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1. Introduction

A rapid evolution in mobility is currently underway worldwide, triggered by advances in technology and in society in general. Electric mobility is gaining momentum at the same time as autonomous driving. The rapid adoption of electric mobility is also helping the planet to achieve its objectives related to greenhouse gas emissions and air pollution in general. To make this change significant, the share of EV's will have to increase worldwide and these EV's will have to be usable for a reasonable service life and mileage.

Global sales of new EVs have been growing steadily in the past 10 and especially 5 years. Despite this rapid growth, the European market cap of these technologies is still relatively small and dependent on subsidies for both vehicles and infrastructure. Also, most EVs and public charging infrastructure in the EU are concentrated in the western and northern part of the continent, with the DTP member states having some of the smallest adoption rates. There is however an ever-increasing rate of adoption also in most DTP states that are part of this project. The EU has taken important measures to facilitate the adoption of charging infrastructure and the market cap of EVs. There are also various initiatives within the individual states, regional and local level which aim to speed up the adoption of these technologies. The extent to which these initiatives have been adopted and financed correlates directly to a bigger market share for EV's.

At the end of 2018 there were around 60 electric motor car models available to European customers, and this number is expected to rise to 214 by 2021 according to a study by transportenvironment.org. More affordable cars should see a bigger share of consumers switching from ICE cars to EVs. After the early success of Tesla Motors and other start-ups, many of them from China, it seems that the big car manufacturers are ready to embrace the EV. Of the 214 models stated above, 92 will be fully electric and the rest plug-in hybrid. Both these technologies rely on the rapid adoption of charging infrastructure in order to make it a viable alternative for most consumers. This means that up to a quarter of vehicles produced by 2025 may have a plug and will help the manufacturers to meet the EU's car $CO2$ emissions of 95 g/km by 2025. Slovakia is forecast to be making the highest number of EVs per capita by 2025. Czech Republic and Hungary will also be significant production centres, while large lithium-ion battery plants will be built all over the European continent.

The change in mobility solutions is also seen in the public transport sector. Electric buses are becoming a reality in many European cities and hybrid solutions are also on the rise. These developments are mostly driven by economy, as public transport is based on fixed lines where sizing of the battery and hence point of return on of investment can be easily calculated. Last but not least, the use of non-polluting vehicles within the nearest vicinity of housing and other public areas gives the highest motivation to go electric. Still, as the number of production of public means of transport exists in fractions compared to the automotive sector, but also as it has to reflect local geographical needs, public authorities, on the local and up to the national level, must work together with industry to develop the standards and good practices of the future.

The trend in Europe and in the DTP countries is for a constant increase in the availability of charging infrastructure, especially in densely populated areas. These facilities have been set up by municipalities, private companies, NGOs and even car manufacturers such as Tesla and Nissan, in order to facilitate the adoption of EVs.

Due to the existence of so many standards and developers of charging infrastructure, one of the key challenges for the future will be to implement those solutions that meet all the criteria necessary for consumer satisfaction and widespread adoption of EVs. Some of these criteria are availability of compatible charging stations, availability of quick charging any time, industry standards for charging, and universal standards for billing. Doing all these right in a specific region will have a measurable positive impact on the adoption of electric mobility.

There are also challenges, such as the relatively high cost of EVs coupled with smaller range compared to ICE vehicles and longer charge duration (using most technologies). These challenges are however of a purely technical nature and the improvements that have been made so far in these fields foresee similar developments in the future. Other temporary changes that may have to be made are linked to human behavior related to trip planning and driving behavior in general (efficient, defensive driving will positively impact EV range). This last point may be however made irrelevant with the advent of self-driving cars. Regarding trip planning, there are online platforms available that can help the user to plan a trip depending on their EV's battery and the availability of charging stations along the route.

Planning and incentivizing the adoption of these technologies will remain critical but the forecast for now is positive, and Europe and DTP states are set for a constant increase in the number and quality of charging stations and range of EVs, and thus for an increased acceptance and adoption of electric vehicles. Electric Cars

Plug types and charging standards

Currently there are three practical charging solutions for EVs available: conductive charging, inductive charging and battery swap. Conductive charging is by far the most widespread and can be split in two categories, AC and DC charging, with varying charging speeds. Cars can accept faster charging speeds than in the past and this trend is set to continue, so it is important that the charging infrastructure keeps up with these developments. Chargers using these technologies can come in the form of charging facilities similar to petrol stations (true for fast charging DC infrastructure) but can also be integrated in the roadside environment, such as street lights, parking meters, even hidden beneath the pavement, etc. (mainly slow AC charging).

It is up to the local authorities to decide about the technology that they will encourage or implement in their municipalities but they must keep in mind that these technologies will have to be part of a larger local, national and regional mobility ecosystem. The local adoption of a specific charging infrastructure will affect the types of EVs that local customers will purchase. As such, it is critically important that local and state authorities work together with all other actors involved in electric mobility when adopting and implementing a plan for the future in this field.

It has been shown that the availability of charging infrastructure plays an important role in the adoption of EVs. Overwhelmingly, for a common daily use, most consumers want to charge their EVs at home and or at work. The priority will therefore be to implement these solutions in a way that is useful for the end customer and sustainable in terms of the power grid and the local development. On the other hand, consumers also signal that in order to fully swap to EVs from gasoline cars, that they will require fast chargers that will allow them for quick "refills" during long journeys, for example.

The analysis below will focus on the current and future developments of electric charging infrastructure in the DTP countries that are part of this project, namely: Austria, Croatia, Czech Republic, Hungary, Romania, Slovak Republic, Slovenia, Serbia and Montenegro.

Key barriers, which can be observed, are that the majority of consumers aren't adapting to or adopting the new technology for a variety of reasons such as high e-vehicle price, lower price for polluting ICE cars, limited range of EVs, low price of oil, mediocre availability of charging stations, long charging time and inconsistent nature of subsidies/incentives.

For the deployment of a charging infrastructure, the main barriers for key stakeholders and investors can be seen in investment costs, billing technologies & systems, unpredictable share of electric vehicles in the mobility market, consumer behavior and uncertainty about future market players. Last but not least, the growing momentum of the hydrogen technology in cars and whole economy is posing a new threat and uncertainty in counting the economic return of the investment into charging infrastructure.

It can be said that e-mobility and its infrastructure are already topic across the regions of the project partnership, which also show the number of documented done projects and studies described in the feasibility studies.

Plans and incentives for further development should include research in recharging time and infrastructure, wall boxes, highway car parks, public refueling, regional target groups and location planning.

In recent years, the development of electric vehicles and charging technology has progressed strongly. The electric vehicle cannot anymore be considered only as a vehicle concept for purely urban use as even long-distance journeys with electric vehicles are possible provided that proper charging infrastructure is available. It remains to be seen whether advanced e-vehicle concepts will be introduced to the market in the upcoming years, which will have long-term suitability. If these vehicles will be able to replace conventional fossil fuel driven vehicles due to their improved performance, the demand for quick-charging stations will also increase rapidly. Comparing the small proportion vehicles with their use of the rapid-loading columns, an increased demand for this technology, especially on motorways and expressways, is expected in the future. Nevertheless the same can be said about the hydrogen fuel cell vehicles, which share the same constraints both in vehicle costs and in infrastructure, nevertheless they are backed by strong financial consortiums.

This includes the location and geographical distribution of the charging infrastructure, charging concepts and connection performance, standardization and standardization of charging cables, plugs and communication facilities, charging stations safety requirements and possible network effects by the rectifiers of the charging units of the batteries. The establishment of the charging infrastructure is a critical factor in the initial phase of electric mobility, in particular, when it comes to reducing the advantage of the low energy costs of electrically driven vehicles by means of cost-intensive charging infrastructure. This also applies to billing systems at public charging stations.

For the charging of EVs with electric power, three practical technological solutions exist: charging the vehicle with a connector (conductive charging), via electromagnetic induction (inductive charging), or by taking the depleted battery out and replacing it by a charged battery (battery switching). Such charging facilities can be implemented as stand-alone facilities or integrated into other street furniture, such as street lighting or parking meters.

Conductive charging

Conductive charging means that electric power is transferred to the vehicle by using an electric cable and a connector. The actual charging of the battery within the vehicle must take place via a direct electric current (DC). The alternating current (AC) from the electricity network can be directly passed into the electric vehicle, where it is rectified to DC for charging the batteries. This is referred to as AC charging, or on-board charging because the charger/rectifier is located inside the vehicle.

Alternatively, the current can be rectified outside of the vehicle and DC fed into the vehicle. This is called DC charging, or off-board charging because the charger/rectifier is located outside the vehicle. In the following, first different forms of conductive charging facilities in general will be presented. Then the discussion will focus specifically on AC charging and DC charging respectively.

There are different ways in which battery electric vehicles or PHEVs can be charged via plug-in charging. Four 'modes' of charging technology are commonly available. Each of them can involve different combinations of power level supplied by the charging station (expressed in kW), types of electric current used (alternating (AC) or direct (DC) current), and plug types.

The power level of the charging source depends on both the voltage and the maximum current of the power supply. This determines how quickly a battery can be charged. The power level of charging points ranges widely, from 3.3 kW to 120 kW. Lower power levels are typical of residential charging points[1].

- Mode 1 (slow charging): allows vehicle charging using common household sockets and cables. It is commonly found in domestic or office buildings. The typical charging power level is 2.3 kW, but the overall limit is up to 3,6 kW. Household sockets provide AC current.
- Mode 2 (slow or semi-fast charging): also uses a non-dedicated socket, but with a special charging cable provided by the car manufacturer. A protection device

that is built into the cable offers protection to the electrical installations. It provides AC current. The charging power is within the same limit as Mode 1.

- Mode 3 (slow, semi-fast or fast charging): uses a special plug socket and a dedicated circuit to allow charging at higher power levels of up to 22 kW. The charging can be either via a box fitted to the wall (wall box), commonly used at residential locations, or at a stand-alone pole, often seen in public locations. It uses dedicated charging equipment to ensure safe operation, and provides AC current.
- Mode 4 (fast charging): also sometimes referred to 'off-board charging', delivers DC current directly to the vehicle. An AC/DC converter is located in the charging equipment, instead of inside the vehicle (hence off-board transformation of AC in the grid to DC in the battery) as for the other levels.

One disadvantage of high-power, fast charging is that the stronger currents mean that more electricity is lost in heat during the transfer, i.e. the efficiency is lower. Moreover, fast charging can decrease battery lifetime through battery overheating, reducing thus the number of total battery charging cycles. Fast DC charging points are also around three to ten times as expensive to install as a simple AC charger, so many users are reluctant to invest in the additional costs. While some new electric vehicle models are provided with a DC charging facility, others require the purchase of an additional charging device

Conductive charging facilities are built in diverse forms. Two basic forms can be identified. Wall-boxes are mounted on walls or posts. This is a cost-efficient solution for private or public parking garages, or parking spaces next to buildings. If charging facilities are to be installed at curb side parking spaces or in big open-air parking spaces, more expensive charging posts (also called charging pillars) must be used.

Each charging facility can have several socket outlets or connectors. Wall-boxes usually have 1 or 2, and charging pillars 1, 2, or 4 socket outlets or connectors. If wall-boxes or charging pillars are installed outdoors, the body housing needs to provide protection from weather and other environmental influences. These requirements are stated in the rule of application VDE-AR-N 4102 and the norm DIN VDE 0100-722. For an installation outdoors, a protection level of at least IP44 has to be implemented. This IP (intrusion protection) level stands for protection from intrusion by small objects bigger than 1 mm and protection from splash water. Charging facilities located next to roads have to be constructed in a way that they are protected from collisions. Such a protection can also be installed in front of the charging facility, for instance in the form of a bollard.

If the facility is installed in special environments with, for instance, extreme temperatures, high humidity, or possible flooding, the type of the casing has to be agreed upon by the distribution network operator.

Electricity can be distributed using single-phase or three-phase systems. Households commonly use single-phase power for lighting and powering appliances. It allows only a limited power load. Commercial premises commonly use a three-phase system, as it provides higher power.

Plug types

There are different types of charging plugs for chargeable vehicles. Type 1 is used in American (US) and Japanese vehicles, and Type 2 in European vehicles. The plug enables data exchange between the vehicle and the charging device. For example when the battery is full, the command signal travelling through the car switches the charger off.

The Type 1 connector is used in American (US) and Japanese chargeable vehicles. The connector enables single-phase current feed of up to 80 amperes. The battery charger in the vehicle determines the capacity of the current that can be used for charging the car.

Type 1 charging plug and socket
Source: https://plugit.fi/en-gb/article/etusivu/types-of-charging-plugs-for-electric-vehicles/135/

Type 2 connectors are used in European vehicles. They are found in standard public charging points in Europe. The connector enables 3-phase current feed up to 63 amperes, however up to 32A is in general use.

Type 2 charging plug and socket
Source: https://plugit.fi/en-gb/article/etusivu/types-of-charging-plugs-for-electric-vehicles/135/

For Combined Charging System (CCS) DC charging which requires PLC (Powerline Communications), two extra connectors are added at the bottom of Type 1 or Type 2 vehicle inlets and charging plugs to connect high voltage DC charging stations to the battery of the vehicle. These are commonly known as Combo 1 or Combo 2 connectors. The choice of Combo 1 or Combo 2 style inlets is normally standardized on a per-country basis, so that public charging providers do not need to fit cables with both variants.

The Japanese-developed CHAdeMO standard is favored by Nissan, Mitsubishi, and Toyota, while the Society of Automotive Engineers' (SAE) International J1772 Combo standard is backed by FCA, GM, Ford, Volkswagen, and BMW.

Both are direct-current quick-charging systems designed to charge the battery of an electric vehicle to 80 percent in tens of minutes, but the two systems are completely incompatible.

Inductive charging

Electric vehicles can also be charged via induction. In this case an electromagnetic field is created in a primary coil, usually installed in the road, which transfers energy to a secondary coil integrated in the vehicle parking above it. Inductive charging faces the obstacle that the development of a generally accepted standard is even more delayed than in the case for conductive charging.

What makes this technology so interesting is that it allows for the hiding of the charging facilities and potentially even the charging process itself, making them totally the user. There is also no need for carrying and manipulation with charging cables, which tend to get dirty in a daily use. The inductive coil can be integrated invisibly into the parking ground. The driver of the vehicle simply needs to park his vehicle on the equipped parking space to charge his vehicle. Authorization and start of the charging process can be automatized. Thus, this seems to be a convenient solution.

The fully automatized charging process also allows recharging during very short parking times of a few minutes only. Additionally, this implementation is safe for users, as there are no open electric contacts.

There are, however, also drawbacks from a technical viewpoint. This technology requires an induction coil and further electrical components to be built into the vehicle. Also, the energy losses during inductive charging are generally higher than when charging via a plug. If the driver parks carelessly and the two induction coils are not well aligned, the power transfer becomes even less efficient.

