californian Roadster became the first electric car on the road that was suitable for highways and lengthier distances. Nowadays, electric vehicles accelerate more constantly and faster than ones driven by gasoline or diesel. The fastest electric car in the world currently is "C_Two" model from the Croatian manufacturer Rimac, which "roars" over the road at more than 400 kilometers an hour. Most of them can travel from 120km/h to 200km/h with driving range between 150 and 350 kilometers on a single charge.

1.2. Modern electromobility as a disruption

Exponentially improving technologies such as solar, electric vehicles, and autonomous (self-driving) cars will disrupt and change the energy and transportation industries as we know it today.

The Stone-age did not end because we ran out of rocks, but because of disruptive technology appearance in the bronze age. Tony Seba in his book "*Clean Disruption of Energy and Transportation: How Silicon Valley Will Make Oil, Nuclear, Natural Gas, Coal, Electric Utilities and Conventional Cars Obsolete by 2030*" explains why the era of centralized, command-and-control, extraction-resource-based-energy sources will not end because of its scarcity, but because of superior technology.

To illustrate how fast, disruptive technology can change the current normal, we will use pictures taken from the same spot thirteen years apart. In Figure 5 from 5th Avenue in New York, there is only one car visible between all the horse-powered carriages. Only thirteen years later, Figure 6, there is only one horse between all the internal combustion engine cars. This sets up an example of how rapid change can be, and we believe it is vital for Europe to be prepared for it.

Figure 5 New York 1900 on Easter morning

Figure 6 New York 1913 on Easter morning [6]

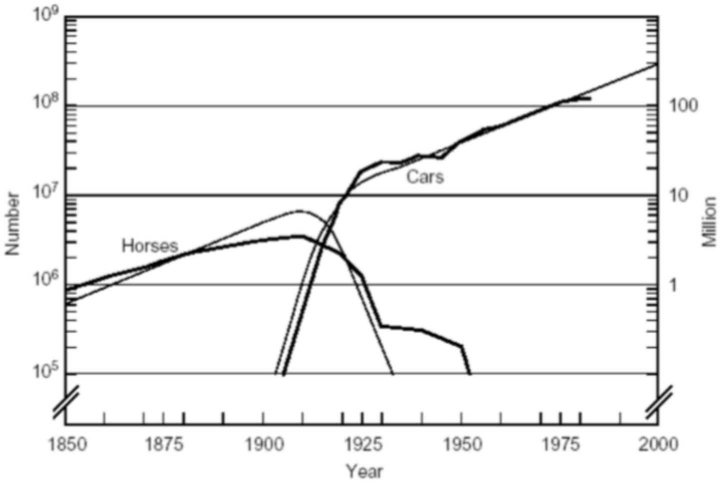


Figure 7 Rapid substitution of horses and cars as a mean of transportation [7]

2. PROGRESSIVE TECHNOLOGIES

Diving deeper into the electromobility, you will find out quickly how complex it is from engineering but also the user's point of view. To make the transition to sustainable mobility as smooth as possible, help of progressive technologies is needed. Fortunately, many new companies emerged and have been able to use recent trends in electromobility for their business growth. Here we will present some of the companies and their solutions that are successfully tackling the challenges of this complex but promising new electric world.

2.1. Types of e-vehicles

First of all, we have to realize electromobility is not exclusively dedicated to electric cars. Today we can already see many successful applications of electric vehicles on water, public transportation, or even construction sights.

Swiss company ABB has been behind many applications of battery-powered means of transportation. One of the most remarkable ones are vessels named Tycho Brahe and Aurora, which are operating on a 4 km route between Sweden and Denmark. These ferries initially built in 1991 have been updated with 4160 kWh onboard battery and can transfer more than 7.4 million passengers and 1.9 million vehicles a year.[8]

Figure 8 Electric ferry operated by ForSea Group

Another way how to divide electric vehicles into different groups is divided by their drive technologies. Table 1 introduces the most commercially known electric vehicles classed by the degree the electricity is used as their energy source.

Abbreviation	FCHEV	MHEV	PHEV	BEV
Full wording	Fuel Cell Hybrid Electric Vehicle	Mild Hybrid Electric Vehicle	Plug-in Hybrid Electric Vehicle	Battery Electric Vehicle
Characteristics	Powered by electricity generated by a fuel cell	No ability to charge from the grid. Powered by both electricity and gasoline	Can recharge the battery plugging the cord, powered by both electricity and gasoline	No gasoline engine, only powered by electricity
Example	Hyundai NEXO	Audi A8	BMW 330e	Tesla Model 3

Table 1 Division by drive technologies in electric vehicle systems

For the use of personal transportation BEV is taken as the most sustainable for now. Figure 9 explains how much of the primary energy is lost on the way from well to the well using different technologies. Battery electric vehicles are by far the best option, with an overall 73% efficiency.

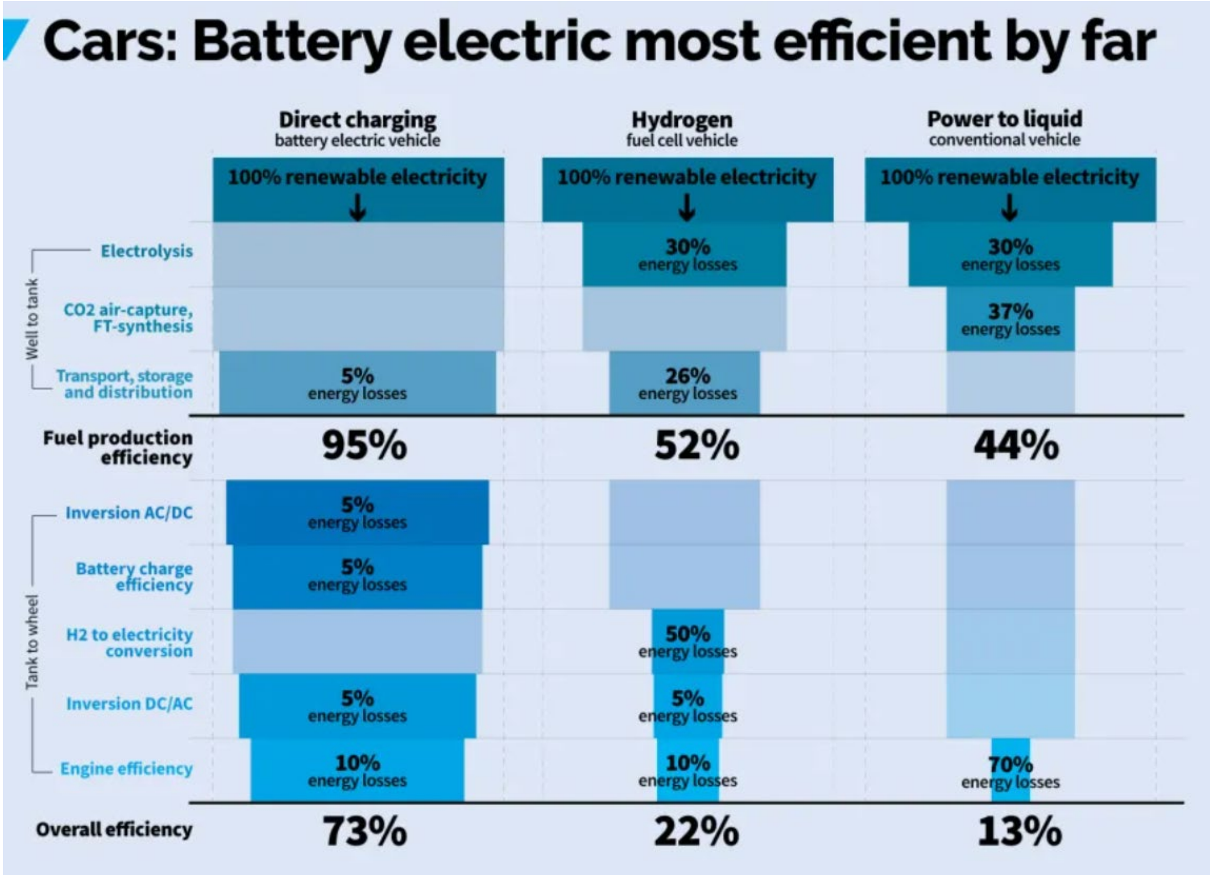


Figure 9 BEV most efficient by far taking well wheel measurements [9]

2.2. Charging solutions

Successful implementation of electromobility cannot be done without a sufficient charging network. Like in other areas, electromobility is also offering multiple charging standards. Fortunately, on the European level, we have reached a consensus, and all European automakers use the same charging standards. This is necessary systems credibility and customer's comfort.

2.2.1. Charging specifics

a) **AC charging** – this charging is available for both BEVs and PHEV. These vehicles are standardly equipped with cables enabling charging from standard Schuko sockets (from the Germa Schutzkontakt.) With the help of a special cable, AC charging can also be used at public charging stations.
b) **DC charging** – charging with direct current. This type of charging is available for the majority of BEV. It is designed for fast charging, more than 50 kW and requires a special charging station, which always includes a connecting cable.

AC charging is primarily used in domestic conditions. Charging via a standard mains socket with a 16 A circuit breaker provides charging power of up to 3.6 kWh. Since the capacity of electric car batteries is reaching tens of kWhs, it takes hours to tens of hours to fully charge your EV. Therefore, this type is more suitable for domestic charging "overnight" than for commercial purposes. Also, with this type of charging, it is necessary to emphasize the control of wiring and sockets to handle charging. If it is an older or worn plug, it must be replaced with an industrial type, which is a few euros more expensive but is manufactured for the permanent load with a higher current. For regular home charging, it is advisable to get a wall charger, the so-called wallbox. Depending on the available power, it will allow charging with power up to 11 or 22 kW (230Vx16Ax3, 230Vx32Ax3). However, the charging ability depends on the power of the built-in charger, which electric cars usually have in the range of 3.7 - 44 kW. Most electric cars have a built-in single-phase 7.2 kW charger, so it is unnecessary to install a charging box with a higher power, which would then not be possible to use in real life.

DC charging is mainly used when traveling long distances. Charging performance does not depend on the performance of the charger in the electric car, so most vehicles support the charging power of at least 50 kW and more. Charging time is therefore reduced from several hours to several tens of minutes. Most current electric cars can be recharged to 80% of capacity on a quick charger in 20 to 40 minutes.

An alternative to current fast-charging technologies in the future may be so-called "battery-swapping", in other words, battery replacement. To date, only Chinese NIO Inc. uses this method commercially in automotive transportation. The global introduction of this technology would require close cooperation between all the world's automakers, which is currently the most significant disadvantage of this method.

Figure 10 Battery swapping station from NIO Inc.

Another successful application of battery swapping has been completed by the Taiwanese company Gogoro, which manufactures purely electric scooters. The scooter has two 1kWh modules under the seat in the storage compartment, which are easily removable and can be replaced with new ones within 6 seconds. More than 1,300 of these stations are located throughout Taiwan.[10]

Figure 11 Battery swapping on Gogoro scooter S1

If battery swapping is not possible, high power fast charging is the solution. Already mentioned Swiss company ABB provides a unique application for public transportation. Using a pantograph charging solution to charge electric buses fully automatically. The main feature is the possibility of rapid charging with power up to 600 kW. This makes it an excellent use of time while the bus stops for its passengers and gives it enough power to operate in the city conditions.

Figure 12 Bus charging using Pantograph down from ABB [11]

2.2.2. Load management

The expected problem of the future is insufficient capacity at individual charging locations, which without a significant investment, can cause a reduction in charging comfort. Therefore, many companies today are dedicated to smart network load management in conjunction with electromobility. Smart management offers the following benefits.

Avoiding peak loads with intelligent load management saves money and guarantees short charging times. Smart load management allows us to maximize the use of available charging infrastructure and avoid the unnecessary costs associated with the requirement for higher capacity. Charging takes place depending on the user profile and capacity limitations.

Charging speed is a key factor influencing user comfort when charging. As already mentioned, the types of electric cars differ in their ability to direct AC current using their onboard charger. In the following scenarios, we will describe how charging can be optimized at the level of multiple charging points in one charging hub, typically an underground car park of shopping centers.

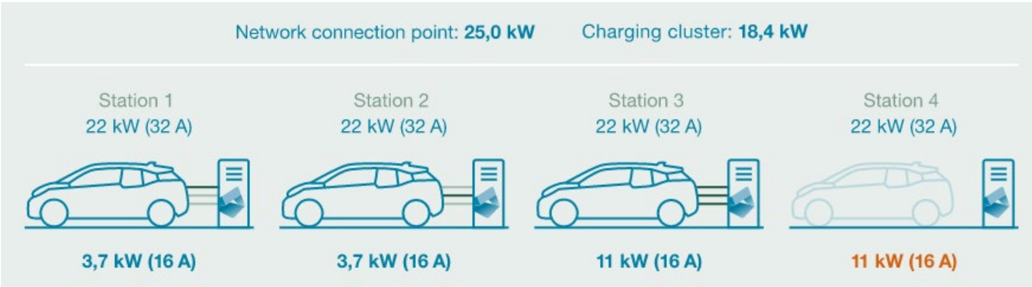


Figure 13 Charging case number 1 [12]

Scenario 1 in Figure 12 shows a situation where the specified charging capacity of three electric vehicles is not exceeded, so the charging capacity is not limited. The maximum capacity (29.4 kW) would be exceeded by a fourth vehicle with a potential charging capacity of 11 kW. The fourth vehicle would not be able to recharge after arriving at the charging station.