Inductive charging systems are already in use for small vehicles in logistic and production halls and for low-speed short-range EVs in business compounds. Inductive charging is also used for public electric buses in the city of Turin in Italy and in Gumi in South Korea. The technology seems interesting where vehicles are driving in closed compounds or circuits. Once the issue of standardization is resolved in the future, this technology also bears high potential for use in public charging.

Battery switching

The third relevant technological solution for the recharging of EVs is battery switching (or battery swapping). This means that the depleted battery is taken out of the vehicle and replaced by a charged battery.

For this purpose specially designed battery switch stations are needed (company Better Place presented its specially designed battery switch station in May 2009). The price for such a fully automatized station amounts to about 500 000 US$. A similar automatized battery exchange station has also been developed within a German research project (NEXT ENERGY) and by the car manufacturer Tesla (battery swap program have been discontinued in favor of Superchargers).

To be able to switch batteries freely, they have to be of exactly the same format. For an application of battery switching in the large scale, manufacturers of EVs would therefore have to agree on a common standard or a selection of standards for batteries for EVs. This would limit their liberties in the design of vehicles, so it is unlikely that such standards will be developed.

An interesting approach which might combine switchable batteries with the flexibility of differently sized battery packs is to use smaller modular elements. Several projects are working on this topic one of them being “Battery in motion” planning to specifically equip EVs with many small modular batteries instead of a single big one. An EV’s battery pack can thus be adapted to the actual use of the EV, and unnecessary weight due to unnecessary batteries can be avoided. This concept might also lead to additional benefits of intelligent battery switching, by lowering the energy consumption of EVs by this weight reduction.

A battery switching facility is convenient from the user’s point of view. Alike to refueling with gasoline today, the vehicle is recharged and ready to drive on within minutes. A battery switching station performs this task fully automatically, similar to a drive-through car wash, so that the driver himself does not have to take care of anything. A single facility could serve several hundreds of vehicles per day, and thus a few such facilities would be sufficient to cover the charging demand arising in an area. The surplus batteries stored at the switching station can potentially be used as a buffer between the electricity system and the suddenly arising demand for recharging from the users. The batteries can be charged slowly at night during times of overall low electricity demand, and they can even be used to feed electricity back into the grid.

Range anxiety is still to this day one of the factors that is in the way of a more widespread adoption of EVs. Range anxiety can be defined as the fear that the car’s battery does not have enough energy to reach its destination and will thus leave the car’s passengers stranded. Or that the car will manage to reach the next charging station, but the recharge will take more than a a few minutes.. This fear is based on the perception that there the charging opportunities along the route are insufficient and/or slow. This perception can be true or based on lack of awareness of existing infrastructure, or, especially for new or prospective owners, just based on preconceptions regarding the vehicle’s indicated range. Charging infrastructure has been increasing everywhere in the EU and in the DTP member states, albeit in different speeds. EU policy in this regard has served to speed up the adoption of charging infrastructure. The 2013 clean fuels strategy’s goal was to standardize the design and use of EV charging points, in summary:

Electricity: the situation for electric charging points varies greatly across the EU. The leading countries are Germany, France, the Netherlands, Spain and the UK. Under this proposal a minimum number of recharging points, using a common plug will be required for each Member State. The aim is to put in place a critical mass of charging points so that companies will mass-produce the cars at reasonable prices.

Based on this strategy, the EU adopted the Alternative Fuels infrastructure Directive in 2014, which recommends a minimum amount of EV charging infrastructure in the EU, around one public charging point for ten electric vehicles. The directive also gives consideration to inductive charging and battery swap. It should be pointed out that besides the public charging stations there are also private car parks with EV charging that are available to the public at a cost. The number of EVs is set to increase constantly and so must the charging stations. As such it is imperative that municipalities form a plan regarding the placement of these chargers before they are needed in order to maximize their usefulness and thus their ROI for potential investors, making them more attractive. As of now, the EC estimates that there will be a need for approx. 440 000 publicly accessible recharging points by 2020, and 2 million by 2025.

Other focus points of the 2015 directive are easy access to location of charging points and standardization of charging points technical specifications. Thinking in the long term, these charging points will also allow the bidirectional flow of electricity in order to incorporate EV batteries into the European smart grid. This forward thinking idea has the potential to drastically increase the versatility of the EU's energy grid and allow for the easier integration of large capacity renewable energy production. EV batteries will thus balance the power grid, charging while renewable energy is readily available and supplying energy to the grid when it is not.

The positive effects of bidirectional flow of electricity can better be capitalized upon if home chargers are also compatible with the technology and there is legislation in place to promote this. The 2018 Energy Performance of Buildings Directive requires a minimum of one EV charging point in all new non-residential buildings but also in buildings that are undergoing major renovations and have a minimum of 10 parking spots. There is also a requirement for a minimum of 20% of parking spots in non-residential buildings to have conduits for electric wiring that will facilitate the installation of charging points and there are other similar prerequisites for various buildings and their associated parking. Due to the slow rate of building renovation, these rules will have a limited effect in a short time frame. What member states can do to facilitate the adoption of EV charging points in buildings, old or new, is to streamline the legal procedures required for the installation of new charging infrastructure.

Standardization and adoption of charge technologies

The integration of EV chargers in Europe's power grid does not depend on any new technology. European companies in the field are currently promoting investment in infrastructure in order to promote the adoption of EVs by making them more convenient for customers.

A rapid market penetration will however only be successful on the basis of a cross-industry agreement regarding the charging and charging payment of EVs. This standardization will bring benefits for all stakeholders and will drive forward progress in European car and battery technology research, development and innovation. For all these reasons, we call upon all stakeholders, transport and energy policymakers, companies in the relevant sectors, and standards bodies to support the drive towards standardization in electric vehicle charging systems.

Standards play a key role in the development and deployment of technology in society, providing an indispensable basis for widespread market penetration and customer convenience. Agreed standards tend to encourage innovation, boost productivity and shape market structure in a way that enhances economic efficiency, reducing or eliminating technical barriers that can create market distortions.

For plug-in vehicles to become a success, both hardware (connector and cables) and communication software standards are a prerequisite to the establishment of a secure investment climate for the required infrastructure. Common standards will generate cost benefits and help to create economies of scale for both electricity companies and the automobile industry. They will also help to avoid the risk of stranded assets resulting from the deployment of interim proprietary solutions and foster the sharing of development costs.

Of course the customer will be the key determinant for the commercial success of electric transport. Common standards will help to ensure the driver enjoys a convenient recharging solution across the European Union that will avoid a multiplicity of different cables and adaptors and/or retrofit costs for adapting to new charging systems. Consumers will be able to choose their electricity supplier, and even more importantly, will be able to charge their vehicle in charging stations across Europe.

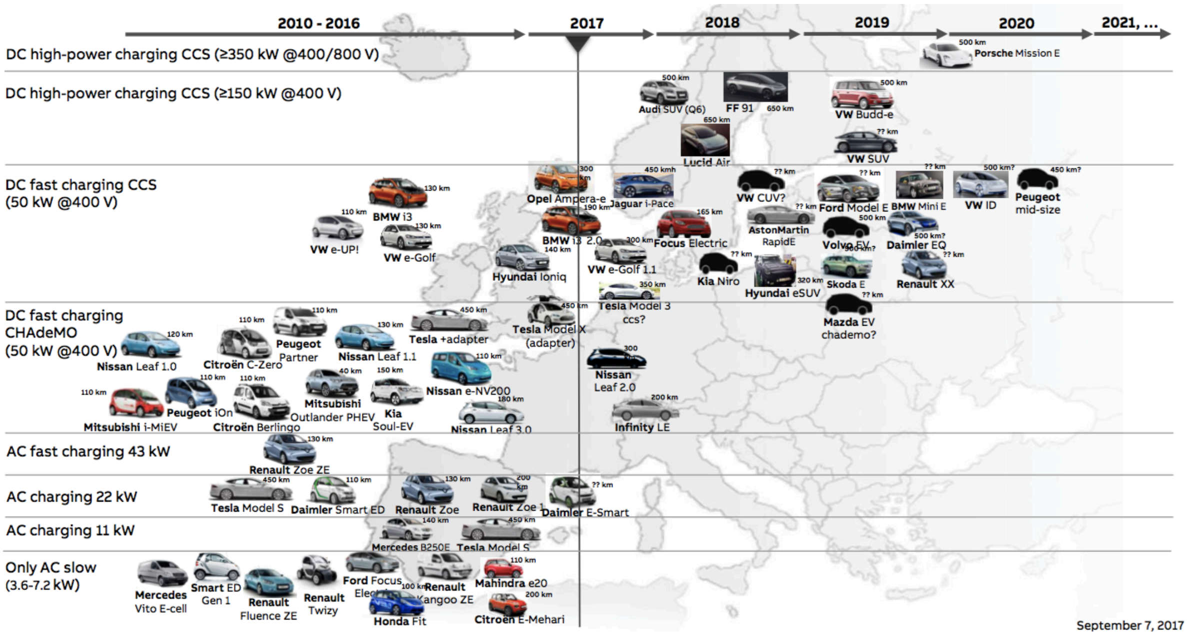
Experts from the electricity distribution business have already been working with automotive companies and original equipment firms to find an agreement on initiating standards for connecting electric vehicles to the power grids. This initiative provides a starting point, the aim being to draw up a roadmap for a rapid standardization process. The common technical approach must then be further developed by the international standardization bodies ISO and IEC.

The signatories to this Declaration, integrated European electricity companies, distribution system operators, and national electricity sector associations, support the development of pre-standards for vehicle charging, with a view to driving forward market deployment. They hereby commit themselves to apply these pre-standards when developing infrastructure and vehicle connections, conscious that this approach will enable them to gain early experience with business models and to better assess the impact on the electricity grid when the standards are officially approved by ISO and IEC.

Next steps:

- Application of the identified pre-standards until the development of the official standards is completed by ISO/IEC

- Pilot projects for electric vehicles to analyze the impact on existing network architecture and the conditions for the development of a competitive market; future requirements for active demand management and storage possibilities need to be scrutinized in the light of the growing grid integration of renewable energies and challenges in balancing the power supply
- Continuous and credible contributions to the research and development of emerging electric drive and battery technologies
- Cooperation among the various stakeholders to ensure a clear, stable regulatory framework conducive to investments, in order to attain mass market deployment of electric vehicles
- Creation of appropriate incentives to overcome market hurdles and initial commercialization hurdles for this technology; given the uncertainty of the oil price, the right fi scal and tax policies are needed to address the substantial first-cost hurdles facing the consumer
- Deployment and availability of infrastructure to serve consumers with different usage needs - eg different charging options - plus proper integration into the retail electricity market

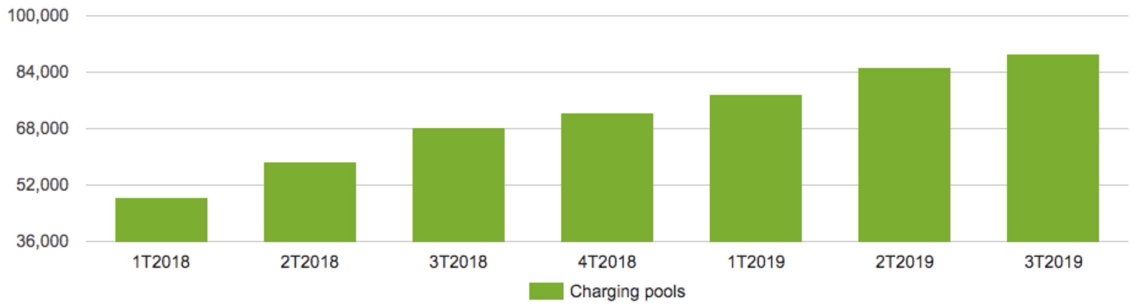


A map of charging technologies and some of the vehicles that use them. Source: https://www.transportenvironment.org/sites/te/files/Electrification%20of%20transport%20in%20Europe.pdf

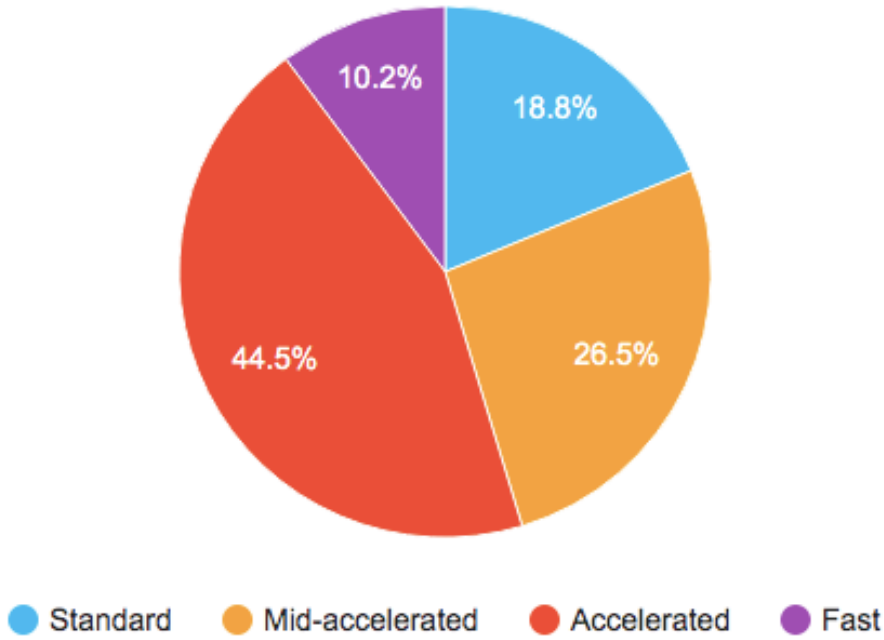
Charging infrastructure in DTP countries

Public charging of EVs can be seen as a public service, similar to services such as public transport, water supply, garbage collection, and others. For such public services, minimal levels of service can be defined which guarantee the availability of a service to all citizens, independent of the actual level of utilization and profitability of the service. Municipalities can decide to commission a charging infrastructure to a provider. In this case following detailed service levels can be agreed and set up as a binding contract. Some of the data below might be outdated due to the rapid pace of investments in this area.

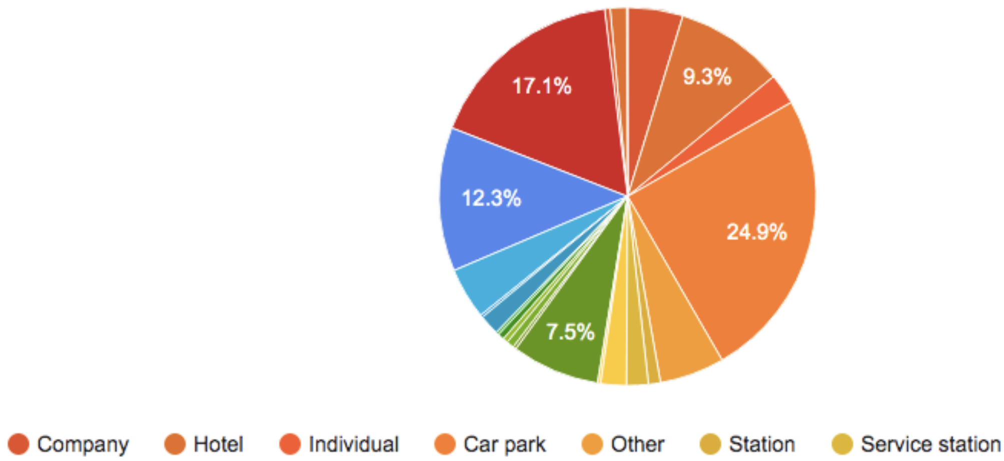
- Quantity of charging points for an area: e.g. at least 0.1 (or 0.05, 0.025) public charging points available for every registered EV in the area.
- Quantity of charging points for individual parking facilities: e.g. every publicly accessibly parking facility with more than 50 parking places should provide at least 1 and for every parking facility with more than 100 at least 2 charging points for EVs.
- Areal coverage:
    - e.g. within the central city area, all locations need to be within a 5 (or 10) min walking distance to a public charging point. For a walking speed of 4 km/h this corresponds to a maximal distance of about 330 (or 660) m to a charging point.
    - e.g. number of charging point per square kilometer (covering an area so that the distance to the next charging point is never bigger than 330 m would require 3 charging points per km2.
- Temporal availability: e.g. between the time of 9:00 and 18:00 h on weekdays, an arriving EV driver has an average chance of at least 70 (or 80) % of finding a free public charging point (i.e. in that time the average occupancy of a charging point is below 30 (or 20) %). If average availability is lower, further charging points need to be installed in the area and/or policies put in place that require EV drivers to move their vehicles, once the charging operation is completed.
- Fast repair / low down times: e.g. if a charging point is reported to be broken, a service technician arrives at the site within 24 (or 48) hours, and the charging point is repaired within 48 (or 72) hours.
- Distribution of fast charging stations along traffic corridors: e.g. along a traffic corridor connecting two big cities, fast DC charging stations are available every 50 (or 75, 100) km, from both sides of the motorway.



The adoption rate of electric car chargers in Europe
Source: https://en.chargemap.com/about/stats



Distribution of plugs by charging speed
Source: https://en.chargemap.com/about/stats



Distribution of charge points by location type
Source: https://en.chargemap.com/about/stats

Charging points for electric vehicles are usually characterised by their degree of accessibility for drivers. The main categories of charging points are generally defined as private, semi-public and public.

Private/domestic charging points

Such charging points are found in homes and business premises. They include dedicated charging boxes or common household plugs. Home charging is a simple option for electric vehicle owners, since no subscription or membership fees are needed to access the charging point. Private charging also occurs when companies install charging points for use by employees on business premises. Home charging naturally tends to be more common in suburban or rural areas than in urban neighborhoods, as it requires the car owner to have access to a private garage or be able to connect the electric vehicle to a household socket. In cities, where vehicles are normally parked on public streets or in semi-public car parks, it is more difficult to access a private charging point.

Semi-public charging points

These types of charging points are situated on private ground, but can be accessed by external users. Examples include charging points located in commercial car parks, shopping centers or leisure facilities. Access to these charging points is typically restricted to clients or customers.

Operators often regard the charging points as a complimentary service or an opportunity to advertise, so they do not charge customers for the power used. In other cases, the electricity used is included in the customer's parking bill, or in the utilisation fee for car-sharing schemes. Most fast-charging facilities are semi-public and, like conventional petrol stations, are built on private ground but open to all paying users.

Public charging points

Public charging points are usually placed alongside roadside parking spaces or in public car parks. While private or semi-public charging points are often wall boxes, the public infrastructure usually consists of standalone charging poles. In some cases, municipal utilities provide these charging points. However, local authorities are increasingly commissioning commercial providers to facilitate the construction and operation of public charging infrastructure.

European Parliament and Council. Directive 2014/94/EU of the European Parliament and the Council of 22 October 2014 on the deployment of alternative fuels infrastructure. The directive obliges EU member states to implement a minimal charging infrastructure for EVs. Such an infrastructure is described by:

"Member States should ensure that recharging points accessible to the public are built up with adequate coverage, in order to enable electric vehicles to circulate at least in urban/suburban agglomerations and other densely populated areas, and, where appropriate, within networks determined by the Member States. The number of such recharging points should be established taking into account the number of electric vehicles estimated to be registered by the end of 2020 in each Member State. As an indication, the appropriate average number of recharging points should be equivalent to at least one recharging point per 10 cars, also taking into consideration the type of cars, charging technology and available private recharging points. An appropriate number of recharging points accessible to the public should be installed, in particular at public transport stations, such as port passenger terminals, airports or railway stations. Private owners of electric vehicles depend to a large extent on access to recharging points in collective parking lots, such as in apartment blocks and office and business locations. Public authorities should take measures to assist users of such vehicles by ensuring that the appropriate infrastructure with sufficient electric vehicle recharging points is provided by site developers and managers."

Charger statistics for DTP counties

DTP Country	Charging pools	Plugs	Chargemap members	Standard	Mid-Accelerated	Accelerated	Fast
Austria	4231	15150	2750	50,7%	30,8%	9,5%	8,9%
Croatia	344	930	168	51,5%	12,2%	20,1%	16,3%
Czech Rep	577	1779	954	6,2%	15,1%	48,2%	30,5%
Hungary	745	2012	1612	5,1%	8,6%	72,8%	13,6%
Romania	143	568	384	18,2%	4,9%	43,4%	33,6%
Slovakia	235	770	354	4,3%	15,7%	34,9%	45,1%
Slovenia	484	1323	420	17,8%	16,1%	53,7%	12,4%
Serbia	26	53	46	3,8%	15,4%	53,8%	26,9%
Montenegro	17	26	3	64,7%	5,9%	29,4%	0,0%
Total	6802	22611	6691	38,8%	24,7%	23,0%	13,4%

The table above was compiled with data from www.chargemap.com. Chargemap is a tool that brings electric car drivers together in order to share information about charging points, which would help them charge their car everywhere. in 2017, they launched the Chargemap Pass: a multi network access RFID card. Their stated goadl is to offer to electric car drivers the best charging experience in order to promote the development of these vehicles, which are less damaging to air quality. The platform has almost 330.000 members worldwide at the time of writing.

Chargemap was used because it's popular in all countries and so it should give a good image of the status of electric chargers in the project countries.

Austria is by far the biggest market for electric charging in the entire DTP project area. There are more than 4000 charging spots registered, but many of them are standard power outlets that are available to users and were thus registered in the program.

Croatia has fewer chargers but the percentage of standard chargers is equal to that of Austria. This can mean that standard chargers are really well mapped out or that there still is significant room for investment in the country.

The Czech Republic shows a different picture to the first two countries. Here almost half of all the 1779 plugs support accelerated charging and are usable for quick top-ups.

Hungary has more plugs, over 2000, and its plugs are faster than the Czech's Republic's, with almost three quarters supporting accelerated charging.

Romania has the lowest number of plugs of all the EU members participating in this project, around 568. However, over three quarters of these support accelerated and fast charging, showing that investments have probably started later so the infrastructure, although small, is on average quite modern.

The same is true for Slovakia, which has nonetheless more chargers than Romania, which is a lot bigger in population and total area.

Slovenia has 1323 plugs and two thirds of these support accelerated and fast charging.

Serbia only had 53 plugs registered, most of these being of the accelerated and fast charging type.

Similarly, Montenegro had 26 plugs but most of these were standard wall chargers. It has by far the fewest plugs and the highest proportion of standard chargers of all the project countries.

Overall, there were more than 22.600 plugs in 6800 charging stations in the project countries and the four charging speeds were all equally represented, albeit there were more than a quarter standard chargers and less than a quarter fast chargers.

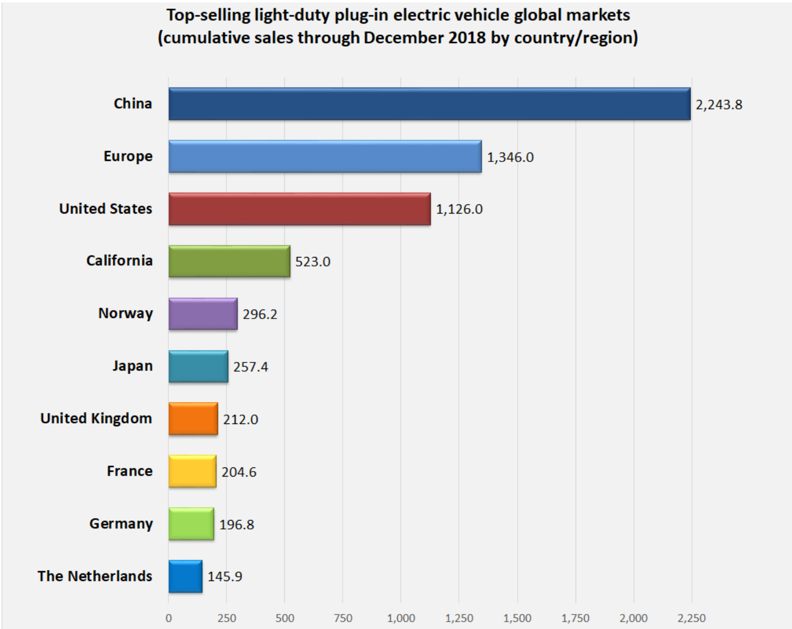
The differences between the countries are of course due to the different time periods when electric charging was introduced and the technology available at that time, but also probably due to the fact that standard wall chargers were not well mapped out in countries with fewer electric vehicle owners. Nevertheless in 6 months the table will look very differently and it would be interesting to check the progress in all the countries and see which kind of chargers are being installed and how many new users sign up for the service.

In conclusion, the state of charger availability is very different in the project countries and it ranges from 15150 plugs in Austria, a relatively small country, to 26 in Montenegro. On the other hand, only around 18% of chargers in Austria offer accelerated and fast charging but this number should be going up in the near future.

Another useful website/app for checking out available chargers in a specific region is www.plugshare.com. Unlike chargemap, plugshare does not offer such a clear view of national statistics so it was not used for any calculations in this study. Its strength however lies in the ability to search for certain plug types in a specific area and applying different filters to the search. This is arguably the most useful resource for someone who is looking for a charger nearby so this app should not be neglected.

Plug-in electric vehicles in the EU and project countries

The adoption of plug-in electric vehicles in Europe is actively supported by the European Union and several European government have set public subsidies and other non-financial incentives to promote their widespread adoption. More than one million plug-in electric passenger cars and vans have been registered in Europe by June 2018, the second largest stock after China. As of December 2018, Norway is the leading market with almost 300,000 units registered, followed by the UK with more than 212,000 units, and France with almost 205,000 units.



Cumulative light-duty plug-in electric vehicle sales in Europe compared to the world's top-selling countries and regional markets as of December 2018. Europe is the world's second largest plug-in market. Source: https://www.eafo.eu/vehicles-and-fleet/lev

Rank	Model	Total sales	2017	2016	2015	2014	2013	2012	2011	2010
1	Mitsubishi Outlander P-HEV	**100,097**	19,189	21,446	**31,214**	**19,853**	8,197			
2	Renault Zoe	**91,927**	**31,302**	**21,735**	18,728	11,231	8,863	68		
3	Nissan Leaf	**84,947**	17,293	18,718	15,455	14,658	11,120	5,210	1,728	144
4	BMW i3	**59,122**	20,855	14,999	12,047	9,744	1,477			
5	Tesla Model S	**54,116**	15400	10,567	15,515	8,734	3900			
6	Volkswagen Golf GTE	**38,993**	9,267	11,329	17,300	1,097				
7	Volkswagen e-Golf	**33,644**	12,663	6,543	11,110	3,328				
8	Volkswagen Passat GTE	**31,632**	13,599	13,11	4,922	1				
9	Renault Kangoo Z.E.	**29,150**	4,233	3,901	4,238	4,197	5,850	5,260	991	
10	Audi A3 e-tron	**28,209**	8,356	6,908	11,791	1,154				
11	Volvo V60 Plug-in Hybrid	**25,694**	1677	4,119	6,349	5,441	8,066	42		
12	Mercedes-Benz C 350 e	**22,049**	6,861	10,125	5,006	57				
13	Volvo XC90 T8	**19,969**	7,847	9,469	2,653					
14	BMW 330e iPerformance	**18,808**	10,117	8,691						
15	BMW 225xe Active Tourer	**16,720**	10,805	5,915						

Top 15 selling plug-in electric car models in Europe

Source: https://en.wikipedia.org/wiki/Plug-in_electric_vehicles_in_Europe

Country	PEV reg. 2017	PEV reg. 2016	Change 2016 - 2017	PEV market share 2017	PEV market share 2016	BEV/PEV 2017
Norway	62,170	44,888	39%	39.2%	29.0%	53%
Germany	53,561	24,626	117%	1.6%	0.7%	46%
UK	48,395	39,044	24%	1.9%	1.5%	28%
France	36,888	29,205	26%	1.8%	1.5%	69%
Sweden	20,031	13,415	49%	5.3%	3.6%	21%
Belgium	14,654	9,390	56%	2.7%	1.7%	18%
Netherlands	9,190	22,875	-60%	2.2%	6.0%	87%
Switzerland	8,029	5,432	48%	2.6%	1.7%	58%
Spain	7,448	3,662	103%	0.6%	0.3%	53%
Austria	7,265	5,063	43%	2.1%	1.5%	75%
Italy	4,827	2,831	71%	0.2%	0.2%	41%
Portugal	4,237	1,873	126%	1.9%	0.9%	42%
Finland	3,055	1,432	113%	2.6%	1.2%	16%
Iceland	2,990	1,158	158%	14.1%	6.3%	29%
Hungary	1,126	310	263%	1.0%	0.3%	67%
Luxembourg	992	306	224%	1.9%	0.6%	36%
Ireland	945	673	40%	0.7%	0.5%	66%
Denmark	913	1,402	-35%	0.4%	0.6%	77%
Poland	907	270	236%	0.2%	0.1%	52%
Czech Republic	630	363	74%	0.2%	0.1%	62%
Slovenia	528	272	94%	0.7%	0.4%	64%
Slovakia	394	55	616%	0.4%	0.1%	53%
Romania	374	162	131%	0.4%	0.2%	62%
Greece	163	47	247%	0.2%	0.1%	21%
Turkey	108	127	-15%	0.0%	0.0%	71%
Latvia	101	46	120%	0.6%	0.3%	70%
Cyprus	99	39	154%	0.8%	0.3%	44%
Lithuania	70	81	-14%	0.3%	0.4%	69%
Estonia	52	56	-7%	0.2%	0.3%	50%
Bulgaria	61	12	408%	0.2%	0.1%	18%
Malta	53	17	212%	0.4%	0.1%	91%

Croatia	23	88	-74%	0.1%	0.2%	35%
EU	290,279	209,22	39%	1.7%	1.3%	46%

European countries new plug-in passenger car registrations and market share
Source: http://www.eafo.eu/europe

The Serbian Statistical Office does not regularly collect and publish data on the total number of registered EVs. However, according to unofficial data, a total of 128 EVs were registered in Serbia (including buses and trolleybuses) as of August 2017.