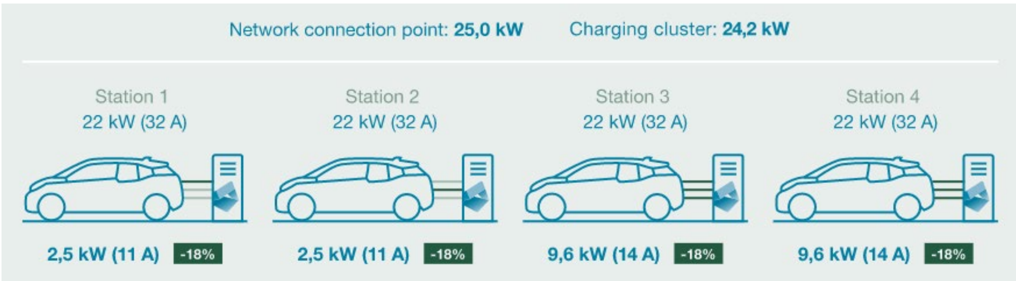


Figure 14 Charging case number 2 [12]

Scenario 2 offers intelligent load control by evenly reducing the capacity of all charging stations by 18 % so that the maximum capacity is evenly distributed among all four electric vehicles.

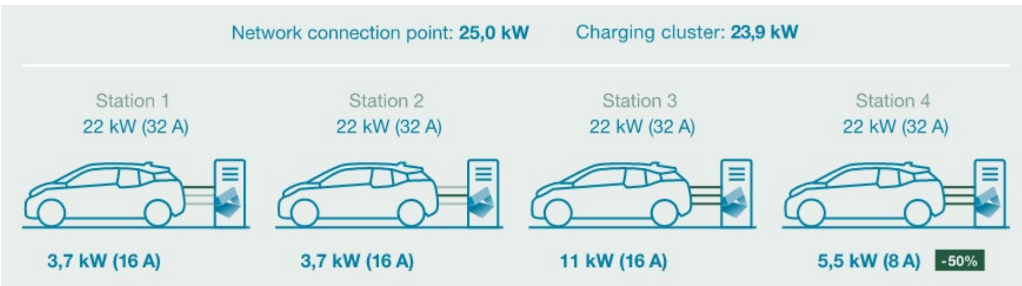


Figure 15 Charging case number 3 [12]

Scenario 3 prefers full power to previously connected cars. To prevent the maximum capacity from being exceeded, the charging capacity of the last vehicle is reduced (by 50% to 5.5 kW). All other cars continue to charge with maximum capacity.

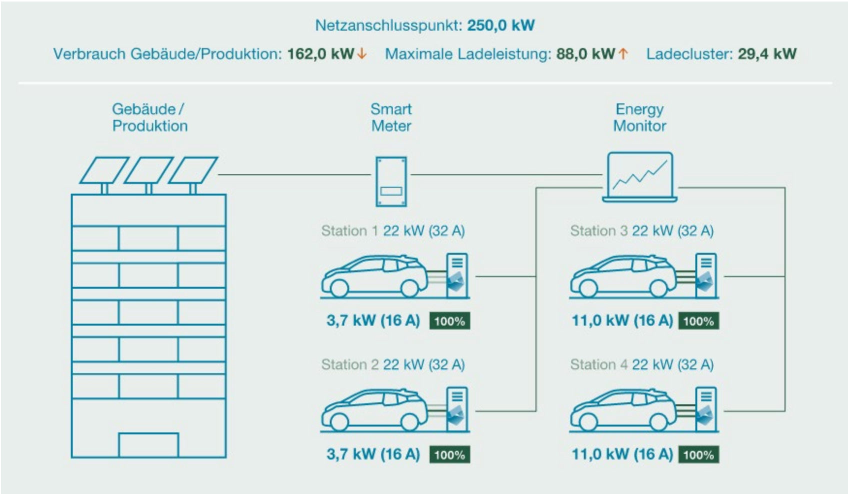


Figure 16 Case 4 dynamic load management [12]

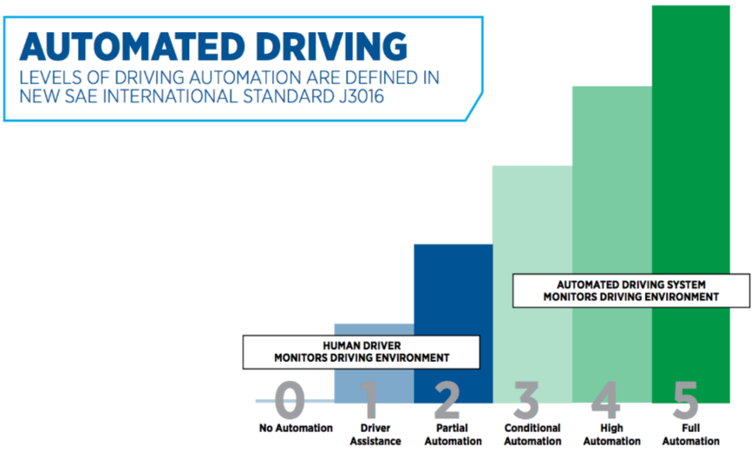
If your charging infrastructure is linked to the network connection of the company building or production facilities, you may use higher charging capacities for your charging points via the network connection point. The load management system dynamically identifies the maximum charging capacity and makes it available to charging points. As electricity consumption in buildings or production facilities decreases, the maximum capacity for a group of charging points increases. This load management represents the most efficient use of all energy resources. The application requires an intelligent electricity meter and energy management software.

With the growing number of electric cars, V2G (vehicle to grid) technology may also become interesting for grid load control. This system allows the car to communicate with the distribution system in order to sell demand response services either by discharging its own battery into the network or by reducing the charging speed.

2.3. Autonomous vehicles

Looking further in the future autonomous vehicles are holding a grand promise for mobility in urban areas. In the new Society of Automotive Engineers, standard J3016, there are five levels of autonomous driving defined:

Figure 17 5 levels of automated driving explained [13]



When we reach levels 4 and 5, it will mean a massive change of transportation and city's infrastructure as we know it. At level 4 systems can drive the vehicle and monitor road conditions; the human driver does not need to take control, but the system can only operate in specific conditions and environments.

Figure 18 Lyft self-driving cars powered by Aptiv using level 4 autonomous driving [14]

Level 5 ensures a fully autonomous vehicle, that can perform all driving and road-monitoring tasks in all driving conditions.

Many opportunities are coming with full self-driving. Bosch's questioned people how would they spend the extra time if the car drove from them. Answers varied from enjoying the view, chatting, surfing the web to socializing.

Given that a typical European car is parked 92 % of the time, full self-driving brings the promise of better utilization of the vehicle [15]. As a consequence, more space in urban areas could be advanced for a better purpose. Just to give you an idea, if Los Angeles would get rid of all the parking lots, the area of whole San Francisco could be moved in to the city.

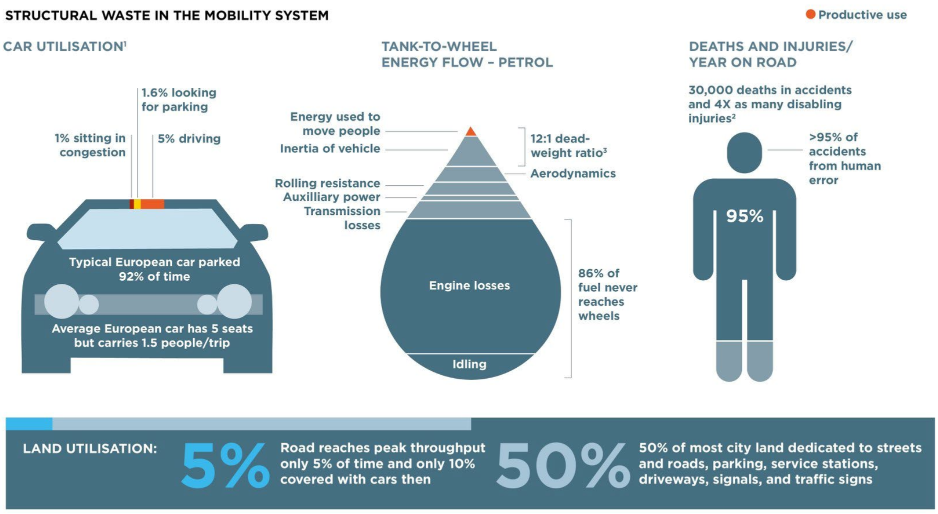


Figure 19 Structural waste in the mobility system [15]

3. PROS AND CONS OF ELECTROMOBILITY

The main advantage of electric vehicles compared to conventional ones is that they are considered environmentally friendly and have zero local emissions. That can easily be turned into a disadvantage, because the extent to which emissions are actually reduced in the overall balance depends on the energy mix. That's why it is important to analyze the whole energy chain and emissions through the entire life cycle of a vehicle, as described in the following figure:

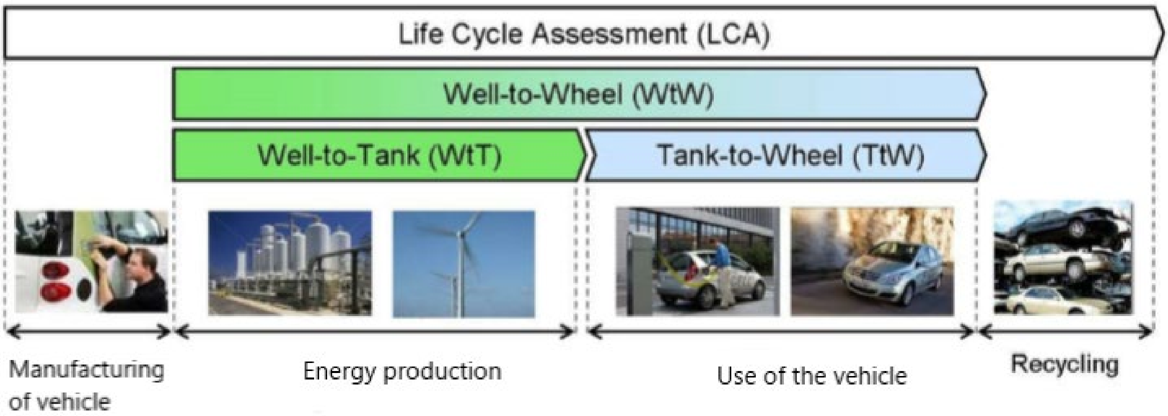


Figure 20 Life cycle of a vehicle and emissions periods [7]

Tank-to-wheel (TtW) emissions arise from fuel use in the car while well-to-tank (WtT) emissions are caused during production and supply of energy (fossil fuel, electricity or hydrogen). Energy mix used for producing electricity has a significant impact on WtT, and finally also on total WtW emissions. As shown in the next figure, well to wheel emissions decrease with an increasing share of renewables. At the X mark, 50% of renewables are covering electricity production, and compared to ΔCO_{2X} is the corresponding emission saving due to electric vehicle.

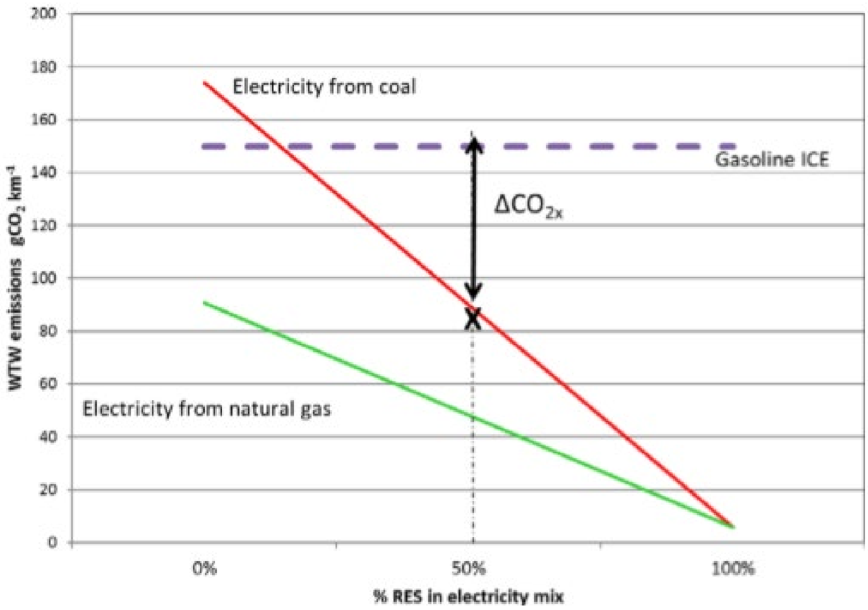


Figure 21 WTW emissions (excl. LCA emissions of the car) depending on the share of RES in electricity generation [16]

It is vital to increase the share of renewables to make EVs more favorable because the production of electric vehicles requires is more energy demanding as when manufacturing a conventional car. The batteries used are heavy, and so the rest of the vehicle must be made lightweight, which requires additional energy for lightweight material production

Energy efficiency is also one of the parameters which have an impact on the total emissions. The efficiency of different types of vehicles varies significantly, but electric cars are more efficient than conventional cars. Unlike for conventional vehicles, total CO_2 emission per km of electric vehicle is decreasing with the increasing number of km driven. Further improvement of vehicle efficiency in addition to more renewables in electricity generation will have a significant effect on reducing those emissions.

On the other hand, there are a few significant reasons for the slow adoption of electric vehicles. EVs have a limited driving range per battery charge, which is a critical and much-discussed parameter and a decisive factor for the acceptance of the electric drive. Usually, it is 200-250km, although recent and more expensive models have a range of up to 450km. Combined with long charging time and the incomplete charging infrastructure, especially of fast charging stations on long-distance routes, makes a significant disadvantage.

Yet, the main disadvantage of electric vehicles is still their high price. The battery is the most expensive part, and costs in the total cost of a car is between 23% and 58%. Higher prices are one of the key reasons for the low deployment of electromobility.