As of April 30th 2019, 99 electric cars are registered in Montenegro.

Interoperability

Electric vehicle public chargers have become quite ubiquitous in some areas, and present in most municipalities. Various companies, NGOs, municipalities, etc, have put these chargers in place and have started to operate them in the last years. These organizations are called Emobility service providers, or EMPs. Unlike traditional gas stations, these charging stations are mostly unmanned and the customer has to initiate the car's charging by manually inserting the correct plug and starting the loading process from the charger's own user interface software. The large number of EMP's would make it impractical and cumbersome for a new user to enter all the car and payment details for each new charger that they might come across. Thus, the industry solution has been the emergence of Charge Point Operators, or CPOs, who operate a larger number of charging points under a common interface.

Any company interested in this field has to understand the difference between an EMP and a CPO and roaming and to fit one or both of these roles into their business model. Basically, the entirety of all EMPs and CPOs in a specific region make up that region charging network and EV charging networks are the platforms that enables them to do business together. A company may be either EMP, or CPO, or both, with different advantages depending on the specifics of each situation.

The EMP is the company that offers the EV charging service to the drivers. By enabling access to a variety of charging technologies, these companies provide value to their customers. EMPs inform drivers about the availability of their chargers, initiate and stop the charging process and handle the customer's accounts and payments.

When not working together with a CPO, EMPs may provide access to 3rd party charging stations through roaming.

Roaming refers to an EV driver's ability to use various charging stations even if they're only a customer of one service provider. In practice, it means that electric car drivers can use charging stations with just one customer account. Being a customer of one charging network opens up access to thousands of charging stations. This is all thanks to roaming, enabled by service providers coming together in order to provide their customers with the optimal user experience.

The CPO on the other hand is operating a larger pool of charging points and provides value to its customers by connecting its smart charging technology to the EMPs chargers. The CPO may also own infrastructure, but mostly as of now they just provide the connection and their aggregated customer and payment database. It is the CPOs job to ensure the proper functionality of the network through methods such as diagnostics, maintenance, transfer of funds, database management etc. Thus CPOs normally rely on the access granted by the EMPs, who are in turn incentivized by providing access to a bigger pool of potential customers.

In the end, it is the CPOs that ensure the interoperability of the EV charging network. Some CPOs have taken this concept a step further by signing interoperability agreements that allow their respective customers to use the other's charging network. The CPOs thus increase the visibility of an EMP, their range of acquisition for prospective customers and, in the end, their sales.

Going long distance the DTP area in an electric vehicle

Long distance trips in EVs are no longer an adventure that has to be planned meticulously ahead of the date of departure, like it was only 5 years ago. There are both advantages and disadvantages of going electric long distance. Of course, a vehicle with a long range will be more practical but the availability of fast charging along the route may have more impact on the duration and complexity of the trip.

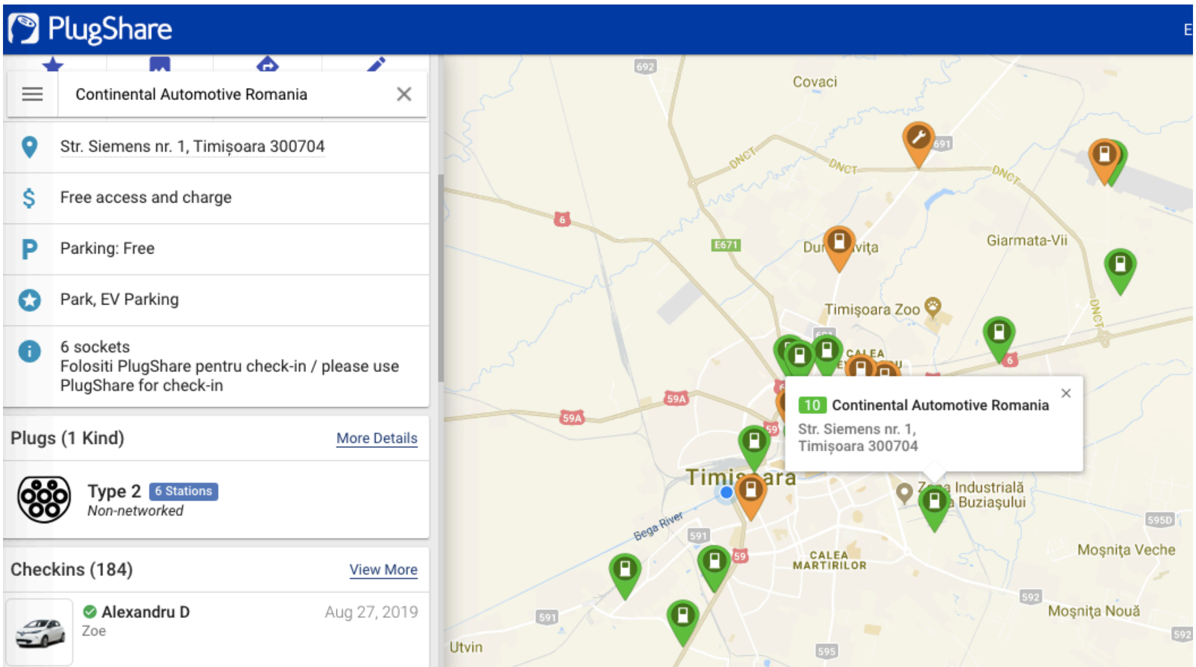
Advantages:
- Lower fuel costs
- Lower maintenance costs
- Easy to use
- Eco-friendly
- Rising popularity, meet like-minded people

Disadvantages:
- Range anxiety
- More planning required
- Longer charging time

The trip will depend on the location of the charging stations, so the first step is to do some research and plan out a route around the charging stations. Drivers must always be sure that there is a charging station within range. When planning a longer trip in an EV in Europe or the DTP area we recommend using a European charger app like plugshare or chargemap, which are free smartphone apps that can show the user:

- Location of charge points
- Type of connectors availabe (results can be filtered)
- Charge speed
- Payment options
- Availability of chargers

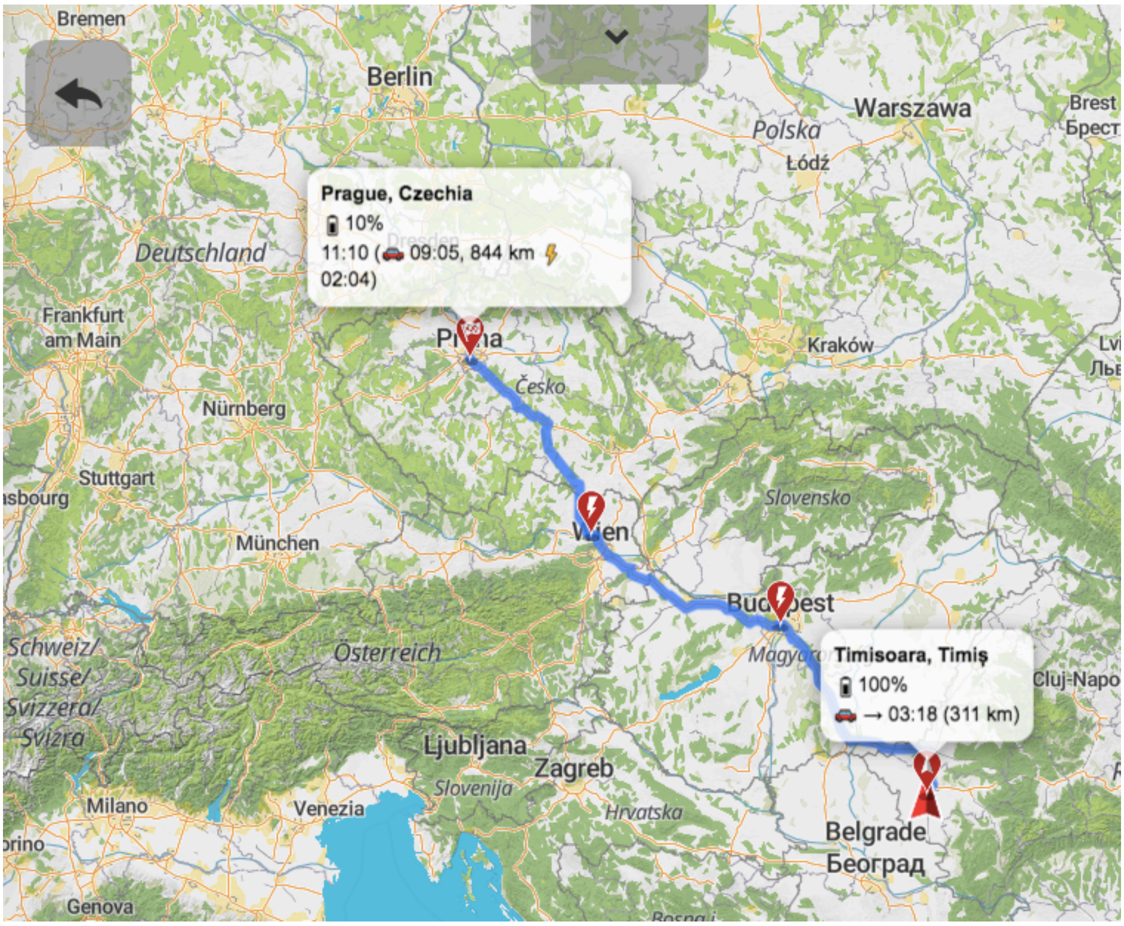
Users can customize each charger location to provide additional information such as the precise location, nearby facilities, problems they encountered and to upload useful photos of the charger location.



Charge point information as shown by plughsare
Source: https://www.plugshare.com/location/123143

The apps above are very useful as they have a lot of good information about the chargers and can even facilitate paying as described below, but they will not plan the entire trip for the user. There are better options for this. One of them is the intuitively named abetterrouteplanner.com. Using this app, users can put in information regarding the car they have, the starting and ending point, desired speed, and other information to help the app plan the route.

The planning screen for abetterrouteplanner. The red route in the bottom right corner is the first leg of the route, where speed was limited to 120 km/h to reach a quick charger that was far away.
Source: https://abetterrouteplanner.com/



Above: A trip from Timisoara, Romania to Prague, Czech Republic. Trip duration 7h50min, similar to a ICE car due to existence of very fast charging on the route. Source: https://abetterrouteplanner.com/

Chargers are usually located in places where it is practical to park the car such as those in the list below. We recommend choosing chargers in places with public facilities such as shopping, eating, or sightseeing in order to pass the time more quickly.

- Car parks
- Public parking
- Tourist attraction
- Hotel with own parking
- Restaurant with own parking
- Shopping centers

Unfortunately, it is not possible to use the same cable and charge card at all chargers. Things are easier inside a single country but going abroad can present some unexpected difficulties due to the lack of standardization. Drivers need to have all the right cables for their vehicle.

The physical connection alone is not enough to charge a car. As electric car chargers are usually unmanned, one will have to have the right payment method in order to charge. Countries will have different providers but there are charge cards and apps that work with most charging stations in Europe, like the ones from the charger apps presented above and many more.

Obviously, cars have different driving ranges. A fully charged battery of a new Renault ZOE has a driving range of 400 kilometers. In reality, this comes down to 250-300 kilometers providing you're only driving on the highway. It is possible to extend this range by slowing down. 90 km/h is usually a good mix between range and speed.

If however a driver is in a situation where there is not enough range to get to the nearest charger, it is important to remember that electricity is available almost everywhere. Home chargers are slow but they work and any private and public building will have an outlet. EVs are still new and their drivers have a good image so people may be more than happy to help out a driver in need.

The truth is that going on an electric road trip is possible without a lot of planning but it will require some flexibility. Flexibility is needed not only for the driver's mindset but also for charging, so having all the right chargers and long cables can really make a difference. In 2016, a Dutch man started a journey called plugmeinproject, a road trip with an EV that started in the Netherlands and ended up in Southeast Asia, then Australia, after crossing some of the most uninhabited terrain on the planet, proving that power outlets are indeed everywhere.

Finally, it is good manners to not occupy charging places when the car is finished charging, and to move it to another parking spot until departure.

Electric mobility policies

In the European Alternative Fuels Strategy, it is believed that an appropriate combination of fuels will be able to break the dependence on oil and improve energy supply security. Furthermore, the European Union (EU) also considers that the development of alternative fuels would improve economic growth, strengthen industry competitiveness, and promote employment. Lastly, alternative fuels reduce greenhouse gas (GHG) emissions from transportation, which allows the targets set in the H2020 strategy to be attained.

The H2020 strategy is the most ambitious EU package to date and it seeks to fight against global warning. It includes a specific 20% target for increasing the share of the renewable energy source (RES), which is up to 20% for the final energy, and reducing GHG emissions up to 20% from the 1990 levels. The European Council extended this objective to 40% by 2030. Without setting an obligatory objective, the White Paper on Transport also establishes the aim of reducing 60% CO2 emissions in transportation by 2050.

As one of the main alternative energy sources for transportation, the electric motor could be used mainly on the highway, in cities, and rail transportation for travelers and for delivering goods. Electric vehicles (EVs) could reduce GHG emissions and improve city air quality and, therefore, the health of their populations because they only emit natural by-products rather than exhaust fumes. Yet, from the potential buyer perspective, this environmental benefit may be less important because society by nature, is individual and hedonic.

To balance these factors and promote electro-mobility, Member States (MSs) have established incentives to increase the demand. Like other, low carbon energy strategies, market penetration speed could be increased by public policies.

The most important measures include tax measures, those oriented toward infrastructure, financial incentives for the purchase support of Research and Development (R&D) projects, and projects enhancing consumer perception.

Based on the amount collected, the most important taxes in the EU are the value-added tax (VAT), registration fees, and the vehicle ownership tax. The first of these is not significant in this study because no Member State (MS) has established a reduced VAT when purchasing EVs (Ukraine for example has 0% VAT for EVs). Therefore, common rates are applied and the tax rates range up to 27% in Hungary.

Within the EU28, there are widespread measures to promote EVs, which prioritize infrastructure use. In this sense, Directive 2014/94/UE of the European Parliament and the Council on the deployment of alternative fuel infrastructure commits member states to setting up sufficient charging points available to the public before 31 December, 2020. The aim of this directive is to facilitate circulation in densely populated areas especially in urban and suburban areas and networks determined by these member states.

The 2010 European Parliament Resolution regarding vehicles establishes that innovating propulsion systems, which are both electric and hybrid, will help guarantee future competitiveness of the automobile industry. This Resolution underlines that EVs represent a technological advancement that requires the integration of certain innovation strategies and technological developments through adequate financing and the promotion of R&D.

MSs offer both financial and non-financial incentives to promote electro-mobility. These include tax credits (discounted vehicle license, registration fees, and more), purchase subsidies, subsidies for the installation of charging stations, high occupancy vehicles lane access and free parking access, R&D projects funding, and educational programs.

The most popular measure using infrastructure to promote the use of battery electric vehicles is favoring the installation of charging stations. Yet, in most states, charging stations are limited to the major cities. Unfortunately, the integration of charging stations in Smart Grid Systems has not been a focus. The second, most extended measure is free parking for EVs. This measure is also limited especially in large cities. Undoubtedly, the penetration of EVs in each country does not depend solely on the promotional measures implemented by the public sector.