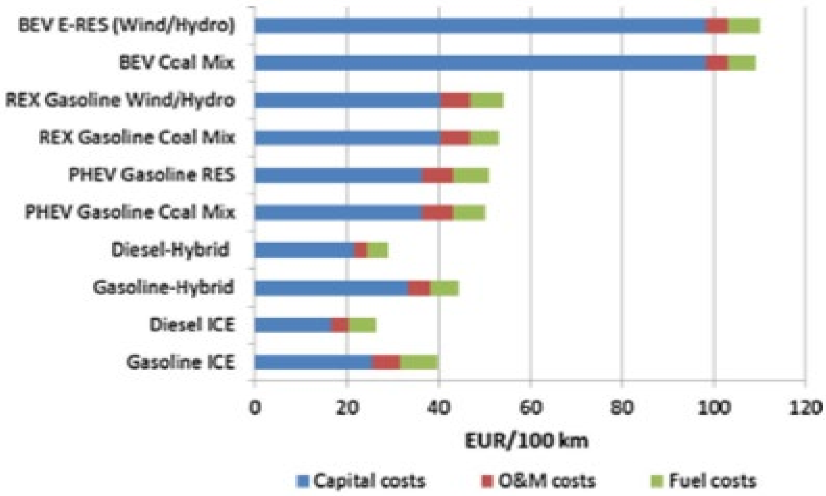


Figure 22 Mobility costs of electric vehicles (car size 80 kWh) compared to other types of vehicles [16]

Policymakers and governments are trying to make EVs more attractive by providing subsidies, registration-tax reductions, or other incentives that differ from country to country and are changeable over time. EVs must first be competitive with a conventional vehicle, both on price and performance, to transform and electrify the transport sector.

EVs have great potential in improving the quality of life, especially in cities and urban areas. Not only they can reduce air pollution, that is a massive problem in bigger cities, but they can also reduce noise pollution. Despite low noise, they also provide a pleasant driving experience with its high torque right from the start.

4. CHANGES ELECTROMOBILITY BRINGS

Electromobility is a system defined not only as the electric vehicle, but also as driver, charging infrastructure and all related regulations and standardization. It refers to consumer profiles, potential users, sales, forecasts, market barriers and incentives, public policies, regulations and all purchasing and operational behaviors related matters, as well as batteries, utilities, and all related system functionality and practical matters. The opportunities and issues electromobility brings will have lifestyle implications for large parts of the population. EVs offer to make cities smarter and more sustainable, but there bring a lot of uncertainties and challenges from technology development, economic viability, consumer satisfaction, and environmental sustainability perspectives.[17]

The diffusion od EVs is facing some technical and social barriers, like limited range, premium price, and immaturity of battery technologies. Another facet is the demographic aspect, which is a product of education, level of awareness, availability, road network, driving pattern, daily mileage, employment status, and household income. [17] Following figure shows the diffusion of EVs in the market and current state, based on Rogers *Diffusion of Innovations:*

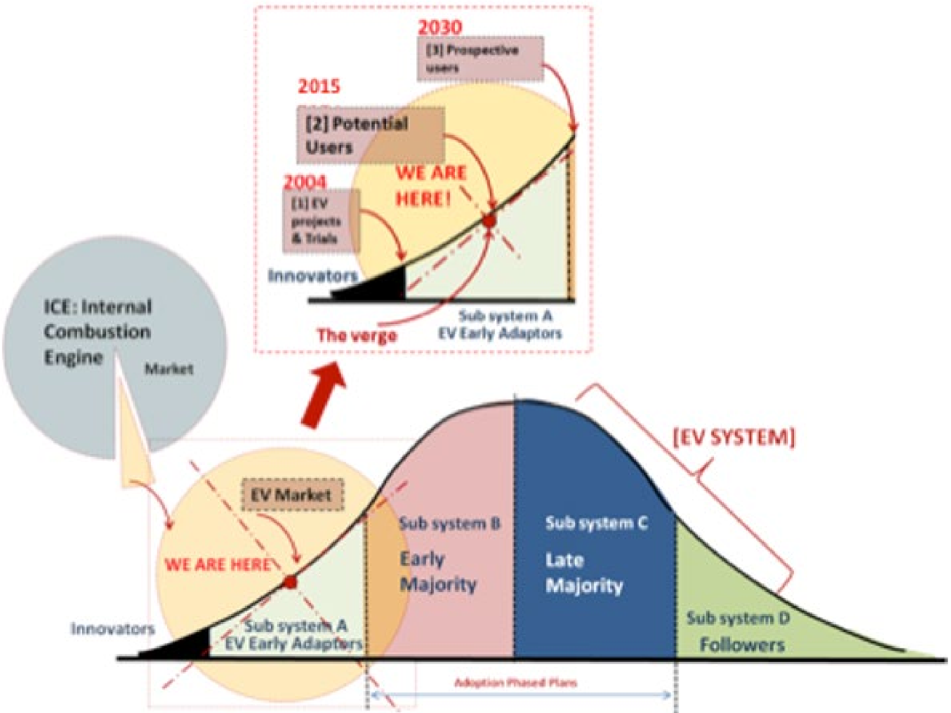


Figure 23 Diffusion of EVs [17]

To reach sustainable goals for 2030, stakeholders and planning authorities and policy makers must act.

4.1. Political conditions

As mentioned in the chapter before, one of the main challenges in the deployment of electromobility is affordability. Electric vehicles are still more expensive than regular ones, so the customers are not economically motivated in buying them. Governments play a huge role in conquering this challenge. There is a broad type of measurement they can implement in order to make EVs financially closer to ICEs. The direct way they can change it is through taxes. Some countries have already lowered or also abolish taxes on purchasing an electrical vehicle. That has proven as an effective praxis, for example, in Norway, where the number of newly bought EVs rises rapidly[1]. The political framework is not only crucial in achieving lower vehicle prices but also to force and allow faster penetration into the market. It could be done through variety of measurements. Some countries offer free parking for electric vehicles, or free tolls, which has an important impact on lowering overall costs of owning a car. Governments and policymakers can also set higher taxes on conventional vehicles combined with CO_2 excise duties and higher taxes on fossil fuels gasoline and diesel. Those measurements increase costs for conventional vehicles, but can hurt customers whose income is lower and who would have problems with purchasing and could be forced to buy a used and inefficient car that emit more GHG. To solve those issues, governments can offer subsidies for purchasing electrical vehicles.

Political measurements should affect both consumers as well as producers. Already, some governments set some rules in obligations for automotive industries. To enhance interest at car manufactures to produce and sell more electric vehicles and work on improving technologies, fines could be set if specified values are exceeded. Also, there could be set driving bans for vehicles with diesel engines, that are already being considered in numerous metropolises - for example in London, Mexico City and Paris.

On top of that, small electric vehicles like electric pedal scooter, hoverboards, or other micromobiles represent an alternative. To use them properly the framework of conditions for them must be created and implemented successfully.

The problem is that all those measurements, although shown they succeed excellent (in Norway), are still set in a few countries and are not taken seriously yet. That is mostly due to lack of government interest, either because it takes a lot of financial expenses and support or because it is of no popularity to the public.

4.2. Economic effects

Electromobility could trigger one major economic problem. From the point of view of vehicle development, it is positive that the lack of a combustion engine and mechanical drive train is giving freedom to engineers and designers. For the economy and the labor market, electromobility will result in job losses in the automotive industry (including suppliers) because an electric drive is less complicated and requires fewer components than a combustion engine.[18] Those economic effects should not be underestimated, since, only in Germany almost 114,000 jobs will be lost, according to a study conducted by the Institute for Labor Market and Occupational Research in December 2018, due to the switch to electric drive systems for passenger cars. The main reason for this is the much simpler design of the drive train. For example, Volkswagen reported that 7,000 jobs in the Hanover and Emden plants had become obsolete as a result of their electric offensive.[18] In current times, where the global crisis of the corona virus took its consequences (the sales of all vehicles dropped down sharply, and many factories closed for an extended period) it would be even harder to maintain jobs in the industry and to invest in developing more efficient technology. One of the great challenges

[1] The highest proportion of new registrations of electric vehicles is in Norway (46.7 %), followed by the Netherlands with 4.7 %.

nowadays that is also caused by unfavorable economic situations is that the production of cars slowed down, and the prices are unlikely to drop, so the ability of customers willing to buy electric vehicles is even more questionable. High costs of producing electric cars, as well as accompanying infrastructure, is solvable only with effective governments measures and subsidies and can be done if the world succeeds to manage the current crisis and its consequences in short time.

Also, one of the possible problems that could have an economic effect is the supply issue. Since electric vehicle's main part is battery, which is made of rare minerals like lithium, increased production of batteries could lead to lack of those materials and increased prices finally. Recycling of those batteries is energy intensive, and metal recovery alone cannot pay for recycling costs, so the subsides are needed in order to protect industries and environment.

4.3. Environmental issues

Although considered eco-friendly vehicles, electric vehicles still cause some severe issues regarding the environment. Firstly, as mentioned before, through life cycle emissions, they are responsible for, which could lower with higher shares of renewables. Other problems are linked to the battery. Increasing the share of electric vehicles will result in significant number of batteries that have to be recycled. Recycling of batteries creates an issue because they are made of chemicals and some dangerous components that must be disposed accordingly. Mining of those components that contain lithium and some other minerals, also affect destroying the landscape and ground and is hazardous for habitants in the near of those mines.

The amount of lithium used in batteries is relatively small, about 0.15 kg/kWh and for a typical EV battery capacity (25 kWh) the percentage of lithium used in the total battery mass is between 1.2 and 2.4%, so for a battery pack a significant amount of additional materials is needed, such as nickel, cobalt, aluminum, manganese.[19] Projections on material availability for EV batteries are shown in the following figure:

Li-ion battery	Demand (kg/ kWh)	Demand for 1.6 billion EVs (1000 tons)	World reserves (1000 tons)	World reserve base (1000 tons)
Lithium	0.15	6000	9900	11,000
Nickel	1.2	48,000	71,000	150,000
Cobalt	1.2	48,000	6600	13,000
Manganese	1.2	48,000	540	5,200,000
Phosphate	0.8	32,000	16,000	n/a
Aluminum	0.04	1600	n/a	n/a
Iron/steel	0.4	16,000	77,000	n/a

Table 2 Demand for raw materials versus world reserves[19]

According to currents scenarios for the reduction of CO_2, the cumulative amount of rechargeable electric vehicles produced by 2050 would be 1.6 billion. Assuming all EVs would have a typical battery capacity of 25 kWh, and all batteries are expected to contain the same chemistry, the total material demand until 2050 is shown. The world reserves of lithium are big enough for that future demand. Still, there could be a shortage of some other materials so the material availability would be a significant problem. Due to increasing demand for the various elements, to ensure their future availability, recycling will be necessary. For example, using recovered cobalt and nickel for lithium battery results in a 51% saving of natural resources.[19]

The impact of recycling itself on the environment varies based on the type of batteries. Lithium batteries don't present significant environmental concerns beyond fire safety and landfill utilization like lead-based ones do. Due to the EC directive 91/157/EEC, in the EU, a very good system for collecting and recycling of lead acid batteries has already been established.[19]

4.4. Technological challenges

High share of renewables is essential to give electromobility its true meaning as ecofriendly, but it comes with some negative side effects. Renewable systems are very volatile in energy production, and scientists and engineers are still trying o figure how to create dependent and stable source out of them. Electric vehicles require more renewable electricity, causing more volatility in the grid, but they could also serve as a solution. Batteries in EVs can be used to achieve grid stability, so an increasing number of EVs with a growing share of renewables improves stability in the grid.

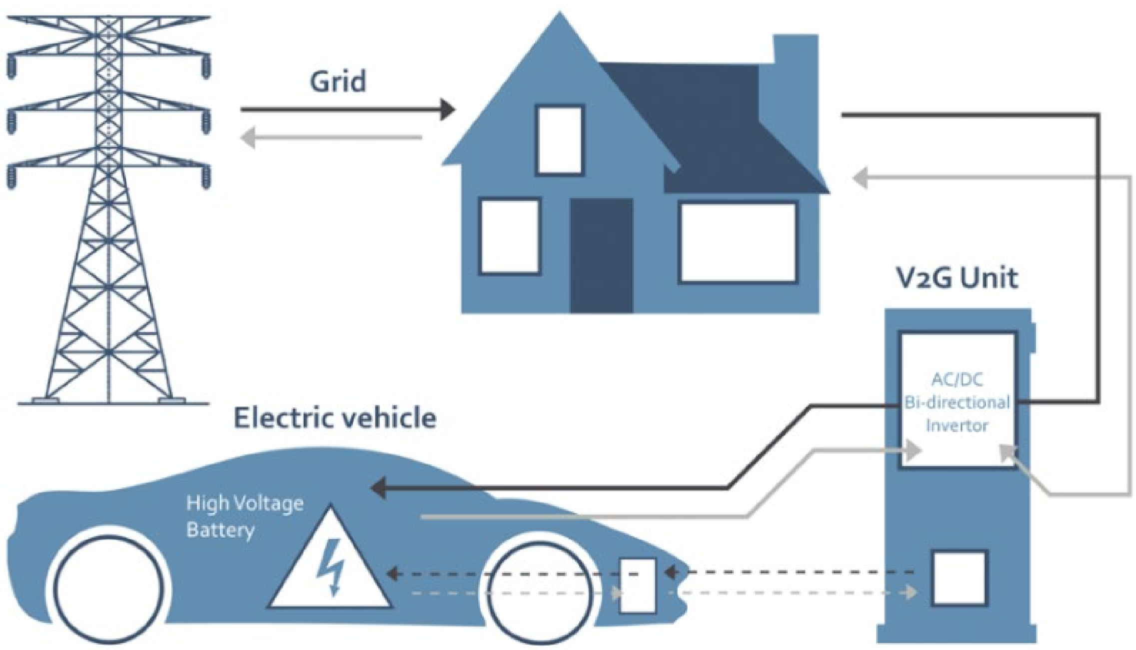


Figure 24 Vehicle to grid concept[20]

When there is excessive energy production, EVs serve as electricity storage, while when there is low production, EVs batteries serve as a source of electricity. This is especially useful with a high share of photovoltaics, whose output is sort of predictable in day rhythm. If electric vehicles are left plugged into smart, two-way charging points when not in use, their batteries can feed power into the network at times of peak demand. Smart chargers can also control when cars recharge to avoid stressing the network and to store surplus power when demand is low. This will allow the grid to operate more efficiently, support high levels of renewables, and rely less on fossil fuel power stations. One concern it that discharging energy from a stationary EV stresses its battery, which is one of its most expensive components.[21]

Battery is the most challenging part of the vehicle. Although in the past there were hardly any serious battery research (electrochemistry), at least in Europe, they are catching up. The main objectives of battery development are to reduce costs and increase range. In addition to the enhancement of lithium-ion technology, battery researchers worldwide are also working on making new types of battery systems ready for series production. These include lithium iron phosphate ($LiFePO_4$) technology and - to an even greater extent - solid-state batteries, in which both electrodes and the electrolyte are made of solid materials.[18] This would enable a higher energy density. Several car manufacturers have announced that they will use solid-state batteries in their electric cars from around 2025 onwards and a few are investing in their own battery system production facilities, what will speed up the production and bring more security in supply.

Improving the charging infrastructure by adding more stations increases the drivability of vehicles. But, the slowness of charging represents an issue. Compared to fuel stations, where refueling lasts a couple of minutes, recharging of EVs can last up to hours. Fast charges are imperative to make EV more attractive to consumers, and charging technology has to be optimized. It is a challenge to plan where to locate a charging station, especially in dense, urban areas. There is no single factor in choosing the location, all sort of different patterns and factors must be considered, as behavioral and social injury, the practice of driving, charging pattern of drivers, etc.

All in all, electromobility offers opportunities for new concepts and for moving away from a tried and tested basic design that is decades old. Many companies see opportunities for the establishment of new technologies (e.g. for additive manufacturing processes and automotive lightweight design) or for their market entry into the automotive industry (e.g. manufacturers of electric motors). [18]

4.5. The social aspect of EV use

Until some of the major technical and economic challenges are solved, drivers could be negatively affected. The low range and long charging may cause anxiety and stress. High prices and the perception of limited mobility resources are a significant purchase barrier. Consumers may not have sufficient knowledge of how the range limit could affect they daily routine. Although, for most of the drivers, using the car on a daily basis is without problems, worrying if the battery would last for all their activities causes anxiety, which leads to pessimistic vision of things. Driver experience could be ruined if they are stressed worrying and overthinking about their journeys, the distance between origin and destination, route choice, congestion, and traffic management. Adaptation and acceptation of new technologies represent an issue to some too.

5. ELECTROMOBILITY WORLDWIDE: CURRENT MARKET DATA [22]

According to International Energy Agency's (IEA) latest report[2], electric car deployment has been snowballing over the past ten years, with the global stock of electric passenger cars passing 5 million in 2018, an increase of 63% from the previous year. Around 45% of electric cars on the road in 2018 were in China – a total of 2.3 million – compared to 39% in 2017. In comparison, Europe accounted for 24% of the global fleet, and the United States 22%

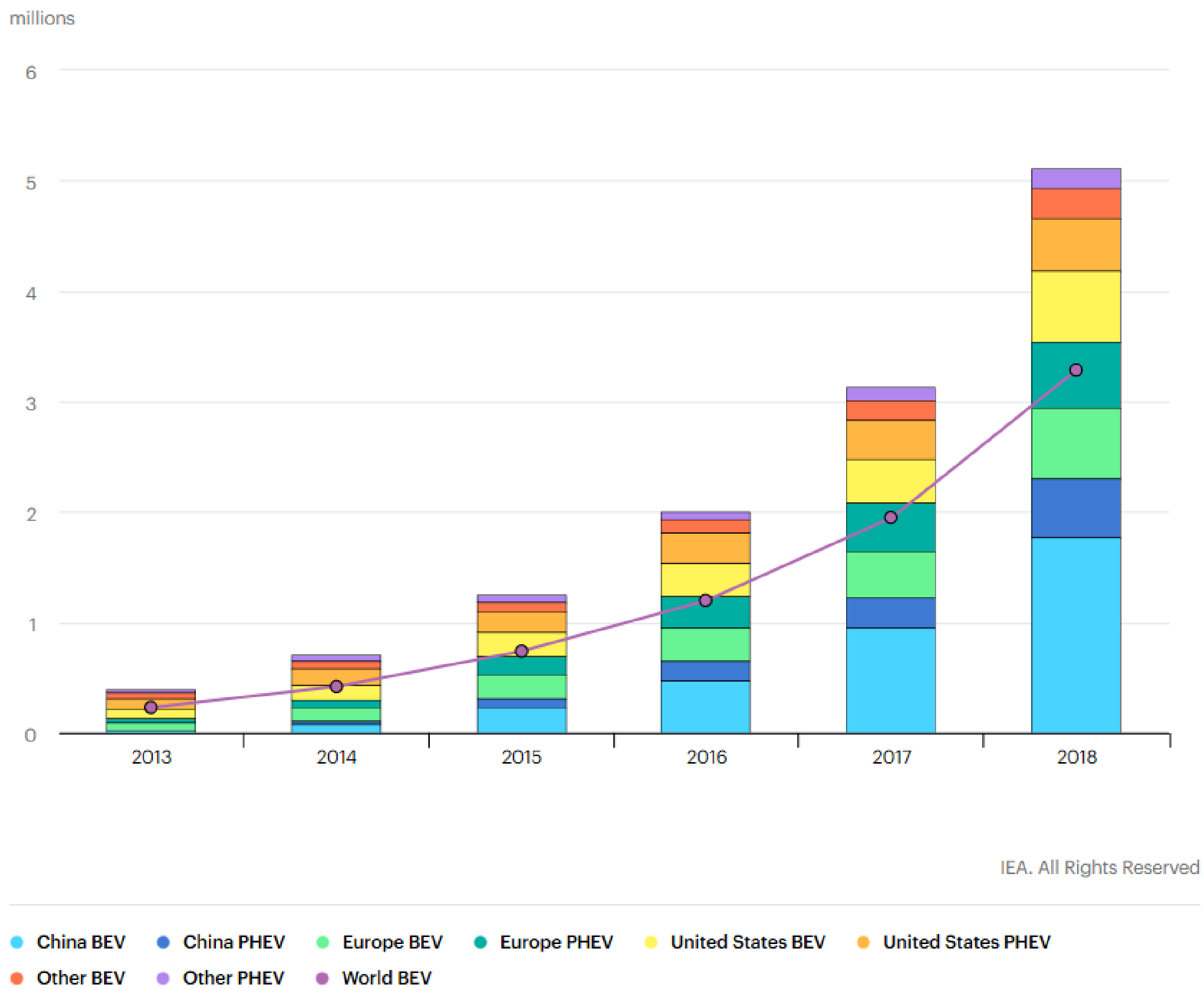


Figure 25 Electric car deployment in selected countries, 2013-2018 [22]

China remained the world's largest electric car market with nearly 1.1 million electric cars sold in 2018, and with 2.3 million units, it accounted for almost half of the global electric car stock. Europe followed with 1.2 million electric cars and the United States with 1.1 million on the road by the end of 2018 and market growth of 385 000 and 361 000 electric cars from the previous

---

[2] Global EV Outlook 2019, IEA see more on https://www.iea.org/reports/global-ev-outlook-2019

year. Norway remained the global leader in terms of electric car market share at 46% of its new electric car sales in 2018, more than double the second-largest market share in Iceland at 17% and six-times higher than third-highest Sweden at 8%.

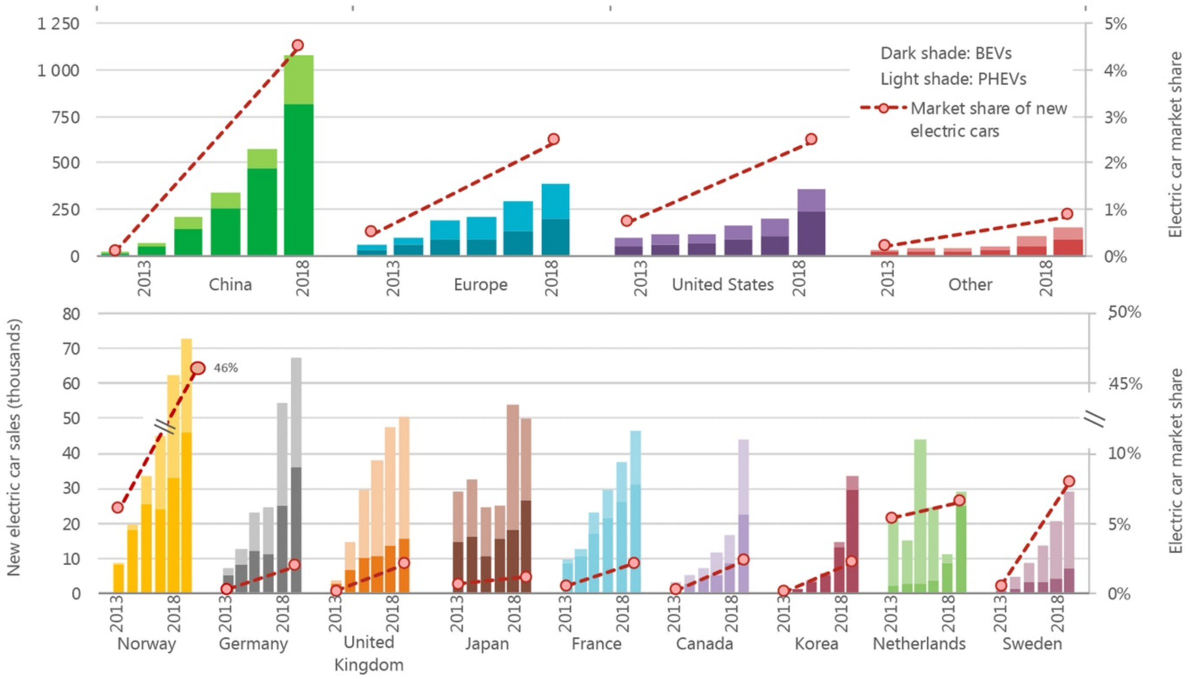


Figure 26 Global electric car sales and market share, 2013-18 [22]

Electric two/three-wheelers on the road exceeded 300 million by the end of 2018. The vast majority are in China. With sales in the tens of millions per year, the Chinese market for electric two-wheelers is hundreds of times more massive than anywhere else in the world. In 2018, electric buses continued to witness dynamic developments, with more than 460 000 vehicles on the world's road, almost 100 000 more than in 2017.

In addition to conventional passenger vehicles, low-speed electric vehicles (LSEVs)[3] in 2018 were estimated at 5 million units, up almost 700 000 units from 2017. All LSEVs were located in China. Shared "free floating" electric foot scooters flourished very rapidly in 2018 and early 2019 in major cities around the world. These foot scooter schemes now operate in around 129 cities in the United States, 30 in Europe, 7 in Asia, and 6 in Australia and New Zealand.

In freight transport, electric vehicles (EVs) were mostly deployed as light-commercial vehicles (LCVs), which reached 250 000 units in 2018, up 80 000 from 2017. Medium truck sales were in the range of 1 000-2 000 in 2018, mostly concentrated in China.

The number of EV chargers continued to rise in 2018 to an estimated 5.2 million worldwide for light-duty vehicles (LDVs). Most are slow chargers (levels 1 and 2 at homes and workplaces), complemented by almost 540 000 publicly accessible chargers (including 150 000 fast

[3] LSEVs are passenger vehicles that are significantly smaller than electric cars, to the point that they are not subject to the same official approval and registration requirements as passenger cars.

chargers, 78% of which are in China). With the 156 000 fast chargers for buses, by the end of 2018 there were about 300 000 fast chargers installed globally.

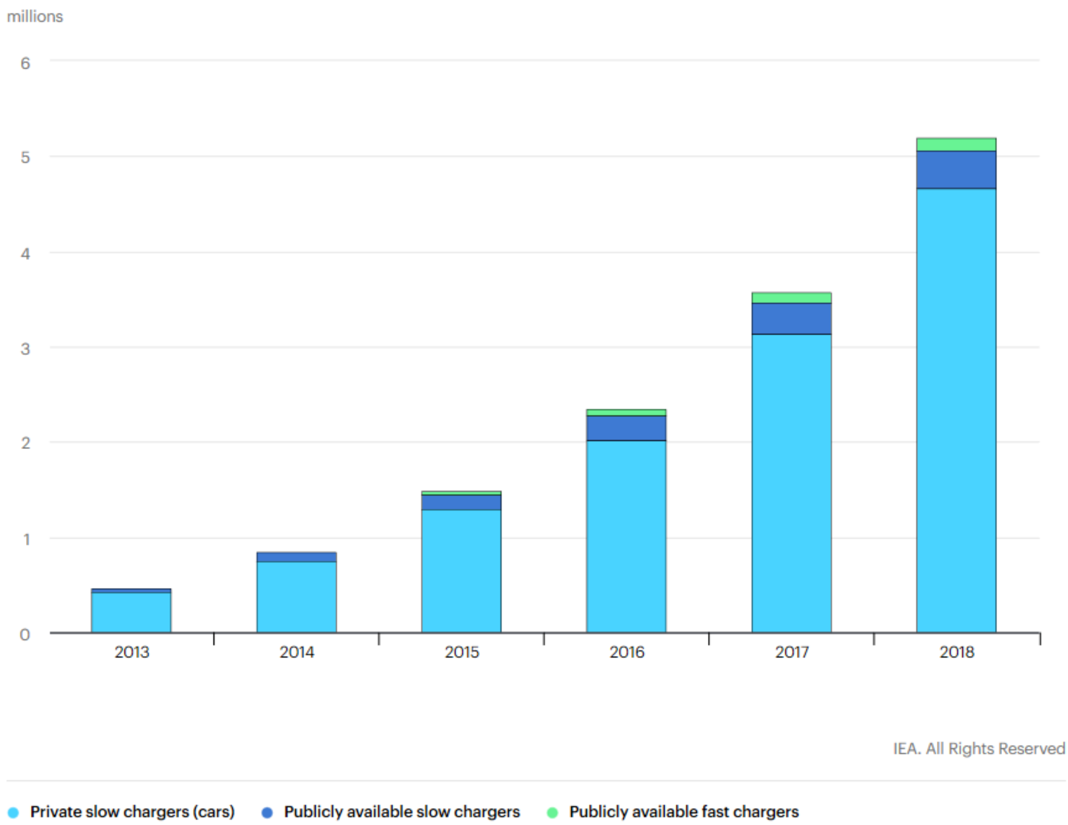


Figure 27 Global installation of electric LDV chargers, 2013-2018 [22]

The global EV fleet consumed an estimated 58 terawatt-hours (TWh) of electricity in 2018, similar to the total electricity demand of Switzerland in 2017. Two-wheelers continued to account for the largest share (55%) of EV energy demand, while LDVs witnessed the strongest growth of all transport modes in 2017-18. China accounted for 80% of world electricity demand for EVs in 2018. The global EV stock in 2018 emitted about 38 million tonnes of carbon-dioxide equivalent (Mt CO2-eq) on a well-to-wheel basis. This compares to 78 Mt CO2-eq emissions that an equivalent internal combustion engine fleet would have emitted, leading to net savings from EV deployment of 40 Mt CO2-eq in 2018.