Offering member states the possibility to use a wide range of policy instruments to promote electro-mobility in the context of the H2020 strategy is important, in a similar way to how they promote renewable energy sources. Higher market penetration rates of EVs occurs in countries where the registration tax, ownership tax, or both taxes have developed into a partial green tax by including CO2 emissions in the calculation of the final invoice. The countries with a more intense use of EVs also fund charging stations to facilitate electro-mobility. In the case of the the automobile industry being relevant at the national level, public funding also supports R&D projects by focusing on EV deployment.

When deciding on lowering or eliminating taxes, countries must keep in mind that EVs could become part of future smart electricity systems in a twofold sense. First of all, their batteries could be considered as a (disperse) storage system for better management of demand peaks. Lessons learned from vehicle to grid pilot projects would be useful. Second, if a dynamic tariff system is deployed at the national level, different prices of electricity for charging EVs could reduce the risk of disruption by enhancing power capacity.

In addition, communication programs could play a crucial role in promoting electro-mobility through two ways. First, misperceptions of the main advantages of EVs could be reduced through adequate information programs co-funded together with private companies. Second, remarkable efforts in communicating available public incentives could help to shift potential consumers to EVs.

Future developments

Innovative mobility concepts such as electric mobility, "Park and Ride", and carpooling, which meet the needs of urban residents at the same time are making their way into urban centres. It is not feasible to plan infrastructural mobility concepts only focusing on the technical requirements (of charging infrastructure) without taking into consideration future mobility needs and new mobility concepts (mobility as a service). The impact of new mobility concepts can already be observed with car sharing implementation, impact of UBER, while the impact of autonomous vehicles can only be imagined.

With tendency of cities towards smart cities (with mobility being part of it) plans for future charging infrastructure need to accommodate enough flexibility to accommodate new requirements (e.g. incorporation into smart grids) and changed mobility demands deriving from behaviour changes. It is expected that urban residents of the future will most likely use vehicle sharing services or using services on demand (including autonomous vehicles) coupled with advanced public transport services and move away from owning the vehicles.

While planning for immediate future and investment into charging infrastructure it is strongly recommended that cities identify and actively involve stakeholders related to mobility (not only e-mobility). Additionally involvement of its citizens and two-way communication in necessary in order to develop cities in a way to suit its residents.

As of July 1st, new four-wheeled EV models in the European Union require a noise-emitting device (Acoustic Vehicle Alert System, or AVAS) that kicks in whenever the vehicle is driving below 19km/h (12MPH). The system will theoretically prevent pedestrians and cyclists from being caught unawares by cars that would otherwise be near-silent. All new EVs, including those from existing lineups, will have to include noisemakers by 2021. Cars already on the streets are likely to get retrofits.

2. Light Electric Vehicles

Types and descriptions

Still there are more and more vehicles on Europe's roads. While electric passenger vehicle sales have increased rapidly over past years, they represented just 1.2 % of all new cars sold in the EU in 2015. In all, approximately 0.15 % of all passenger cars on European roads are electric. Collectively, just six EU Member States account for almost 90 % of all electric vehicle sales: the Netherlands, the United Kingdom, Germany, France, Sweden and Denmark. The market share of EVs, in number of new registrations (sale), in the DTP region (eGUTS countries), with the exception of Austria, is below 1% and is counted in tens, max. hundreds of vehicles sold per year.

Regarding the eGUTS (DTP region) countries, again with the exception of Austria, it can be said that the electric mobility in this region is indeed at the very beginning. To some extent, this is definitely related to the performance of the economy, and thus to the GDP and the purchase power of the country's population and also due to low e-mobility awareness of population.

A crucial point for greater e-mobility deployment in the eGUTS (resp. DTP region) countries could definitely be a well-chosen fiscal support mechanism and subsidies for e-vehicles purchase at national level.

Between 2006 and 2014, there was a steady growth of electric bikes sales in the EU. It is estimated that around 1.325.000 e-bikes were sold in the EU in 2014, almost 14 times as many as in 2006. (Just for comparison, the year 2015 saw the global threshold of 1 million electric cars on the road exceeded, closing at 1,26 million.)

Analogous to e-cars, e-bikes are still considerably more expensive than conventional bikes. While there have been a large uptake in several countries (Germany, Netherlands, Belgium), the development of e-bike market is still in the take-off phase in majority of countries. Purchase subsidy schemes could help to bridge this price gap.

E-bikes (pedelecs) allow for longer distances to be cycled with the same level of effort compared to conventional bikes and even for longer distances of up to 20 km the time difference with the car (electric or fuel-driven) is marginal. Additionally pedelecs (e-bikes) are option for solving problems with congestions and land-taken in limited urban areas (contrary to e-cars).

The psychological barriers preventing the spread of electric vehicles remain the same as before, namely the short driving range and the high cost of the batteries. The performance and cost of the rechargeable batteries will be crucial to the success of electric mobility. Life cycle analyses are another important element, i.e. the process of considering the total ecological and economic costs of the battery from the availability of the raw materials right through to recycling.

All this must go hand in hand with the support of innovative business models capable of generating revenues, necessary also for provision of a development fund (e.g. tailor-made rental of e-cars (e-vans) for business purposes; operative leasing; support and introduction of e-car sharing and e-bike sharing systems in the urban areas etc.).
EVs of all types lie at the heart of future sustainable transport systems, alongside the optimisation of urban structures to reduce trip distances and shift mobility towards public transportation.

Electric bicycles (e-bikes)

Pedelecs (Pedal Electric Assisted Cycles) or EPACS (Electric Power Assisted Cycles) are much like bicycles, however when pedalling the rider gets progressive assistance from the electric drive system. There are many different types of electric assisted bike, the most popular and highest selling pedelec is the sub *250 watt pedelec/ sub 25 km/h bike*.

Pedelecs (= low - powered bicycles) are electric bikes that are propelled with physical strength (are equipped by pedals); additionally, up to a speed of 25 km/h, propulsion is assisted by an electric motor with a maximum power output of 250 W. Pedelecs differ very little from conventional bicycles in how they are operated. This *lower power vehicle* does not have to be type approved like motorised vehicles and is regulated through CEN standards (with work ongoing to make a global ISO standard), it is seen as essentially a bicycle by all public authorities. Insurance is not required for such bikes, and they can be ridden without a driving licence or moped certificate.

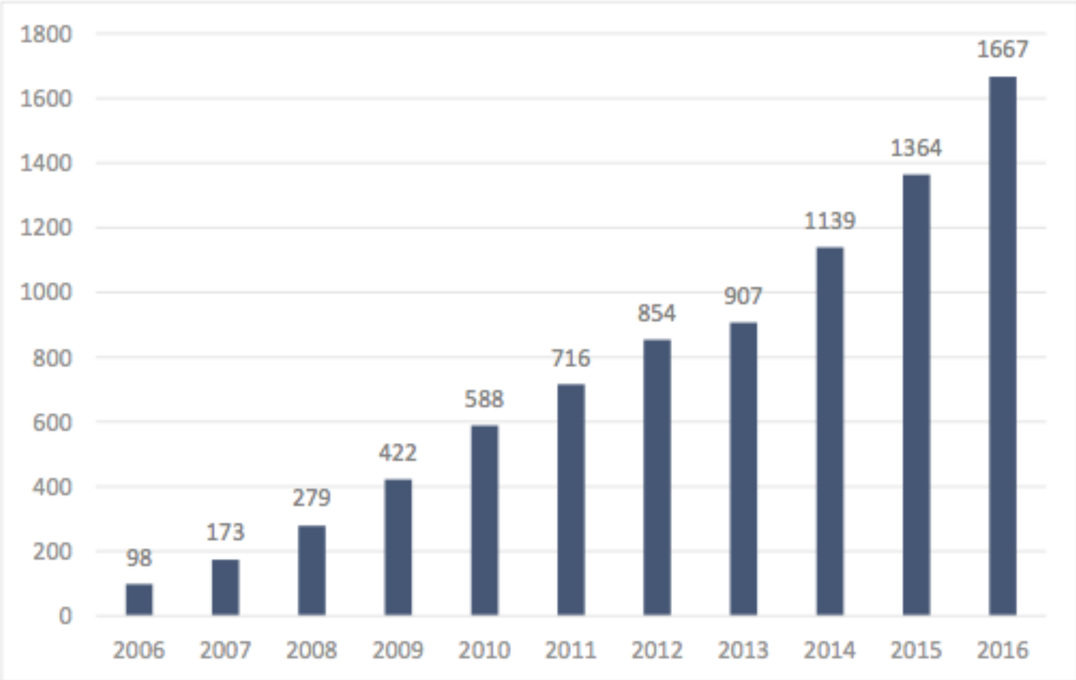
"Speed pedelecs" (= higher powered pedelecs) are regulated within type approval. Even though they are pedal assisted they are viewed as motorised vehicles by the EU authorities. Here are the two relevant categories for these vehicles:

- L1e-A "powered cycles" – of speeds up to 25 km/h and power cut out at 1000 watts
- L1e-B "mopeds" – of speeds up to 45 km/h and power up to 4000 watts

The relevant EU legislation is Regulation (EU) No 168/2013 of the European Parliament and of the Council of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quad cycles. L1e-A deals mainly with cargo type bikes, while L1e-B deals with so-called 'speed' pedelecs. Due to their higher maximum speeds, speed pedelecs can compete on travel time with cars for even longer distances than low-powered pedelecs. With a top speed of 45 km/h, they can now replace up to 90% of car journeys and have excellent active transport credentials. On the other hand, they bring some safety and infrastructural issues which justify treating them as a category different from conventional bikes and low-powered pedelecs. (e-bikes) that must be licensed and registered, have a greater power output range and can be propelled without pedalling.

In some cases we meet with the definition of *E-bikes* as bicycles with electric motors that can be ridden without pedalling, i.e. entirely electrically powered. E-mopeds and e-scooters also run on an electric motor and need no pedaling. They usually allow higher speeds, 45 km/h or more, but require registration and a driving license in some countries.

Other types of electric road vehicles are also increasing in number. As shown in the figure below, around 1.66 million e-bikes were sold in the EU in 2016, compared to only 98 000 in 2006. This number is expected to further increase to 62 million by 2030. Most of these e-bikes are being used in a few Member States (for instance, Germany, the Netherlands, Belgium and France) and are imported, mostly from China. In general, e-bikes are still more expensive than conventional bikes, but purchase subsidies in some countries (see the section on local, regional and national incentives) have somewhat helped to overcome this trend.



Number of e-bikes sold in the EU, 2006-2016 (in thousands)

While demand for electricity-driven buses, mopeds, scooters and motorcycles is on the rise, demand for electric trucks remains limited, awaiting further technological progress in the area of batteries. Currently, there are around 2 500 electric buses in Europe – a relatively small number compared to the overall 725 000 buses (mostly diesel) in operation. However, a number of cities (for instance, Paris) are planning to electrify most of their bus fleet in the near future. Some cities (such as Berlin, Brussels and Paris) are also offering shared e-scooter services. As for electric trams, they have been in use for decades and are a proven technology.

Electric scooters (E-scooters)

Electric scooters, not to be confused with electric mopeds, are powered stand-up vehicles using a small electric motor. They are classified as a form of micro-mobility and have a platform in the center where the rider stands. Recently, e-scooters have surged in popularity all over the world due to the introduction of ride-share companies that operate an app that the user can use to rent the scooter, usually by the minute or hour. These have been introduced in cities all around the world, but mostly in the United States, China and the European Union.

E-scooters are cheaper than taxis, take less effort and skill than a bike and are more convenient than regular public transport. Due to their small size, low costs and practicality, the customer base of these business models has increased at an accelerated pace over the last five years. This situation however has not been without its downsides.

During the last 2 years e-scooters have taken over many cities. There are already more than 200 cities where these are available. The market leaders are Bird and Lime in the USA and Voi, Tier, Circ and Flash in the EU. The market is however very dynamic, with most of these providers not generating any profits, and this statistic can change at any time.

The drawbacks of this technology are the large number of e-scooters discarded everywhere on the roadsides, and an increasing number of accidents and deaths related to their use. Cities have started to fight back against the discarding of these scooters by introducing stricter rules regarding where they can be dropped off, either in specially designated areas or by limiting the places where these can be dropped off, as to not include busy streets or areas with a large number of tourists.

The safety statistics on the other hand are more worrying. As it is still a relatively new form of mobility, with a very low entrance barrier, a large number of their customers are inexperienced when it comes to the operation of these vehicles and or regarding the general rules of the road (using e-scooters does not require a driving license. Road users are not used to looking out for e-scooters and may well confuse them with pedestrians due to the similar stance of the rider. As opposed to pedestrians however, an e-scooter can usually maintain a speed of 20-25 km/h even when cornering.

Due to these factors and the novelty of the technology, the legislative response has been differed between counties, even between EU member states.

The drawbacks and issues with the early adoption do not seem to slow down their popularity and their adoption rate is set keep increasing. According to the market research report published by P&S Intelligence, the European electric scooters and motorcycles market is expected to reach $892.4 million by 2025, with a CAGR of 26.2% during the forecast period. The major driving factors for the growth of the market are deployment of electric scooters for sharing services, rising concerns over greenhouse gas emissions, government initiatives, and implementation of stringent emission regulations.

Charging infrastructure for light electric vehicles

For the charging of light electric vehicles such as electric bicycles and electric scooters, two possibilities exist: they can also use EV charging facilities for cars as those described above, if a household-type or smaller plug connection is provided. Alternatively they can use charging facilities dedicated to LEVs.

As with bigger EVs the three technological solutions of conductive and inductive charging, and battery switching can be applied.

For the conductive AC charging of LEVs, several manufacturers of electric bicycles, batteries, and charging infrastructure already use the EnergyBus plug standard. This standard includes a specification of a plug system, with magnets for attachment, as well as a communication protocol. In 2014 work has started to transfer the EnergyBus system into an international IEC/ISO standard.

With most LEV models the user can easily take the battery out and take it into his home or working place for recharging at a household socket. This possibility and the fact that LEV are mostly used for short-range trips indicates that the demand for public LEV charging facilities will probably be low. But special applications are interesting, such as integration of conductive charging into electric bicycle rental stations. The simplicity of battery handling of LEVs makes the installation of battery swapping stations for electric bicycles and electric scooters interesting for touristic regions.

Statistics

E-bikes

Customers are showing more and more interest in electric bikes, in fact the number of electric bicycles sold in the European Union shows a very positive trend. Countries such as Germany, the Netherlands, and Belgium are leading as top purchasers of electric bicycles, followed by France, Italy and Austria. The global e-bike market was valued at USD 14,755 million in 2018, and is expected to grow at a CAGR of 6.39%, during the forecast period of 2019-2024.

Apart from the growing consumer preference toward recreational and adventure activities, the adoption of e-bike applications in several sectors, like logistics and e-bike rental services, is expected to drive the market studied during the forecast period.

- The market has been segmented by propulsion type and application type. In 2018, by propulsion type, pedal-assisted e-bikes dominated the market, and accounted for 88.32% of the global market. By application type, city/urban e-bikes dominated the market.
- Asia-Pacific is expected to dominate the global market. In Asia-Pacific, China dominated the regional market. The largest consumption of electric bikes is in China that has boosted the sales figure, and thus influencing the growth of the global market for electric bikes. The import and export volumes in China are also large, and China has always been the largest exporter of electric bikes. The Government of India has also encouraged to use electric bikes. By the end of

2035, the government is looking forward to convert fuel vehicles into electric vehicles.
- Some of the major players in the e-bike market are Giant Bicycles, Merida, Trek Bikes, Riese & Muller, and M1 Sporttechnik.

In the Netherlands, a country known for its affinity towards bikes and excellent cycling infrastructure, there are now more e-bikes sold than non-electric bikes. Between 2017 and 2018 the e-bike market grew by 9% in a single year. This is the steepest increase to date. According to figures from Dutch industry organizations RAI Association and BOVAG more than 1 million bicycles were sold in 2018, with revenues of €1.22 billion of which €823 million were from e-bike sales. The average price of a bicycle in the Netherlands is now €1,207. In 2011 the average was €734, when e-bikes were 15% of bicycle sales in The Netherlands. This trend is also seen in DTP member states, but at a slower rate and is difficult to discuss without any quantitative data.

The global pedal-assisted or pedelec market is expected to reach USD 18,655.90 million by 2024, and is expected to witness the fastest growth rate. The European region accounted for 20.12% of the global market, and is expected to witness the fastest growth rate of 6.23%, during the forecast period, after Asia-Pacific region. The European region was dominated by Germany, followed by France and Italy.

E-scooters

Most electric scooters in Europe are not owned by the end customer but are instead operated as a fee based service, classified as electric scooter sharing.

Stockholm-based Voi and Barcelona-based Wind — both founded less than two years ago — have attracted the most investment. In total six European headquartered scooter startups have raised funding; including Movo, an electric bike and scooter startup which mostly operates in Latin America, but is based in Madrid. A few more European scooter companies, such as Troty (Brussels), have not announced funding rounds. Meanwhile, Tallinn-based ride-hailing firm Bolt (previously known as Taxify) has also entered the scooter market, with vehicles in a handful of European cities — and a platform to help other e-scooter operators launch and manage fleets.

As for employees, Circ has the biggest headcount in Europe — although Bird last week announced plans to hire 1,000 people in Paris over the next few years.

Companies seem to have barely announced one round of funding before they're announcing another — this is because many expect this to be a winner-takes-all market. The startup which can "win" the most cities will likely be the one to win out over all — and launching in a new city takes considerable capital investment.

As of April 2019, Paris appears to be the hub of e-scooter sharing in Europe, followed by Berlin. Lime, Bird and Taxify have already launched in Paris.UK is expected to be the next hotspot for e-scooter sharing development as both Lime and Bird have set their sights on launching operations.

Due to their popularity and widespread adoption, in Europe e-scooter sharing biggest competitor is bicycle sharing. As opposed to bike sharing, scooters have a shorter theoretical reach and need charging stations and a certain population density to be feasible. They offer no health benefits and are charged by the minute. There are however also many advantages. Scooters are better suited for hilly terrain and have a small form factor, especially when collapsed. Thus users can take them onboard trains and buses and benefit from multimodal transport when used together with the public transport network.

Rentals and sharing

As of this moment we did not identify any major electric bike sharing schemes in the DTP countries. There are a number of projects, mostly financed through EU structural funds, that make smaller numbers of e-bikes (typically dozens, usually up to 100) available to locals and tourist. These initiatives are mostly pilot projects and one of their objectives should be to provide best practices for future developments coming from industry. Thus, while non-electric bike sharing schemes are quite common and very in size from small to large (hundreds or even thousands of bikes), electric bike sharing has not had a chance to become popular yet. This may be due to the inherently higher cost of electric bikes compared to electric scooters which has kept the size of most project in the DTP area small, usually a few dozen e-bikes at most.

Electric scooter sharing however is popular and still gaining ground despite problems with the placement of the scooters and their charging infrastructure, legislative void, accidents and vandalism inflicted on these vehicles.

As of March 2019, E-scooter sharing in Europe was only available in 30-35 cities as compared to 90+ cities in US. Europe`s e-scooter sharing market comprises larger number of European players, but with small fleet sizes. US based Lime and Bird are present only in 22 unique cities.

Fundamentally, there are three type of players active in the scooter sharing market. The first category is comprised of on-demand taxi providers like Uber, Lyft, Taxify and Grab. The second category being that of bike sharing providers, who have now broadened their offerings to include e-scooters like Jump and Lime. The third being, e-scooter only sharing providers like Bird, E-cooltra and Scoot.

Best practices

Electric Bikes

Electric bike share schemes are suitable for cities with any level of cycling. We recommend their introduction in cities with small cyclist communities, where they will encourage cycling and make it more visible for all traffic participants.

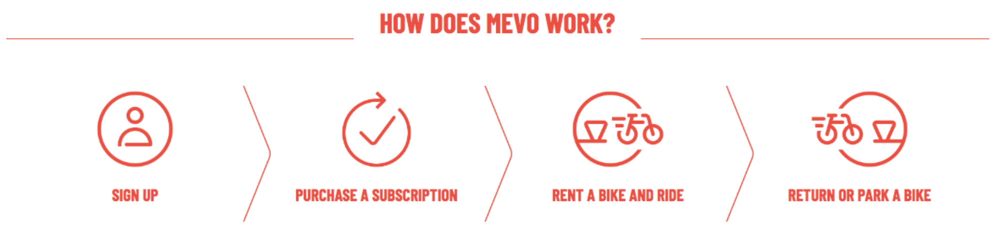
Non-electric bike share and are more likely to be effective in relatively flat areas due to their lower cost, complexity and weight. However, in cities with hilly topography, electric bicycles are generally more suited and can open up cycling to a large part of the community that would not have considered this activity otherwise. While not as important for the mobility function, electric road bikes can be set up in a network with longer distanced where the charging opportunities are fewer.

While this may depend on local regulations, most members of the population could potentially use a shared or rented bicycle. Students and tourists are usually important customers of a bike-sharing scheme. Students might be interested in cycling but might not have the space to store their own bike, or the finances to afford one, while tourists might be interested in cycling both as a mean to explore the city and to save some time and money in traffic. The registration process hiring stations must allow the tourists to register within the network.

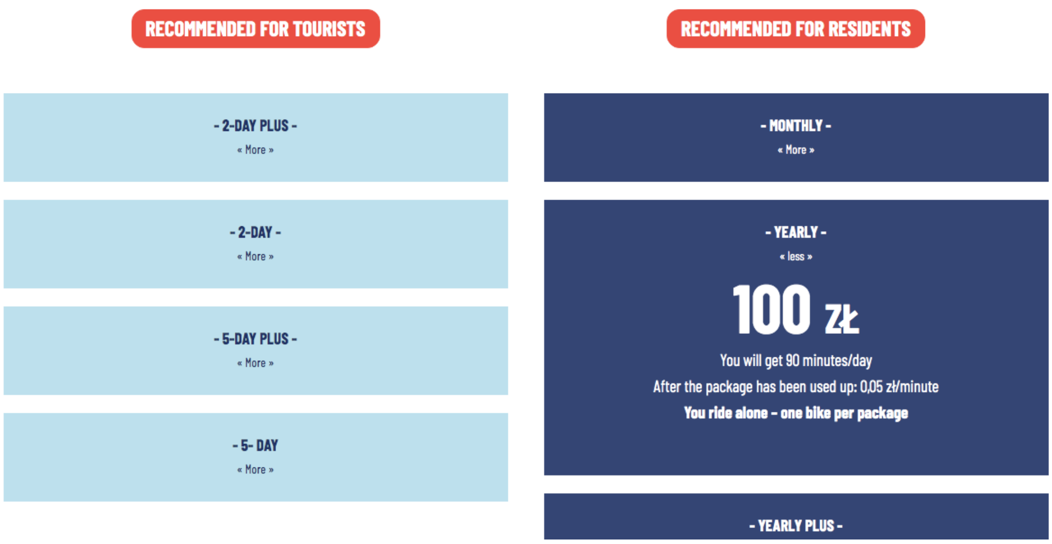
The cost of these schemes are dependent on its size, complexity and funding model. Electric bicycle rental and dockless electric bike sharing should come at close to no extra cost for public authorities. The cost of the charging stations, bikes and other required components can however be quite steep. Worldwide, the companies tend is to overcome this barrier by gathering large sums of capital through VC funding and using this capital to implement their networks. There are also annual operating costs, influenced by the cost of labor, level of vandalism and miles travelled, which can amount up to 1-2000 Euros per bike.

Thus the most important resource required from a local public authority will be the time of its workers, who will need to work together with the operators of these vehicles. The private nature of this activity does not require a large amount of input from the municipalities themselves. In the case of dockless bikes, just like with dockless scooters, the local authorities will have to develop a set of rules regarding their parking and charging throughout the city. We see no need for a public authority to undertake this sort of endeavor by itself. Instead there are a larger number of companies interested to get into this business.

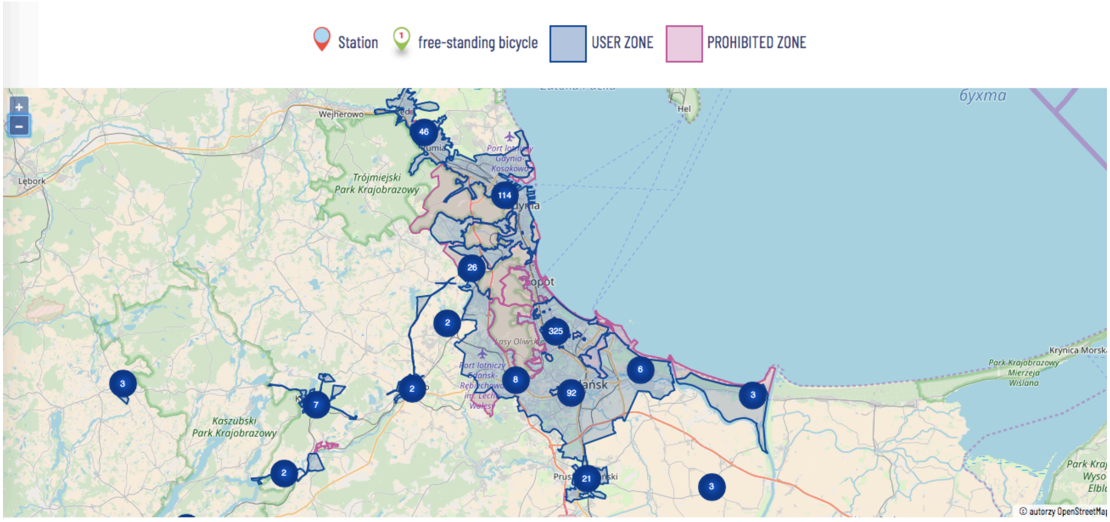
A great example of good practices for this type of investment is the project "Construction of Metropolitan Bike System OMG-G-S", website https://rowermevo.pl/en/, no. RPPM.09.01.01-22-0016/17-00, co-financed by the European Regional Development for the Pomeranian Voivodeship, Poland. Mevo Metropolitan Bicycle is the most modern system of urban bicycles in Europe, adapted to the needs of all of us. It consists of 4080 bicycles placed across 660 stations in 14 communes. The citizens and tourists of Gdańsk, Gdynia, Sopot, Tczew, Puck, Reda, Rumia, Kartuzy, Sierakowice, Somonin, Stężyca, Władysławowo, Żuków, and Pruszcz Gdański, during their everyday communication are able to use bikes equipped with conveniences such as the assisting electric motor, GPS modules or electric lock. Bicycle rental is intuitive and done in three simple steps using a smartphone or a debit card.



The sharing scheme offers different levels of paid subscription that allow the user to rent out bikes for longer or shorter amounts of time, and the user must pay a fee for every exceeded minute. Users who are not registered also have the option to rent a bike and pay by the minute but this variant is more expensive long term.



As mentioned previously, the bikes have been spread all over a larger region and are used for transportation between and in towns. The digital maps clearly outline the permitted and prohibited areas and the entire website and app are translated in numerous languages, while still being simple and intuitive to use even for someone who comes across it for the first time. The rental scheme is Europe's largest for electric bikes, having surpassed Madrid and Barcelona by the total number of bikes installed.



Another best practice example was the comes from the Croatian Postal Service, where in total 180 ebikes substituted old and obsolete moto scooters that the Post was using for everyday deliveries. Total value of the project was 3,738.825,00 HRK (appr. 498.000,00 €). The purchase of the ebikes was also co-financed by the FZOEU by 49%. The results of this project were used in the PRO-E-BIKE project as a part of the evaluation process.

Electric scooters

Generally speaking, a city is recommended for electric scooters if it suffers from increasing pollution, congestion and has more than 100,000 inhabitants. The density of the population is also a very important variable seeing how scooters are most appropriate for short trips in densely populated areas.

Road quality is also an important criteria as the scooter's smaller wheels do poorly when faced with potholes or any other larger-scale problems with the road surface.

Electric scooters are still a new mobility solution and it will take time before all road users will get used to them. However, we predict that electric scooters will become integral to European mobility in most large and medium sized cities as long as appropriate traffic legislation will be put into place.

Cities must act now and come up with new legislation regarding the parking and charging of these vehicles so that they will not obstruct pedestrians and other traffic. Especially at night we recommend clear rules regarding the parking, with clearly outlined rules and areas being made available through the rental app. Another recommendation is to compel the service operators to remove defective vehicles from public spaces as quickly as possible.

All in all, there are many rules and regulations that will have to be created and made consistent among the member states but these vehicles are here to stay and by keeping legislation up to date with the technology, EU cities have a chance to improve the mobility of their inhabitants and to drastically reduce greenhouse gas emissions in busy areas. These changes in mobility will clear up valuable space in the busiest parts of the cities that can be put to good use for the benefit of the general public.

Las but not least, any mobility plan that takes into account electric scooters and bicycles must integrate them in the existing public transport network. Electric bicycles for example are well suited for riding longer distances to and from a public transport station, where the bicycle will be parked and used by another customer. Intermodal public transport networks offer the highest flexibility to the customers and have a high return on investment for the municipalities if they are done right.

As far as electric scooters are concerned, they are more limited as far as the overall range but are much smaller, cheaper and are also foldable. While a scooter may not be an enjoyable experience for a long ride on a very uneven road surface, its true value starts to show when it can be taken onboard a train and used as a first mile / last mile type of transportation. All in all, intermodal parking with public transport stations and electric vehicle hire offer the most flexibility and the most value for their users but also come at a higher cost than regular public transport stations.