IEA also predicts future growth, based on the policies and measures that governments around the world have already put in place, as well as the likely effects of announced policies, including the Nationally Determined Contributions made for the Paris Agreement. This scenario, called the EV30@30 Scenario, reflects a policy case characterized by a wider adoption of EVs at a global scale. It sets an aspirational goal for all EVI[4] members of a 30% market share for electric vehicles in the total of all vehicles (except two-wheelers) by 2030. Under the Scenario, EV sales would reach 44 million vehicles per year by 2030:

---

[4] The Electric Vehicles Initiative (EVI) is a multi-government policy forum dedicated to accelerating the introduction and adoption of electric vehicles. Thirteen countries are currently participating in EVI: Canada, France, Japan, Norway, Chile, Germany, the Netherlands, Sweden, China, India, New Zealand, United Kingdom, and Finland.

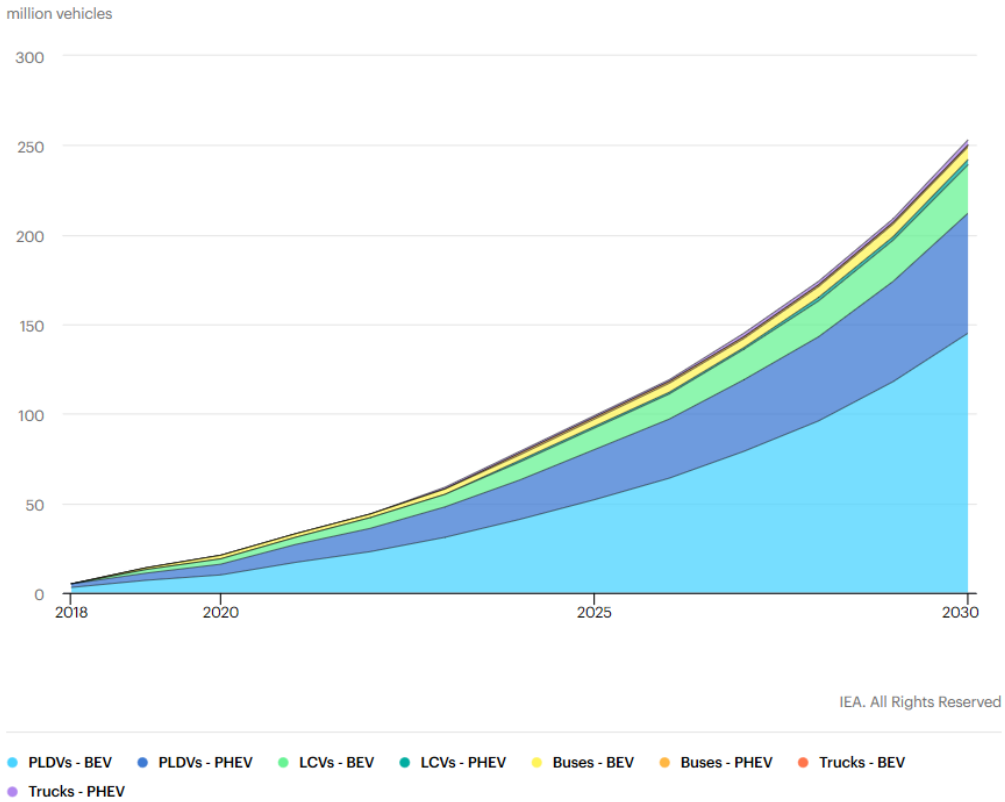


Figure 28 Electric vehicle stock in the EV30@30 scenario, 2018-2030 [22]

With decarbonizing grid, WtW emissions from EV fleet are smaller and the benefits of transport electrification on climate change mitigation will be higher.

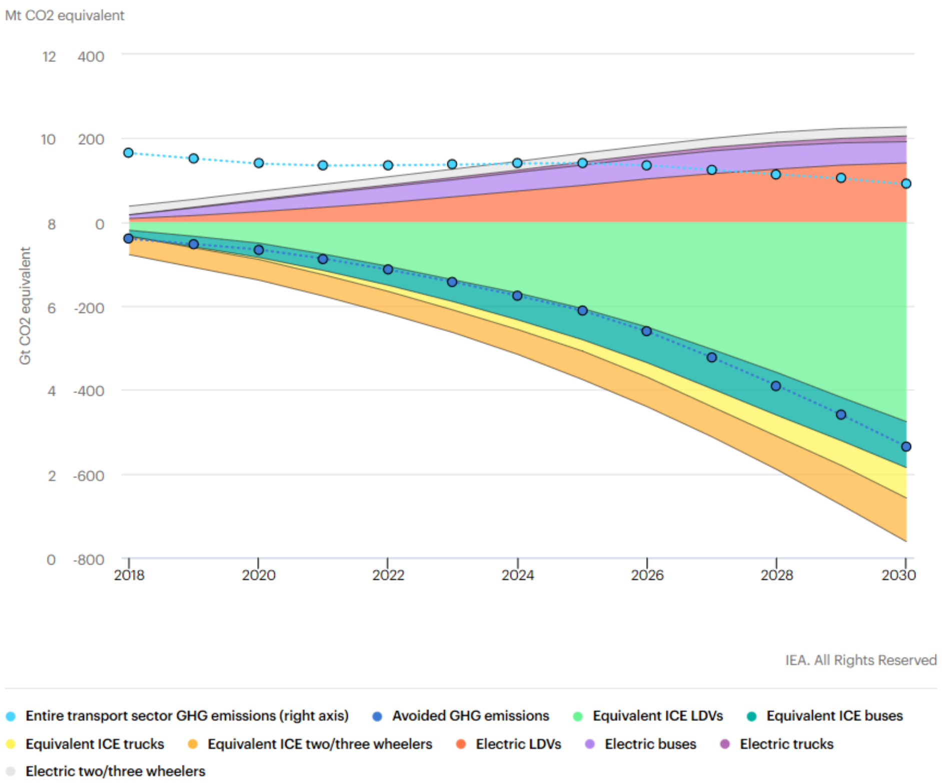


Figure 29 Well-to-wheel net and avoided GHG emissions from EV fleets by mode and total GHG emissions form the transport sector in the EV30@30 Scenario [22]

Some of the major policies regarding electromobility that have been made are the following:

- In the European Union, several significant policy instruments were approved. They include fuel economy standards for cars and trucks and the Clean Vehicles Directive which provides for public procurement of electric buses. The Energy Performance Buildings Directive sets minimum requirements for charging infrastructure in new and renovated buildings. Incentives supporting the roll-out of EVs and chargers are common in many European countries.
- In China, policy developments include the restriction of investment in new ICE vehicle manufacturing plants and a proposal to tighten the average fuel economy for the passenger light-duty vehicle (PLDV) fleet in 2025 (updating the 2015 limits). The use of differentiated incentives for vehicles based on their battery characteristics (e.g. zero-emissions vehicle credits and subsidies under the New Energy Vehicle mandate).
- Japan's automotive strategy through a co-operative approach across industrial stakeholders, aims to reduce 80% of greenhouse gas (GHG) emissions from vehicles produced by domestic automakers (90% for passenger vehicles) – including exported vehicles – to be achieved by 2050 with a combination of hybrid electric vehicles (HEVs), BEVs, PHEVs and fuel cell electric vehicles (FCEVs). Fuel economy standards for trucks were revised and an update of fuel economy standards for cars was announced.
- Canada outlined a vision for future EV uptake accompanied by very ambitious policies in some provinces, such as the zero-emissions vehicles (ZEVs) mandate in Quebec (similar to one in California). British Columbia announced legislation for the most stringent ZEV mandate worldwide: 30% ZEV sales by 2030 and 100% by 2040. This places Canada in a similar framework as the ten states in the United States that have implemented a ZEV mandate.
- India's announced the second phase of the "Faster Adoption and Manufacturing of Electric Vehicles in India" (FAME India) scheme. It reduces the purchase price of hybrid and electric vehicles, with a focus on vehicles used for public or shared transportation (buses, rickshaws and taxis) and private two-wheelers.
- In Korea, the scope of national subsidies for all low-carbon vehicle purchases increased from 32 000 vehicles in 2018 to 57 000 in 2019, adding to other policy instruments including public procurement, subsidies and rebates on vehicle acquisition taxes, reduced highway tolls and public parking fees). An ambition to scale up overseas sales of low-emission vehicles produced in Korea was also announced in 2018. It is accompanied by a goal to boost production capacity to more than 10% of all vehicles by 2022, and the use of financial support and loan guarantees to major industrial players.

Growing momentum on the policy front is also emerging in other countries. Key examples include Chile, which has one of the largest electric bus fleets in the world after China. Chile's aim is to electrify 100% of its public transport by 2040 and 40% of private transport by 2050. New Zealand also has high ambitions and has adopted a transition to a net-zero emissions economy by 2050. Both New Zealand and Chile joined the Electric Vehicles Initiative (EVI) in 2018.

		Canada	China	European Union	India	Japan	United States
Regulations (vehicles)	ZEV mandate	✓*	✓				✓*
	Fuel economy standards	✓	✓	✓	✓	✓	✓
Incentives (vehicles)	Fiscal incentives	✓	✓	✓	✓		✓
Targets (vehicles)		✓	✓	✓	✓	✓	✓*
Industrial policies	Subsidy	✓	✓			✓	
Regulations (chargers)	Hardware standards**	✓	✓	✓	✓	✓	✓
	Building regulations	✓*	✓*	✓	✓		✓*
Incentives (chargers)	Fiscal incentives	✓	✓	✓		✓	✓*
Targets (chargers)		✓	✓	✓	✓	✓	✓*

Notes: * Indicates that the policy is only implemented at a state/province/local level. ** Standards for chargers are a fundamental prerequisite for the development of EV supply equipment. All regions listed here have developed standards for chargers. Some (China, European Union, India) are mandating specific standards as a minimum requirement; others (Canada, Japan, United States) are not. ZEV = zero-emissions vehicle. Check mark indicates that the policy is set at national level. Building regulations refer to an obligation to install chargers (or conduits to facilitate their future installation) in new and renovated buildings. Incentives for chargers include direct investment and purchase incentives for both public and private charging.

Figure 30 EV-related policies in main regions [22]

Examples of policy measures related to battery manufacturing include:

- In China, policy support aims to stimulate innovation and induce consolidation among battery manufacturers, giving preference to those that offer batteries with the best performance.
- In the European Union, the Strategic Action Plan for Batteries in Europe was adopted in May 2018. It brings together a set of measures to support national, regional and industrial efforts to build a battery value chain in Europe, embracing raw material extraction, sourcing and processing, battery materials, cell production, battery systems, as well as reuse and recycling. In combination with the leverage offered by its market size, it seeks to attract investment and establish Europe as a player in the battery industry.
- In countries with a smaller domestic market, as is the case for Japan and Korea, the policy support is to reinforce export markets.

6. AT and CZ comparison

Austria and the Czech Republic are relatively easy to compare since they are of similar size and population. Both countries are part of the European Union, yet their way of approaching electromobility is different. It is essential for both of them to grab the opportunity of the upcoming e-mobility trend not only for the sake of environment, but also because the automotive sector is a significant employer in the region of central-eastern Europe.

6.1. Austria

E-mobility is often seen as an interdisciplinary issue, with the potential of several innovation fields such as energy, environment and transport. Austria has an extremely favorable starting position for implementing e-mobility, owing to the commitment that is reflected in well-established research and support programs, initiatives, and large demonstration projects, high technological know-how in enterprises, a well-developed transport system, as well as an efficient energy system featuring 70% renewable energy in the power supply mix. E-mobility in and from Austria is an enormous opportunity, mainly for the technology and business location Austria, to successfully position itself, with innovative state-of-the-art technology in the automotive and automotive supply industry, and with intelligent energy and mobility services, on international markets.[23] With every 9th job in Austria linked to the automotive industry and Austria having the 2nd highest E-Car inventor concentration in Europe, the development of alternative drive trains has become a critical factor in ensuring the competitiveness of the Austrian economy.

6.1.1. Vehicles on the road

Austria has a population close to 9 million[5], of which 57.3% is urban. In 2018, there were approximately 4.9 million[6] passenger cars registered in Austria which represents an increase of 64 percent in comparison with 1990. Some of the studies have shown that Austrian drivers are affected by high fossil fuel prices, which forced them to use public transportation and car-sharing models. More than half of their journeys lie within a five km distances, of which 30% is only up to two kilometers. Almost half of the car owner are not willing to pay more for electromobility. Still most of them are likely to buy firstly diesel (50%) and gasoline (30%), and then alternative ones like HEVs (15%) and BEVs (5%).[23] But, the trend for choosing alternative vehicles is positive and the number grows every year.

---

[5] The current population of Austria is 8,999,385 as of Tuesday, May 12, 2020, based on Worldometer elaboration of the latest United Nations data. https://www.worldometers.info/world-population/austria-population

[6] https://www.statista.com/statistics/452369/austria-number-of-registered-passenger-cars/

In January 2020, there were 5,041 million of passenger's vehicle on Austrian roads. Most of them were diesel-driven vehicles followed by petrol-driven cars. BEVs were third in a row by a number of vehicles, but that is hardly comparable to the share the first two types have. Compared to previous years, electricity-driven vehicles[7] are gaining more and more popularity, counting an increase of 3046% from year 2011 (Figure 19). Current number of all electric passenger vehicles is 38 592, which represents only 0.77% of all passenger vehicles.

Vehicle types, fuel types or energy source	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020 Jan
Passenger Vehicle Class M1	4,513,421	4,584,202	4,641,308	4,694,921	4,748,048	4,821,557	4,898,578	4,978,852	5,039,548	5,040,565
Petrol incl. Flex-Fuel	1,997,066	2,001,295	2,003,699	2,011,104	2,019,139	2,038,019	2,080,434	2,139,239	2,179,236	2,179,998
Diesel	2,506,511	2,570,124	2,621,133	2,663,063	2,702,922	2,749,046	2,770,470	2,776,332	2,772,854	2,770,410
Battery Electric Vehicle (BEV)	989	1,389	2,070	3,386	5,032	9,073	14,618	20,831	29,523	30,128
Compressed natural gas CNG (monovalent/bivalent)	2,670	3,109	3,651	4,262	4,775	5,031	5,206	5,542	5,745	5,761
Plug-In Hybrid Electric Vehicle (PHEV)	n/a.	n/a.	408	776	1,512	2,287	3,948	5,710	7,807	8,423
Fuel Cell Electric Vehicle (FCEV)	n/a.	n/a.	n/a.	3	6	13	19	24	41	41
Electric Vehicle Population M1 (BEV, PHEV, FCEV)	989	1,389	2,478	4,165	6,550	11,373	18,585	26,565	37,371	38,592
Electro Vehicle – Change on Previous Year	180.2%	40.4%	78.4%	68.1%	57.3%	73.6%	63.4%	42.9%	40.0%	39.2%
Electric Vehicle Share in Population M1	0.02%	0.03%	0.05%	0.09%	0.14%	0.24%	0.38%	0.53%	0.74%	0.77%

Figure 31 Vehicle population by vehicle type, fuel type and energy source; passenger cars [24]

The following figure displays the growth of electric vehicle population. It rose moderately between 2010 and 2012 (approximately 1,400 in 2012), and continued to rise sharply since then.

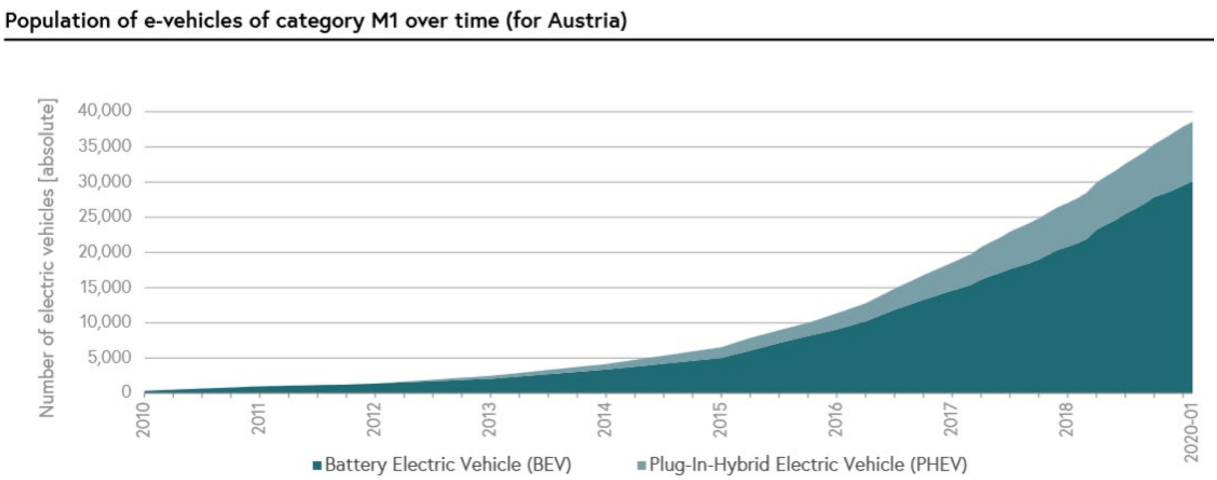


Figure 32 Population of passengers e-vehicles (category M1) over time (for Austria)[24]

In 2020, the share of EVs in newly registered vehicles was 5.46%. In January, the most popular model was the Renault Zoe with 168 units, followed by the BMW i3 with 63 units and the Hyundai Kona with 57 units. In the market share of new registrations in January 2020, Renault takes first place with around 24%, followed by Hyundai with about 11% and then Tesla with approximately 10%. [14]

[7] BEVs+PHEVs+FCEVs

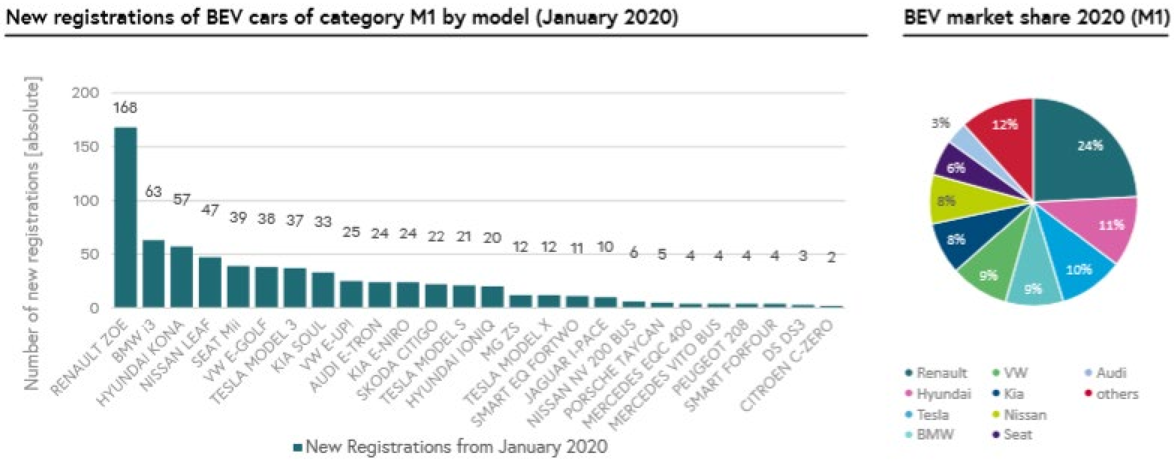


Figure 33 New registrations of BEV cars by model (January 2020) and their market share [24]

There are also other types of electric vehicles on roads in Austria. Their number isn't high yet, but it is expected to grow as technology improves. Most of them are Motorbikes and similar vehicles. The numbers are shown in the following table:

Further Electric Vehicles of the Classes L, M, N	4,024	5,120	5,594	6,067	6,532	7,524	8,912	10,920	13,918	14,154
Motorbikes/Tricycles/Quadricycles (Class L)	3,772	4,565	4,835	5,116	5,324	5,907	7,057	8,614	11,096	11,293
Busses Class M2 and M3	116	126	139	131	138	149	143	154	176	182
Duty Vehicle Class N1 (< 3.5 ton)	135	428	619	819	1,069	1,467	1,711	2,141	2,633	2,666
Duty Vehicle Class N2, N3 (> 3.5 ton)	1	1	1	1	1	1	1	11	13	13

Figure 34 Vehicle population by vehicle type, fuel type and energy source, other types [24]

In Austrian urban areas, especially in Vienna, there is increased use of electric scooters as a transport mean throughout the city area. There are also several company's offering it's renting for low prices. Although it is a 100% electrical mean and it is strongly represented in traffic, it is questionable if it replaces cars or pedestrians. Vienna is also offering an extraordinary attraction, a ride with the first driverless electric-powered bus.[25]

6.1.2. EV supply equipment and charging infrastructure

Renewable energy accounts for 78.4% of Austrian energy production, 29.8% of gross inland energy consumption and 32.5% of gross final consumption of energy, which makes Austria a very favorable starting position for sustainable e-mobility.

At the end of last year, there were 3,746 normal charging points and 554 fast charging points in Austria, that is one Normal Charging point (NCP) on 10 vehicles and one Fast charging point on about 67 vehicles. The figure following shows publicly available regular and fast charging points according to Directive 2014/94/EU:

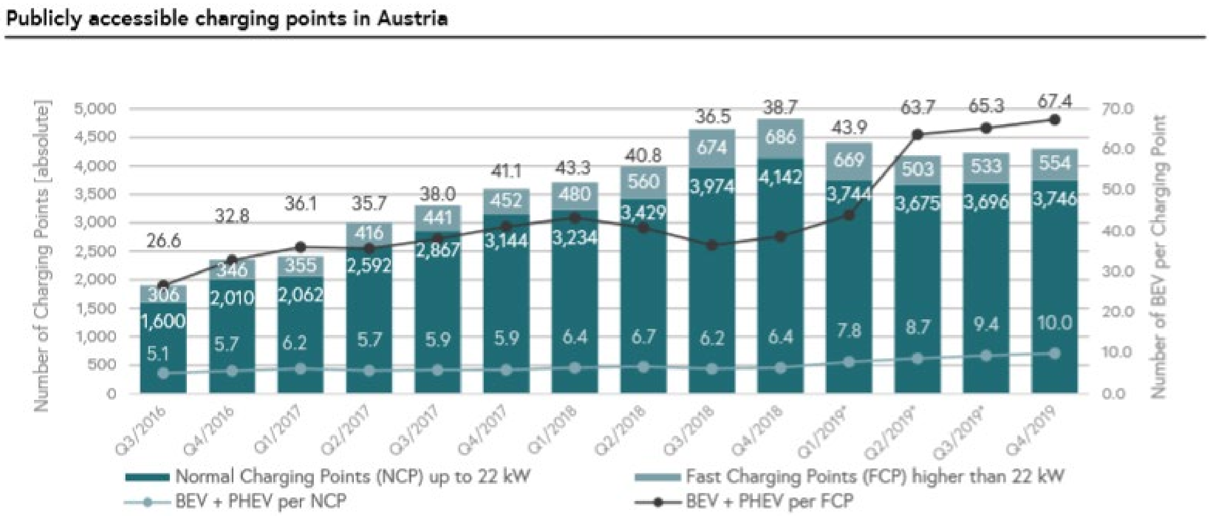


Figure 35 Publicly accessible charging points in Austria [24]

Austrian companies are active in charge point manufacturing, the operation of charge points as well as in the provision of services surrounding charge point operation and use. Nearly all of Austria's charge points are operated either by local or regional energy suppliers (many of which formed the e-mobility association BEÖ in 2015) or the company Smatrics, which is a joint-venture of energy company Verbund and Siemens. The potential for new participatory business models (similar to those already used in renewable energy) is shown by Austrian company ELLA, which builds charging infrastructure crowd-financed by citizen participation. E-Mobility services are supplied by a number of companies ranging from start-ups to large multinationals with e.g. NTT Data steering its international e-mobility business from Austria. With e-mobility also covering FCEV and the corresponding infrastructure, it is important to note that Linde AG started series production of H_2 infrastructure in Vienna in 2014. [15] Industry and research are also collaborating in the technology platform Smart Grids Austria (www.smartgrids.at), which is working on a transition from research and development to an Austrian lead market.

6.1.3. Austrian Automotive Industry

Automotive Industry is one of the most successful branches in Austria, with more than 370.000 employees, of which 41.000 in the production sector. It has an annual turnover of 43 Billion €. In R&D[8], 60 Million € are funded each year, counting 17,1% of all employees who have an average salary of 24.900 €.

Based on its inhabitants Austria has the second-highest concentration of E-Car inventors in Europe (3.2 inventions per 100.000 inhabitants) and is only behind Germany (4.1). Important companies include AVL List (45 patents, 58 inventors), Magna Steyr (16, 21), Magna Powertrain (13, 26), Siemens (9, 15), Fronius International (9, 14), Bosch (7, 4), Magna ECar (7, 13), Kapsch Trafficcom (7, 3) or KEBA AG (7, 2). [26]

[8] Research & Development (R&D)

The E-Bike market is also very dynamic in Austria, even the biggest Austrian producer of bicycles, KTM Fahrrad GmbH, announced in the beginning of 2016 that E-Bikes account for half of their annual revenue.

By a 2016 E-MAPP study[9], the Austrian automotive industry has high innovation potential in area of electric engines, battery technology, fuel cells and power electronics. Also, lightweight design shows good value-added potential for Austria though this cannot be accurately traced back to e-mobility. Austrian competence ranges from the component level such as battery production to system integration.

6.1.4. Policy on e-mobility

Austria sets a wide-range of policies on the national, regional, and local levels to promote e-mobility. The strategic framework is provided on the national level by the Electromobility Implementation Plan "Electromobility in and from Austria", which was jointly published by the Transport, Economics and Environment Ministries. Some of Austria's 9 federal states have regional e-mobility strategies, and some of the larger cities have also integrated e-mobility in their local mobility planning (Figure 24).[26]

Figure 36 Examples of Austrian national, regional and local level e-mobility strategies [15]

On national level is also active climate protection programme *'klima:aktiv mobil'*, which offers urban areas (cities and municipalities) consultation and financial support for the implementation of mobility management measures. Transport Plan Austria, issued by the Federal Ministry for Transport, Innovation and Technology, provides national guidance on transport planning, which includes a strong focus on Sustainable Urban Mobility Plan (SUMP).[27] Although it is SUMP is not compulsory for Austrian cities, it is compiled with transport plans in most of them, especially in Vienna, which is actively engaged in compiling mobility plans following the SUMP approach, that resulted with a new Urban Development Plan

[9] (BMVIT, E-MAPP – E-Mobility and the Austrian Production Potential), conducted by Fraunhofer Austria, AMP and VIF

called STEP 2025. The STEP 2025 Plan provides a multifaceted overview of measures to steer Vienna's development, and this future-oriented mobility strategy was even acknowledged by the European Commission on 20 April 2016 with the 'Sustainable Urban Mobility Planning Award'.