Policies

European Union directive 2002/24/EC defines pedal assist bicycles and exempts them from type approval requirements: "Cycles with pedal assistance which are equipped with an auxiliary electric motor having a maximum continuous rated power of 0.25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25km/h (15.5mph) or if the cyclist stops pedaling." This serves as an informal definition of pedal assist bicycles in the EU. Being an EU directive, individual member states are left to implement the requirements in national legislation. On 1 January 2016 directive 2002/24/EC was repealed by regulation 168/2013, but the definition remains nonetheless the same.

Furthermore, product safety standard EN 15194 from 2009 provides a standard for assessing e-bikes are excluded from type approval by Directive 2002/24/EC".

In January 2019, a controversial rule change was abandoned by the European Parliament. Under the proposal, riders of electric bikes were required to buy third party liability insurance similar to motor vehicles. Had this rule change passed, it would have substantially slowed down the adoption of electric bikes in not just the EU but in all of Europe and the DTP countries. Still, there is no guarantee that similar changes will not be adopted in the future but such a change would discourage millions of people to buy and use e-bikes and undermined many EU efforts and financing aimed at promoting sustainable mobility. Part of the allure of light electric vehicles is that they don't require anything besides the initial purchase and regular servicing to be used on public roads. Most riders are already covered under different types of insurance such as health or personal liability insurance.

Despite lobbying from the industry and the ECF, the EC has not yet made clear the separation between pedal-assist e-bikes and motorized vehicles. Still, this decision reverses the European Commission's proposal to define an e-bike with a 250-watt as a motor vehicle.

There is still the argument that e-bikes and e-scooters can cause significant accidents and injuries to pedestrians and other riders and this requires a formalized pathway for the resolution of such cases. Still, regular bicycles, depending on the rider, can usually match and in fact surpass the 25 km/h and 250W limit of e-bikes, so their potential for damage is similar and yet unregulated other than personal liability laws and insurance.

Regarding the newer e-scooters, whose non-electric predecessors were never as popular and thus regulated as in the case of e-bikes, the legal situation is very different and there are no universal guidelines in place. The explosion of their popularity has caught the governments unprepared and they have often reacted with reactionary and sometimes contradictory legislation that differs between EU and DTP member states (if it exists at all) and is often subject to change. In fact, many of the e-scooters regularly ridden by people are in fact illegal, although due to lack of enforcement this only becomes a problem for the rider in the case of an accident.

Many cities in Europe have been overwhelmed by the rapid, disruptive business model of dockless bike, e-bike and e-scooter and did not have the necessary policies in place when faced with the rapid proliferation of these services. Some cities have banned these rentals, while others have already come around and made them legal again, together with a new set of rules.

Perhaps the best example for this trend is the city of Paris, which has been one of the European cities with the most dockless e-scooters. In Paris, self-service electric scooters no longer have the right to park on sidewalks, where they bothered pedestrians starting July 30 2019. The e-scooters were tolerated as long as they did not interfere with people moving on the sidewalks but have now their parking is prohibited on all sidewalks, pedestrian areas and roadways. Thus they must be parked in parking spaces similar to cars and motorcycle. The French are also planning on banning their circulation on sidewalks in the near future.

The reaction in Paris has been more extreme than that in other cities, but so has the pace of the introduction of these e-scooters. They made the life of the residents more cumbersome in a way, with many interpreting them as anarchic due to the park anywhere policy, and so the local authorities were forced to take drastic action against them.

The story of Paris is a good example for why legislation in this field should be proactive and not reactive, as seen above. The rapid adoption of this mode of transportation in a city must not necessarily inconvenience other residents, as long as issues such as parking, charging and road rules are set in place in time and the people are made aware of these changes.

Some municipalities are also looking into introducing taxes for electric bikes and e-scooters. This is more often the case with e-scooters, as they are a relatively new addition to the market and it's less likely to get a bad reaction from the taxpayers by taxing them instead of bicycles, even if they are e-bikes. This taxation is related to the occupation of the public road domain by vehicles waiting to be hired.

Aside from taxation and the change in parking and riding regulations, there is another legal pathway that municipalities can follow to benefit from these vehicles. Seeing how all dockless electric bikes and scooters have a GPS unit and Internet access, they are a perfect platform for easy sharing of anonymous mobility data between their operators and local authorities. This data will help municipalities to build better public infrastructure, and the clients of these sharing platforms will benefit in turn from these changes. Better infrastructure also equates to less maintenance costs for e-bikes and e-scooters.

In Austria the use of e-scooters is generally restricted on sidewalks. E-scooter riders must adhere to all the traffic rules applicable to bicyclists and use bike lanes where they are available. Some sidewalk access may be permitted by local authorities in certain places, but only for e-scooters under 300W.

Croatia has similar legislation and e-scooters under 250W and 25 km/h can use bicycle facilities and do not require special registration. Any scooters over that limit are equated to mopeds and require AM license and registration.

Hungary has similar views regarding e-scooters and equates them to bikes as long as they are not above the maximum power and speed threshold

Slovenia is now preparing draft legislation that will regulate e-scooters in a similar fashion to bicycles, with similar power and speed requirements to Croatia. Scooters must use the sidewalk when there is no bike lane, which severely limits their practicality and makes them more dangerous to everyone around.

Currently e-scooters exist in a legislative gray area in Romania and this can be seen by their presence on both roads and bike lanes, as the rider considers fit. However, changes to the road rules are being debated that will serve to regulate these vehicles.

E-scooters may thus be defined as vehicles with two or three wheels with a top speed of 40 km/h and equipped with an electric engine with a maximum rated power of 2 kW. E-scooters will follow similar rules as bicycles and will have to use bike lanes whenever these are available. Just like bicycles, e-scooters may be used in a public setting by any person over the age of 14, and a helmet is mandatory until the age of 18. The lighting and reflector requirements will be identical to those for bikes.

In the Czech Republic, e-scooters are unregulated but Prague is looking to introduce new restrictions that would allow them to operate in the city in a safe manner and without major inconvenience. Under these rules, there will be exclusion zones in the busiest areas and parking of shared scooters will only be allowed in certain areas. This should help them be more successful than Segways were in Prague, which were banned due to the increasing chaos after a period marked by a rapid increase in their numbers and use.

In Slovakia, People riding an electric scooters or Segway will be deemed as a driver of a non-motorized vehicle, not as a pedestrian. They will be allowed to drive on the pavement only at walking speed.

Serbia and Montenegro have not yet regulated e-scooters, and have no restrictions on power, speed, public access, age of rider etc. Faced with no regulations but with a similar rise in popularity as in the rest of Europe, some local municipalities have taken action and forbidden the access of electric scooters (and bicycles) on certain public sidewalks, boardwalks and streets.

Future developments and conclusions

The problems that appeared with the rapid adoption of light electric vehicles – bicycles and especially scooters – in urban spaces that were usually not designed for them are similar to the situation that arose at the beginning of the 20th century with the introduction of the car. Speeding drivers, unaware pedestrians, improper infrastructure, parking infrastructure were a problem then as it is now. Cars were never banned from our roads or regulated in such a way that they became impractical. Instead, governments introduced clear and homogenous legislation, changed the roadways and educated the people, and so the automobile ended up defining the 20th century.

Nowadays the busy urban centers of Europe are full of cars and the pollution they cause is becoming less and less acceptable. Municipalities and governments have to recognize that, together with the adoption of electric cars, light electric vehicles are the future of personal urban transportation, and together with public transport they have a chance to define urban transport for the rest of the 21st century. This trend will continue regardless of policy, but regulating these modes of transport in a clear, homogenous manner and making provisions for the parking of dockless electric vehicles will make this transition easier and probably quicker too.

Regarding the technology that lies behind these vehicles, there are probably two areas that may see major changes in the future, even if not in the next 5 years. Advancements in battery technology will make the vehicles lighter, with a longer range than current models and possibly cheaper too. The price of the batteries will of course be influenced by the demand in the car industry and there is a chance that these prices will go up at a certain point, even if just for a few years, as the global demand for batteries increases and companies are slow to react with the expansion of production and mining facilities.

Autonomous self-driving technology is currently under development for cars and the technology may at one point trickle down to LEV's. This might require further changes in infrastructure but the technology is still a few years away before it has any chances to impact this market.

There are many companies producing e-bikes and e-scooters and this is not set to change in the next years seeing how consumers like variety and the entrance barriers to the market are quite low. The situation regarding dockless EVs is however quite different. Many analyst and the companies themselves expect a single large dockless sharing operator to survive in the next 5-10 years, and so investors will keep putting money into the biggest operators and hope that their business model is better than the competition's.

LEVs, whether personal or shared, are a significant shift in transportation. Devices that at first were seen as toys are going to change our urban environments and with it our own behavior. A new age of personal mobility is starting and it has already changed our cities.

3. Electric Public Transport

For most of the 20th century, electric public transport was widely available and widespread in Europe. Electric trams and trolleybuses have existed since the 19th century and are still going strong in many European and DTP cities. The two technologies are suited for different needs.

Trams are inherently more expensive and can carry more passengers. Due to its design particularities, many tram systems in the EU are increasing the size and speed of its rolling stock while also changing the infrastructure, making it faster and grade separated. Systems following these guidelines fall under the definition of light rail and are popular and practical when integrated into a multimodal transport platform.

Trolleybuses on the other hand were always a non-polluting and easy to maintain alternative to buses using combustion engines. Their versatility and use scenarios are similar to buses but they are limited by the need for the charging infrastructure, the overhead power lines that trolleys need to operate. This limit and the ignorance regarding pollution were the factors that lead to the dissolution of some trolleybus networks, especially in western and northern Europe during 1960s and 1970s, but these networks are still going strong in many European municipalities and trolleybus is typical mean of transportation in many DTP cities although the socio-economical changes after 1989 also led to the abandonment of some networks. Trolleybuses have distinct advantages compared to trams and motor buses, and this kept them going in many cities, even if they never came close to fully replacing motor buses. Modern trolleybuses are being often equipped with battery providing auxiliary power. Such vehicle is not 100% dependent to move just under the contact network thus main disadvantage of older trolleybuses is limited. The range of movement on battery energy is based on its capacity but generally these vehicles are capable to travel about 8 – 15 kms out of reach of power lines.

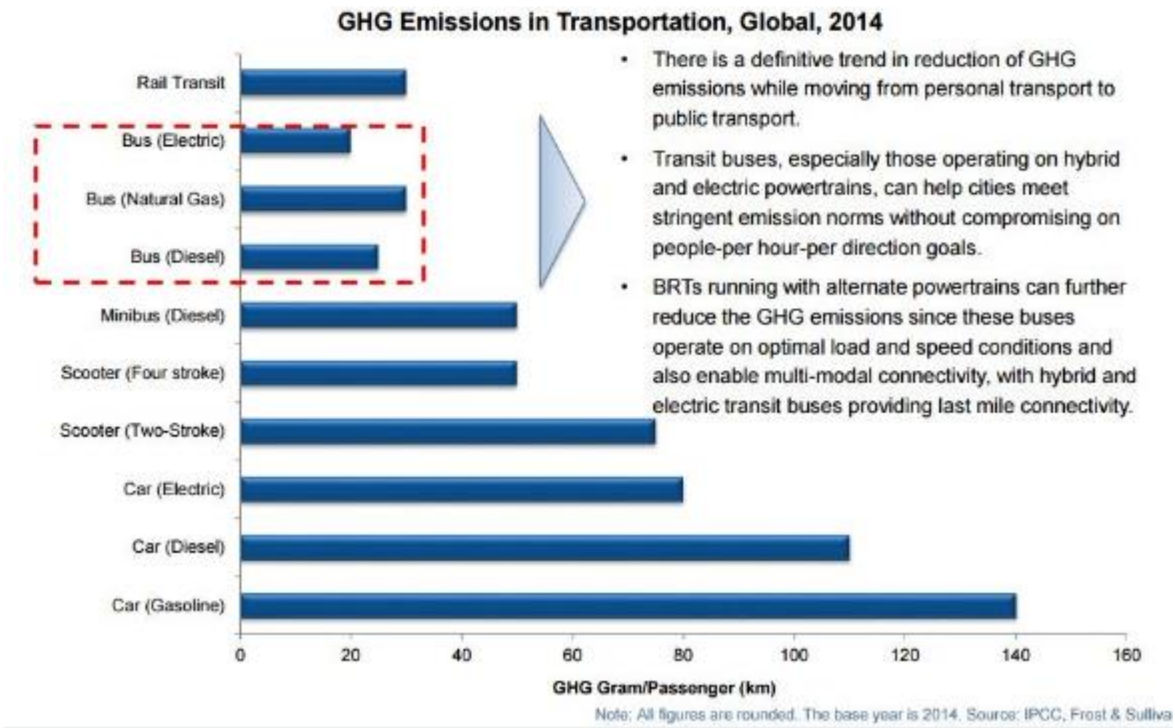
These two technologies have been around for a relatively long time and seem set to keep their place in European cities in the next few years.
Electric buses, or eBuses are buses that are powered by electricity. Battery electric buses, or BEBs, are buses driven by an electric motor that gets energy from the onboard battery system.

BEBs have zero emissions on the consumer side, quiet operation and better acceleration than their old ICE counterparts. As opposed to trolleybuses they do not need the overhead power lines for charging. These vehicles usually recover braking energy and have a smaller cost of ownership than the typical diesel alternatives found in most cities.

There are also drawbacks to the technology, seeing how they still have less range, more weight (which translates in relatively lower passenger carrying capacity) and are more expensive. With current technology and infrastructure, pure BEBs (meaning that even heating and air conditioning are fed from energy in the battery) are only suited for short and medium range city transport/per charge. As most of the bus lines tend to have a mid day pause, charging them during this period and using bio-ethanol heaters makes BEBs suitable even for a whole day long range city service.

eBus state of technology development

The development of electric buses is growing from year to year in terms of both technology and acceptability. Worldwide, the technology is metamorphosing yearly becoming more suitable for public use and need. One of the most important issues that tackle the electric transportation is the high level of CO2 emissions generated by all means of transportation. The following graphic shows a report of 2014 GHG emissions given by transportation per passenger-km:



GHG Emissions in Global Transportation ***Source:***

https://www.slideshare.net/FrostandSullivan/strategic-analysis-of-global-hybrid-and-electric-heavy-duty-transit-bus-market?next_slideshow=1

The 2015 global electric bus stock is estimated to be close to 173.000 vehicles, almost entirely located in China. Close to 150.000 of these are battery electric buses, running 100% on electricity.