Figure 25 gives a broad overview of policy incentives in Austria. The most important include:

- On the national level: Vehicles with CO_2 emissions of 0 Gramm (BEVs and FCEVs) are completely exempted from Registration tax, while hybrids have an allowance of €600. Also, such vehicles are eligible for pre-tax deduction. Besides, the national procurement agency BBG has started a tender for EVs.
- On the regional level: With building codes in Austria being a matter of regional legislation several federal states plan adapting such that charging infrastructure can be easier installed. Also, in the context of implementing Directive 2014/94 in Austria, regions and national level together work on a unified permission system for the installation of charging infrastructure.
- On the local level: Municipalities' policy is quite varied with several cities having introduced e-mobility incentives.

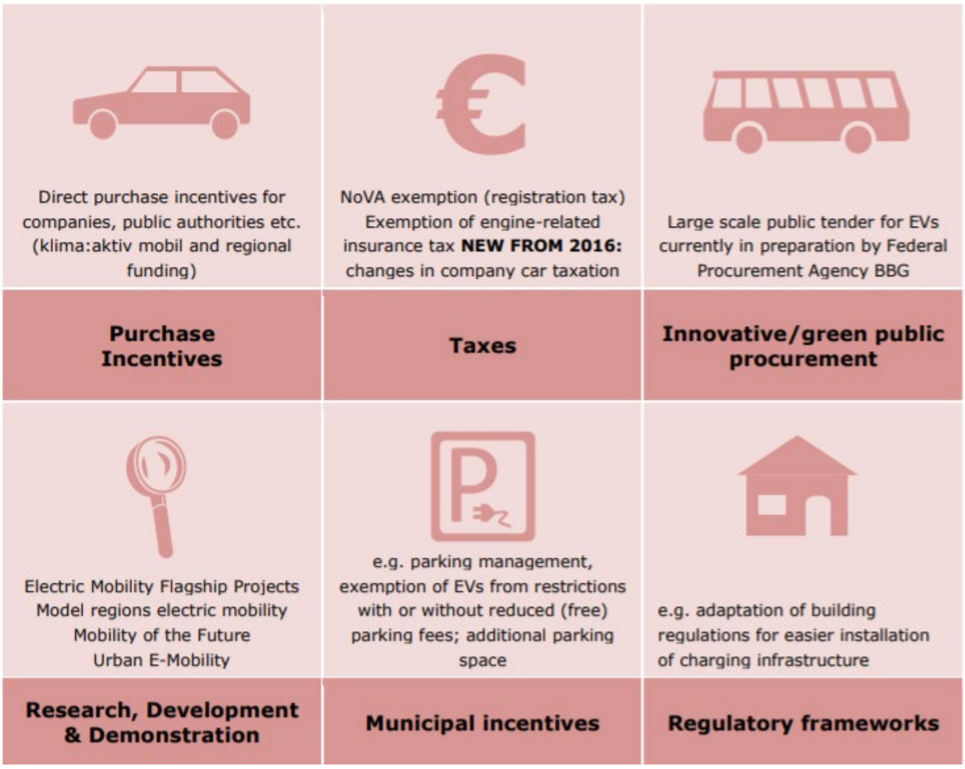


Figure 37 Overview of Austrian policy incentives for e-mobility [26]

6.1.5. Regulatory conditions and funding programs

As said, already a multitude of activities and initiatives on behalf of the Austrian Federal Government, the federal provinces, the cities and municipalities, has been triggered by projects in the fields of research, development, demonstration and model projects, as well as support initiatives all of which have generated most valuable experience, knowledge, and a positive attitude vis-à-vis electromobility. Overall R&D-funding volume for Promotion of alternative propulsion systems and fuels is cca 60 M€ per year.

Already has it been distributed by following the scheme:

- 66,1 Million for electromobility, hybrid and storage technologies.
- 28,3 Million for Fuel cell technology and vehicles
- 26,7 Million for fuels
- 5,4 Million for vehicles with combustion engines
- 4,4 Million for exhaust gas aftertreatment and thermal management
- 3,1 for lightweight
- 1,7 Million for autonomous vehicle's and vehicle electronics [28]

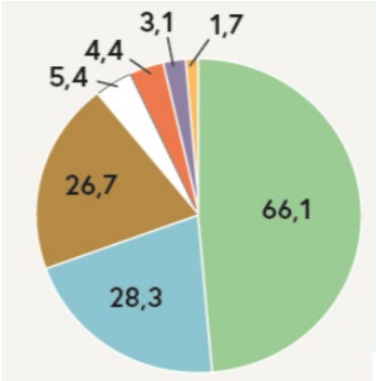


Figure 38 Distribution of technologies in funded R&D-project in EUR [19]

Among other financial Incentives, there are direct aids for vehicle owners. From 2007 to 2013 10,000 EVs were funded with 10.8 M €, among them was 7778 E-Bikes, 566 E-Scooter/Motorcycles and 1118 E-Cars and light duty vehicles. New funding flat rates for EVs are for E-Bikes €400, for E-Scooter €500 and for E-Car €4000.[29]

For promoting EVs infrastructure €400,000 are available for companies, local communities, and associations if they promote climate-friendly traffic measures particularly vehicle fleets turning to alternative drives.

The 'klima:aktiv program' is included as other measures which proffers integral aid in this field to private companies, local associations, and communities.

Companies, municipalities, and cities also receive financial support to develop and implement environmentally-friendly movability management, which adds solutions that are more effective in traffic. In this regard, funding rates are 20% of eligible costs of companies and 40% of eligible costs of cities, municipalities, and regions.

6.1.6. Electromobility services

For Austria as for many markets "Mobility as a Service" is now used as a concept describing the use of a variety of mobility service such as public transport, car sharing, taxis or city bikes through a single interface which is offered by mobility operators. Customers receive information, book and pay services through mobility operators via (often also) mobile applications. Urban areas have well-developed public transport system, bicycle and walking infrastructure so these concepts

Figure 39 E Car-Sharing and E-Taxi schemes in Austria

are working very well. The interest for e-car rental concepts exceeded the supply by far, especially due hotels and commuters.

Figure 40 eMORAIL – combining car, tram and bike [13]

Train operators still realized the possibility and benefits of integrated e-mobility for commuters. eMORAIL (Integrated eMobility Service for Public Transport) is a pilot project of the Austrian train operator ÖBB and offers a mobility package for commuters - from their home to their workplace (see Figure 5). It's a systematic combination of public transport and electric individual transport (e-car, train and e-bike) for the first and last miles.

Mobility services also include the freight sector. A few Austrian projects are focusing on the goal of electrical vehicles for urban freight logistics. CITYLOG EMF (Electric Multifunctional Vehicle) is one of them and has the vision of a holistic approach concerning the reorganization of logistic structures and the concomitant reorganization of the transport technology of goods in sensitive areas - made in Austria. The e-motor propulsion is fuel-cell (hydrogen) based and the vehicle concept consists of a series of 'self-driven' vehicles and 'trailers' that can be coupled to a train, and un-coupled for loading and unloading operations. Every vehicle is 'driving' itself, led by electronic signals to follow the trajectory of the first one, each vehicle is using its separate propulsion unit. Brake-energy will be saved and can be used if the vehicle needs more power. The serial production is expected to be ready in 2016 (see Figure 7). A similar project - "EMILIA" "Electric Mobility for Innovative Freight Logistics in Austria" - aims of the development and experimental implementation of new e-freight logistics concepts for urban areas, by increasing range and reducing costs. [28]

Figure 41 EMILIA - Electrical vehicles for urban freight logistics

6.2. Czech republic

Czech republic has a population close to 11 million with 73,8 people living in urban areas. In 2019, there were approximately 6 million passenger cars registered in Czechia. Czech driver is responsive to the price of the fuel; therefore, it's national plan so far prioritizes natural gas over more significant public charging infrastructure development.

6.2.1. Vehicles on the road

Comparing vehicles in use by age Czechia´s average car is used 14,5 years oppose to Austrian, 8,9 years. This difference creates even more pressure for faster adoption of EVs in the country. Most recent statistics from Central Vehicle Register from January to July 2019 are represented in the table.

Registration of new passenger vehicles depending on the type (January-July)	gas	diesel	CNG	LPG	EV	PHEV	hybrid	total
2018	109150	51366	1540	593	396	188	2328	165422
2019	**105519**	**40838**	**1029**	**331**	**421**	**156**	**4283**	**150314**
year to year change	-3631	-10528	-511	-262	25	-32	1955	-15108
	-3,3%	-20,5%	-33,2%	-44,2%	6,3%	-17,0%	84,0%	-9,1%

Figure 42 Registration of new passenger vehicles in the Czech Republic [30]

From the point of view of individual types of fuels, the current trend in new balance start to appear. The largest decrease (-44.2%) was recorded for LPG passenger cars, but fewer registrations were also recorded for CNG (-33.2%), diesel (-20.5%) and petrol vehicles (-3.3%). Interest in hybrid drives increased significantly, with 84% more being recorded year-on-year. Even the total number of cars registered decreased we see positive changes between electric vehicles.

6.2.2. EV supply equipment and charging infrastructure

Figure 43 shows electricity generation by source in Czech Republic from 1990 to 2018

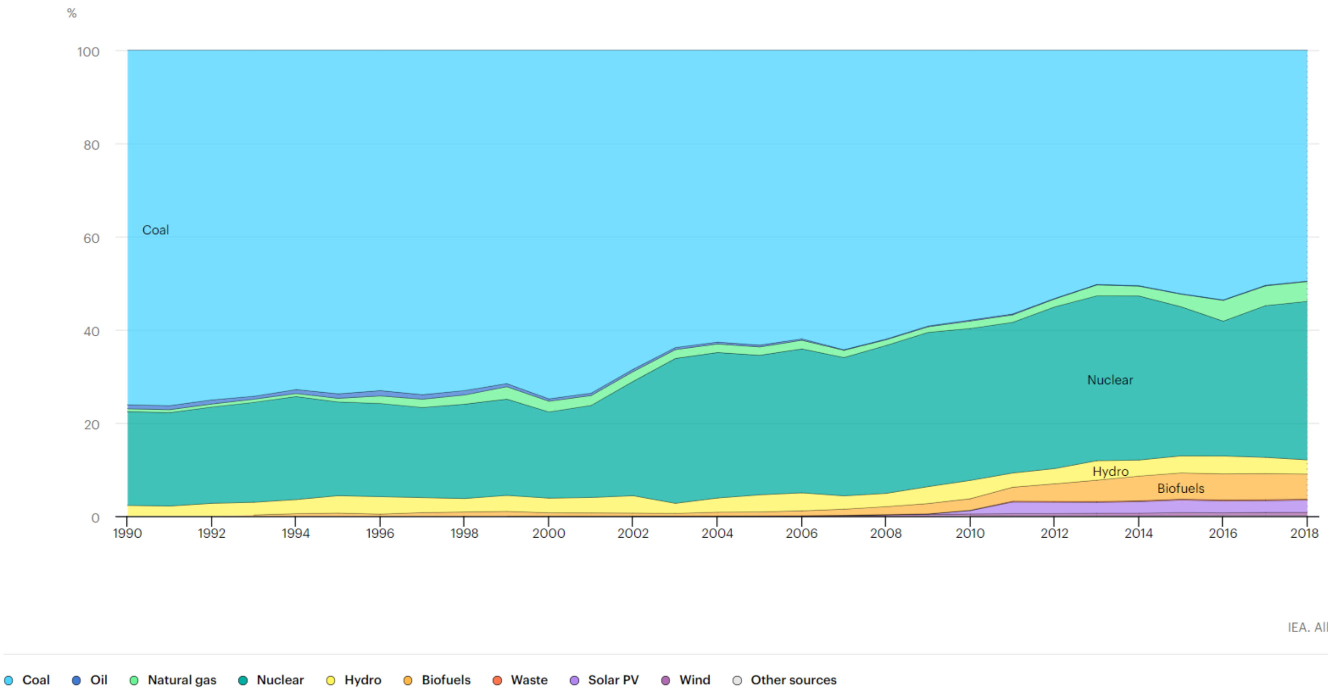


Figure 43 Electricity generation by source, Czech Republic 1990-2018

Being a net exporter of the energy, for the country, itself share of renewables would be higher. Although comparing to Austria, Czech energy mix is relatively dirty. Slow deployment of the renewables is caused by multiple factors. Potential of hydropower has already been utilized, and it is difficult to find new spots for new water powerplants. Another reason of slow renewable deployment is lousy experience from the years 2008 to 2011 when generous incentives were placed for new photovoltaic installations. Because of that, the general public is up to this date still repulsive when talking about solar and wind powerplant projects.

There is no exact statistic on available public charging spots. Estimation is around 450 charging stations with three main providers ČEZ, E.ON and PRE. We should also mention the year 2022, by this year another 375 fast-charging stations will be built thanks to OPD (Operational Program Transport) subsidies in the amount of 130 million Czech crowns.[31]

6.2.3. Czech Automotive Industry

With 20% of the country's industry connected with the automotive industry, the health of the Czech economy relies on car production. In 2016, 127 automobiles were produced per 1,000 inhabitants (1.35m altogether), making the country the second-largest car producer per capita in the world (behind Slovakia). The country is the home of Škoda Auto and other car producers such as Hyundai, Toyota, Peugeot, and Citroën. More than half of the top 100 global tier-one suppliers to the automotive industry operate in the country. E-mobility is being discussed and has been at the core of several official programs. The country has significant potential for the development of EVs.[32]

6.2.4. Policy on e-mobility

There is no specific regulation solely for EVs in the Czech Republic. However, there are some partial regulations favoring electric vehicles.

Tax benefits – there is an exemption from road tax for EVs or hybrid vehicles. Generally, only cars and other vehicles used for doing business are subject to road tax. This measure, therefore, doesn't influence consumers. It also has a limited effect on businesses as the road tax is usually quite low. [33]

No highway tolls - From 1 January 2020, the obligation for drivers of electric cars, plug-in hybrids, and hydrogen vehicles to buy motorway stamps has ended.

Dedicated parking spaces – there are some dedicated parking spaces for EVs including charging points (e.g. parking places only for EVs including a charger) in some cities such as Prague, Ostrava, Brno, Pilsen or other bigger cities. [34]

Benefits when parking EVs – EVs enjoy some preference in the parking policy in Prague (e.g. lower parking fees or allowing parking in residential areas for non-resident EVs).[35]

Preferred (bus) lanes – many have speculated that EVs will have different coloured number plates to clearly distinguish them from combustion engine vehicles. Recently all EVs can register for special plate starting with letters EL, so they are easier to recognize with more EV models coming out. In the future, EVs may receive preferential treatment in city traffic, such as the possibility to use specific lanes. Plans for such laws remain controversial and have attracted criticism on the basis that they could significantly complicate public transport. [36]

Subsidies – there have already been four low carbon technology subsidy programs, and the fifth one continues till 28.06.2020. 50 000 000 CZK are allocated in the last program. As of 10 February 2020, 203 applications for support had already been received, with a request for the allocation of a subsidy in the amount of CZK 92,304,000.

With regard to the significant under-utilization of previous calls of the Low Carbon Technologies support program - the allocation will be increased to the amount of 150,000,000 CZK.[37]

The target group of this incentive is small and medium-sized enterprises and large enterprises.[38]

Support for the installation of charging points – charging points are being constructed by private subjects, mostly large grid operators such as CEZ, E-on or PRE (a large electricity company). Some car manufacturers, such as Tesla are building charging points themselves. Building this infrastructure may be supported by a subsidy based on the Traffic Operation Programme 2014 – 2020, administered by the Ministry of Transport, under which CZK 116,8 billion (EUR 4,6 billion) may be used over time in different rounds. The current and the last round started on March 20th 2020. Only subjects that operate at least 10 charging points can apply for the subsidy and the deadline is June 30th 2020. Based on the approved projects within the completed three calls, the Ministry of Transport will support the installation of 777 charging stations. The aim of the OPD is a construction of the so-called additional network with minimum of 800 charging stations by the end of 2023. In total, the Ministry of Transport has allocated 1.2 billion crowns for the program for the support of infrastructure for alternative fuels within the OPD.

Simplification of obtaining a building permit - A big problem of the Czech Republic is a very long construction procedure. Unfortunately, this also applies to the construction of relatively small service stands, such as AC charging stations, which are often smaller than a conventional parking meter. Nevertheless, it is still necessary to go through a lengthy permitting process, which usually takes several months. But that should soon change.

In the third reading in the Chamber of Deputies, there is now a legislative proposal to amend the government bill amending Act no. 416/2009 on speeding up infrastructure construction. Thanks to this proposal, it would not be necessary to obtain a building permit or apply for a decision on the location of the building for the construction of slow charging stations up to 22 kW. This has the potential to significantly speed up construction time.

Preparation for charging infrastructure in new and reconstructed buildings – EU directive 2018/844 of the European Parliament and of the council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. Document includes set of goals that all EU countries must achieve. The amendment from the year 2018 is replacing article 8. These are the most important suggested duties for EU member states.

With regard to new non-residential buildings and non-residential buildings undergoing a major renovation, with more than ten parking spaces, Member States shall ensure the installation of at least one recharging point within the meaning of Directive 2014/94/EU of the European Parliament and of the council and ducting infrastructure, namely conduits for electric cables, for at least one in every five parking spaces to enable the installation at a later stage of recharging points for electric vehicles.

Concerning new residential buildings and residential buildings undergoing major renovation, with more than ten parking spaces, Member States shall ensure the installation of ducting infrastructure, namely conduits for electric cables, for every parking space to enable the installation, at a later stage, of recharging points for electric vehicles.[39]

It is up to the individual countries to devise their laws on how to reach these goals.

7. CONCLUSION

By definition, we must, at some point, achieve a sustainable energy economy, or we will run out of fossil fuels to burn, and civilization will collapse. Given that we must get off fossil fuels anyway and that virtually all scientists agree that dramatically increasing atmospheric and oceanic carbon levels is insane, the faster we achieve sustainability, the better.

The point of e-mobility in urban areas is to accelerate the advent of sustainable energy so that we can imagine far into the future and life is still good. That's what "sustainable" means, and it matters to everyone.

We are able to see new trends of electric vehicles penetrating market. Unfortunately, their deployment is still quite slow. Because of the ongoing pandemic we are able to see rapid decrease in sales of car overall. Many experts in the sector believe, that this is a great opportunity to speed up arising trends in sustainable mobility. The ball is now on the side of government officials and other stakeholders and they can decide how will they play it. It is great to see bright examples of excellent urban mobility planning in our region like awarded STEP 2025 urban development plan in Vienna. This gives countries like Czech Republic opportunity to learn from the experts and start the effort towards green recovery.

SUMMARY

In a world fighting with global warming and trying to reduce CO_2 emissions, transport sector plays a significant role. As one of the main producers of CO_2, it is necessary to make a change. This change is inevitable, and it must be rapid and comprehensive. Electromobility is a solution. Transferring to electricity driven vehicles lowers the emissions of CO_2 by vehicle, but what is with emissions made by electricity production? This paper will try to answer on what are the current possibilities and analyze overall development of electromobility. Historical improvement will show what are the lessons learned and how can today's technology be enhanced. Since EU is one of the main characters in this battle, overall development of electromobility will be analyzed and compared on its two members, Austria and Czech Republic.

Bibliography

[1] A. Ajanovic and R. Haas, “The impact of energy policies in scenarios on GHG emission reduction in passenger car mobility in the EU-15,” *Renewable and Sustainable Energy Reviews*, vol. 68. Elsevier Ltd, pp. 1088–1096, 01-Feb-2017.

[2] “File:Greenhouse gas emissions, analysis by source sector, EU-28, 1990 and 2017 (Percentage of total).png - Statistics Explained.” [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Greenhouse_gas_emissions,_analysis_by_source_sector,_EU-28,_1990_and_2017_(Percentage_of_total).png. [Accessed: 10-Jun-2020].

[3] “What you should know about electromobility - Infineon Technologies.” [Online]. Available: https://www.infineon.com/cms/en/discoveries/electromobility/. [Accessed: 10-Jun-2020].

[4] *SYSTEMS PERSPECTIVES ON ELECTROMOBILITY 2017 Edited by Björn Sandén and Pontus Wallgren*. .

[5] M. Nilsson, *Paving the road to sustainable transport : governance and innovation in low-carbon vehicles*. Routledge, 2012.

[6] “fifth avenue 1900.” [Online]. Available: https://fountainheads.goedkoopeenwebsitelatenmaken.nl/5th-avenue-1900/. [Accessed: 10-Jun-2020].

[7] D.-I. D. F. and D.-I. M. L. U. D.-I. W. GAWLIK, “Smart Grids und Elektromobilität,” 2019.

[8] “Largest emission-free electric ferries for ForSea | ABB Marine & Ports - Marine References.” [Online]. Available: https://new.abb.com/marine/marine-references/forsea. [Accessed: 11-Jun-2020].

[9] “This Stunning Chart Shows Why Battery Electric Vehicles Win | CleanTechnica.” [Online]. Available: https://cleantechnica.com/2020/06/10/this-stunning-chart-shows-why-battery-electric-vehicles-win/amp/?__twitter_impression=true. [Accessed: 11-Jun-2020].

[10] “(No Title).” [Online]. Available: https://www.gogoro.com/gogoro-network/. [Accessed: 11-Jun-2020].

[11] “Pantograph Charging | Pantograph Down | ABB.” [Online]. Available: https://new.abb.com/ev-charging/products/pantograph-down. [Accessed: 12-Jun-2020].

[12] “Load management & monitoring | Digital Energy Solutions.” [Online]. Available: https://www.digital-energysolutions.de/en/load-management-and-monitoring/. [Accessed: 11-Jun-2020].

[13] “SAE International Releases Updated Visual Chart for Its ‘Levels of Driving Automation’ Standard for Self-Driving Vehicles.” [Online]. Available: https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-“levels-of-driving-automation”-standard-for-self-driving-vehicles. [Accessed: 12-Jun-2020].

[14] “Lyft’s self-driving car service in Vegas passes 50,000 rides.” [Online]. Available: https://mashable.com/article/lyft-self-driving-cars-las-vegas-50000-rides/?europe=true. [Accessed: 12-Jun-2020].

[15] “THE RECIPE FOR TENFOLD RESOURCE PRODUCTIVITY IMPROVEMENT.”

[16] A. Ajanovic and R. Haas, “Economic and Environmental Prospects for Battery Electric- and Fuel Cell Vehicles: A Review,” *Fuel Cells*, vol. 19, no. 5, pp. 515–529, Oct. 2019.

[17] E. Y. Elbanhawy, “To understand, model and design an e-mobility system in its urban context,” *undefined*, 2015.

[18] “Electromobility: Definition, Vehicles and Future.” [Online]. Available: https://www.spotlightmetal.com/electromobility-definition-vehicles-and-future-a-810482/. [Accessed: 10-Jun-2020].

[19] A. Ajanovic and R. Haas, “Electric vehicles: solution or new problem?,” *Environ. Dev. Sustain.*, vol. 20, no. 1, pp. 7–22, Dec. 2018.

[20] “IGNITIS innovation hub.” [Online]. Available: https://ignitisinnovation.com/2019/12/11/vehicle-to-grid/. [Accessed: 10-Jun-2020].

[21] “Smart energy: Why vehicle-to-grid technology is on the move | Internet of Business.” [Online]. Available: https://internetofbusiness.com/smart-energy-why-vehicle-to-grid-technology-is-on-the-move/. [Accessed: 10-Jun-2020].

[22] “Global EV Outlook 2019 – Analysis - IEA.” [Online]. Available: https://www.iea.org/reports/global-ev-outlook-2019#executive-summary. [Accessed: 10-Jun-2020].

[23] A. Dorda and M. Nikowitz, “Strategy and instruments for a successful implementation of electromobility in Austria.”

[24] R. Zoe, “E-Vehicles Population E-Vehicles New Registrations Electromobility in Austria,” 2020.

[25] “Driverless Buses in Vienna’s Seestadt On The Road Again | Metropole.” [Online]. Available: https://metropole.at/driverless-buses-in-viennas-seestadt/. [Accessed: 16-Jun-2020].

[26] “IA-HEV Task 24 : Economic Impact Assessment of E-mobility-Austria THE ECONOMIC IMPACT OF E-MOBILITY IN AUSTRIA TASK 24 COUNTRY REPORT.”

[27] “Austria | Eltis.” [Online]. Available: https://www.eltis.org/mobility-plans/member-state/austria. [Accessed: 10-Jun-2020].

[28] A. Dorda, “Welcome to the 14 th A3PS Conference Diverse Powertrain Concepts for a carbon-neutral future.”

[29] J. Cansino, A. Sánchez-Braza, and T. Sanz-Díaz, “Policy Instruments to Promote Electro-Mobility in the EU28: A Comprehensive Review,” *Sustainability*, vol. 10, no. 7, p. 2507, Jul. 2018.

[30] “Historicky nejvyšší počet registrací elektromobilů v ČR na Evropu nestačí | Centrum dopravního výzkumu, v. v. i.” [Online]. Available: https://www.cdv.cz/tisk/historicky-nejvyssi-pocet-registraci-elektromobilu-v-cr-na-evropu-nestaci/. [Accessed: 12-Jun-2020].

[31] “Ministerstvo dopravy ČR - Média a tiskové zprávy.” [Online]. Available: https://www.mdcr.cz/Media/Media-a-tiskove-zpravy/Na-nove-dobijeci-stanice-elektromobilu-pujde-dalsi. [Accessed: 12-Jun-2020].

[32] “Automobilový průmysl - CzechInvest.” [Online]. Available: https://www.czechinvest.org/cz/Sluzby-pro-investory/Klicove-sektory/Automobilovy-prumysl. [Accessed: 12-Jun-2020].

[33] “16/1993 Sb. Zákon o dani silniční | Aktuálne znenie.” [Online]. Available:

https://www.epi.sk/zzcr/1993-16#p3. [Accessed: 13-Jun-2020].

[34] “Mapa dobíjecích stanic | Elektromobilita.cz.” [Online]. Available: https://www.elektromobilita.cz/cs/mapa-dobijecich-stanic. [Accessed: 13-Jun-2020].

[35] “S elektromobilem můžete parkovat v Praze zdarma i v zónách pro rezidenty. Zde je návod - Aktuálně.cz.” [Online]. Available: https://zpravy.aktualne.cz/ekonomika/auto/vyhodou-elektromobilu-v-praze-je-bezplatne-parkovani-prinasi/r~ec4ec2da778f11e7bc9f002590604f2e/?redirected=1528818509. [Accessed: 13-Jun-2020].

[36] “Příloha k memorandu o budoucnosti automobilového průmyslu v České republice ‘Český automobilový průmysl.’”

[37] “NÍZKOUHLÍKOVÉ TECHNOLOGIE - Elektromobilita - V. výzva | MPO.” [Online]. Available: https://www.mpo.cz/cz/podnikani/dotace-a-podpora-podnikani/oppik-2014-2020/vyzvy-op-pik-2019/nizkouhlikove-technologie---elektromobilita---v--vyzva--251085/. [Accessed: 13-Jun-2020].

[38] “MINISTERSTVO PRŮMYSLU A OBCHODU Řídicí orgán OPERAČNÍHO PROGRAMU PODNIKÁNÍ A INOVACE PRO KONKURENCESCHOPNOST 2014-2020.”

[39] “DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (Text with EEA relevance).”