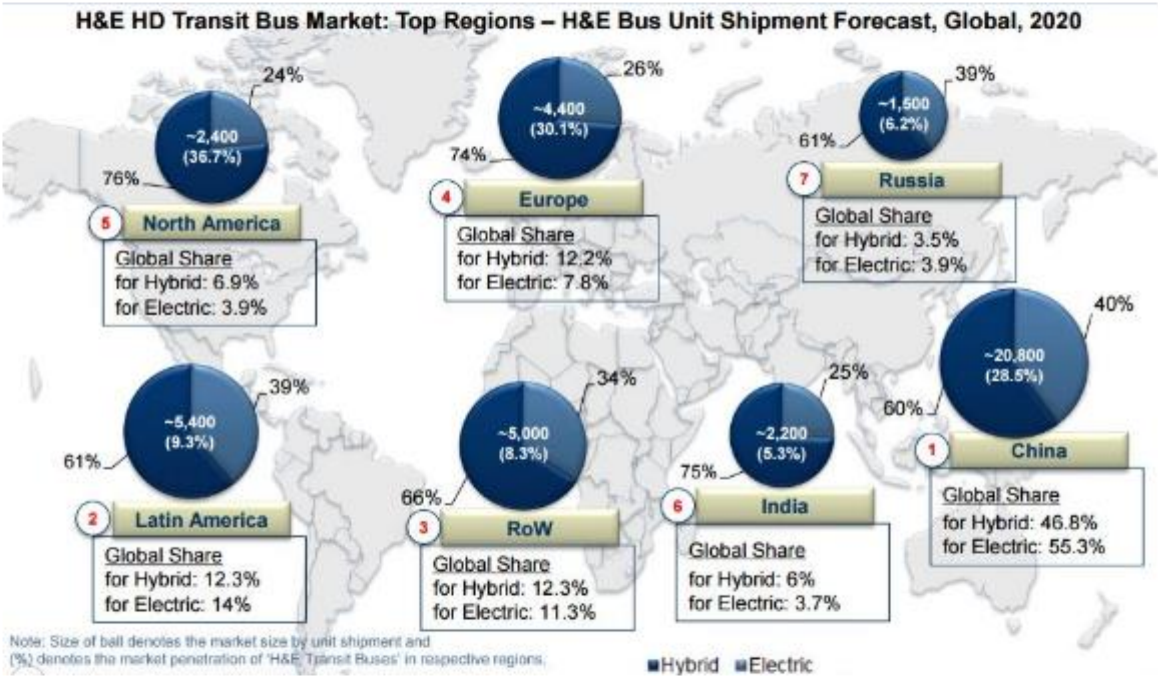
The electric bus stock grew nearly six fold between 2014 and 2015, demonstrating support for rapid public transport electrification from the Chinese government, which is driven by the urgent need to limit air pollution levels in Chinese cities. By 2020, China plans to have over 200.000 electric buses on its roads, accompanied by a network of close to 4.000 charging stations dedicated to buses.

In other countries, electric bus fleets do not reach the level of China – in the EU-28 there are more than 500 battery electric buses with the highest numbers in Austria, Belgium and the Netherlands (European Environment Agency, 2016). Still the bus fleets are moving towards alternative fuels - only in there are currently 2.307 hybrid buses, 8 hydrogen fuel cell buses, and 71 pure electric buses in use out of a total bus fleet of 9.588.

According to new Dutch legislation, from 2025 onwards city public transport will have to be carried up by zero-emission buses only. As such not only all bus fleet will have to be exchanged, but, more importantly, even bus depots will have to convert into small range power plants in order to be able to recharge megawatt hours of energy every night without causing power cuts in the local power line network. As such measures such as fields of FVE arrays and wind turbines and installed within the premises of the depots.

A variety of models of hybrid vehicle are currently used. These include Alexander Dennis Enviro200H, Wright Electrocity, Optare Tempo, Skoda Perun Hybrid and BYD electric bus single-deckers and SOR NS12 Electric, Volvo B5LH, Wright Gemini 2, Alexander Dennis Enviro400H, New Routemaster and Wright SRM double-deckers.

The Strategic Analysis of Global Hybrid and Electric Heavy-Duty Transit Bus Market show some interesting perspectives, for the transition to hybrid and electric buses:

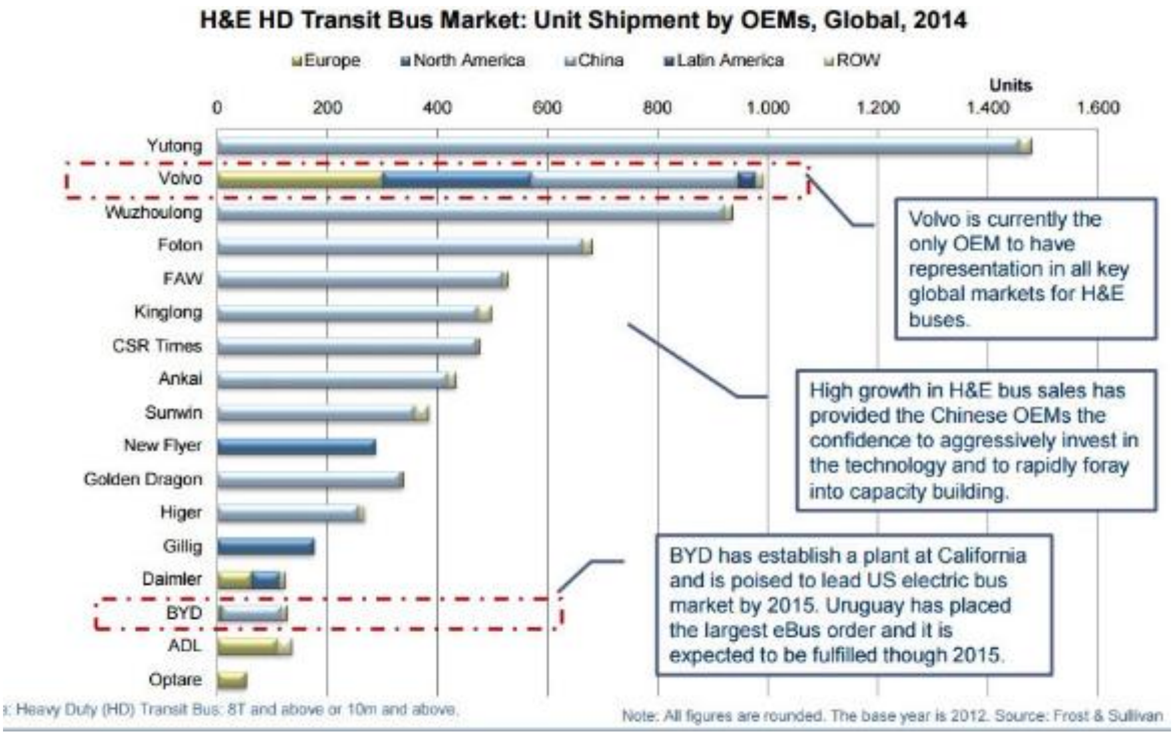


Hybrid and Electric Transit Bus Market/Regions

Source: *https://www.slideshare.net/FrostandSullivan/strategic-analysis-of-global-hybrid-and-electric-heavy-duty-transit-bus-market?next_slideshow=1*

As shown above, the share of H&E buses is likely to increase to 15% from the current 5.5% of total transit bus sales.

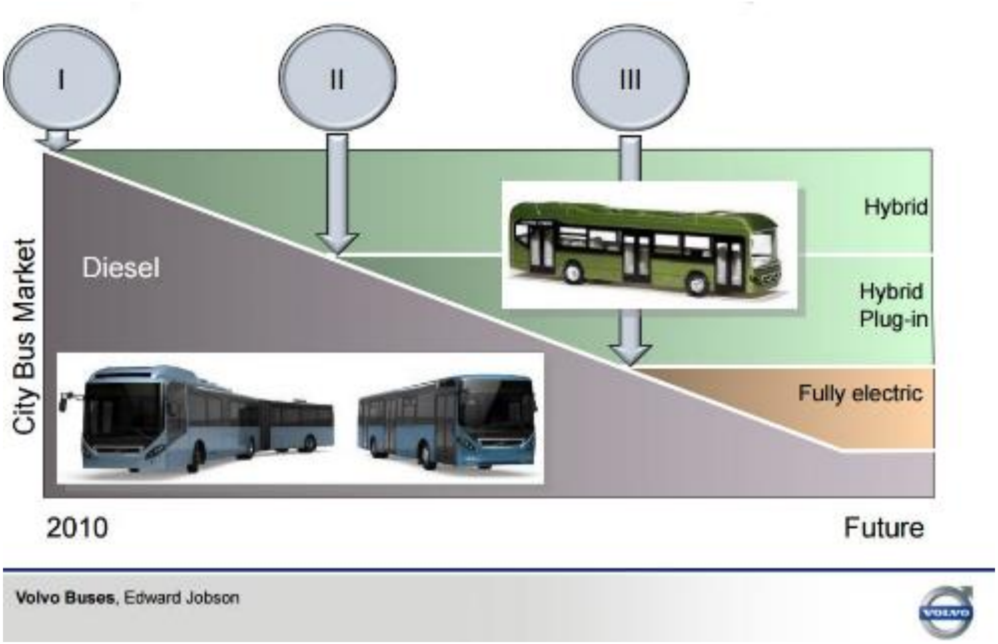
In terms of Unit Shipments of electric and hybrid buses, the graphic bellow show the main OEMs from 2014:



Bus Market - Unit shipments by the main OEM's

Source: *https://www.slideshare.net/FrostandSullivan/strategic-analysis-of-global-hybrid-and-electric-heavy-duty-transit-bus-market?next_slideshow=1*

The biggest manufacturer of buses in Europe is the VOLVO Company. According to the company's state report, their policy involves a path to Energy Efficiency and Green Efficiency:



VOLVO's direction in bus manufacturing ***Source:*** http://nho-transport.no/getfile.php/Filer/Foredrag%20og%20innlegg/Seminar%20GF%202012/VOLVO%20Buss%20Environmental_Jobson.pdf

In 2016, Volvo sold 533 electrified buses, encompassing hybrids, electric hybrids, and all-electric buses. The largest single market for Volvo's hybrid buses thus far is the UK, which accounts for almost half (1.425) of the total of 3.000 sales. Other major markets are Colombia (468), Sweden (196), Spain (137), Germany (135), Switzerland (129) and Norway (109). Over the past two years, demand for Volvo hybrid buses has also increased in Eastern Europe, with a healthy sales trend in Estonia (44) and Poland (48).

Regarding the DTP region, Czech Republic stands out with 3 BEB and hybrid trolleybus manufacturers: SKODA ELECTRIC, SOR Libchavy and EKOVA. In Poland, the company SOLARIS Bus and Coach (BEBs and trolleybuses) has, with the earlier aid of its German owners, become one of the leading European players. Currently, SOLARIS has been purchased by the Spanish large vehicle producer CAF. Last but not least, the Slovak Troliga bus manufacturer, polish Ursus bus or the Hungarian Ikarus have shown their prototypes and small series of electrified buses in the last decade.

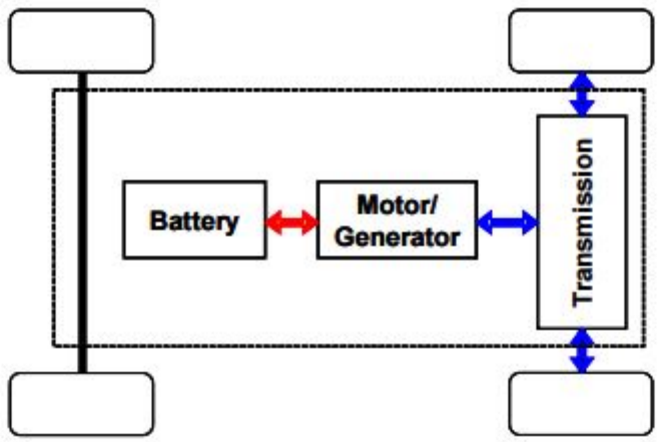
Another market is represented by the midibus vehicles (BEMBs), which include vehicles of up to 8 m length with carrying capacity between 20-35 passengers. The Slovak company Rošero P has delivered more than 40 BEMBs around Europe, having biggest fleets in Sweden and the Netherlands. New players arriving on the Market is the Dutch VDL, Spanish Indcar or Slovenian/Serbian Feniksbus,

Basic electric bus configurations

This summary presents the differences between the basic EV configurations that also apply to buses.

Battery Electric Vehicles

A battery electric vehicle (BEV) is a vehicle that is powered entirely on electric energy, typically a large electric motor and a large battery pack. Based on the type of transmission; the use of a clutch, gearbox, differential, and fixed gearing; and the number of battery packs and motors there are many variations on the BEV design. However, a basic BEV system is shown in the figure below. Configurations below apply to all multi-wheeled EVs including buses.

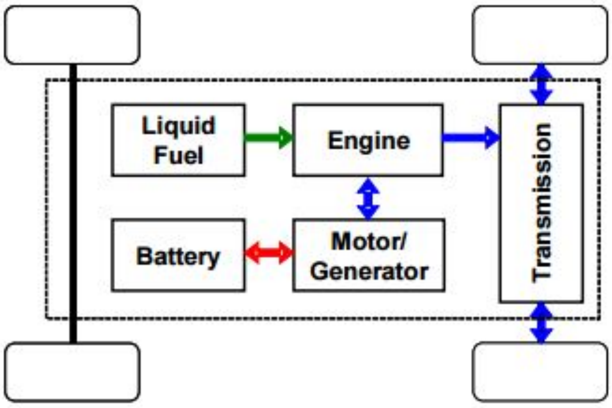


Schematic of a battery electric vehicle (BEV) powertrain ***Source:***

http://web.mit.edu/evt/summary_powertrains.pdf

Mild Hybrid Electric Vehicles

Unlike a BEV, a hybrid electric vehicle (HEV) relies on two energy sources, usually an internal combustion engine and an electric battery and motor/generator. A Mild Hybrid is the least electrified type of HEV. A Mild Hybrid is a conventional internal combustion engine (ICE) vehicle with an oversized starter motor that can also be used as a generator, usually called an integrated starter-generator (ISG) or a belted alternator starter (BAS), and an oversized battery that powers and is recharged by the motor. A simple Mild Hybrid system is shown in figure below. In a Mild Hybrid, the engine must always be on while the vehicle is moving. However, the motor/generator can be used to enable idle stop in which the engine is turned off while the vehicle is at idle. The motor/generator can be used at high loads to assist the engine and increase vehicle performance. At low loads, it increases load on the engine and recharges the electric battery.

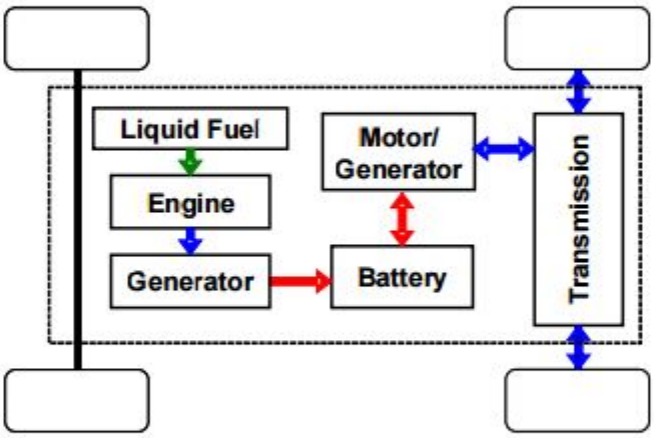


Schematic of a Mild Hybrid powertrain ***Source:*** http://web.mit.edu/evt/summary_powertrains.pdf

Series Hybrid Electric Vehicles

In a Series Hybrid there is a single path to power the wheels of the vehicle, but two energy sources. As shown in figure 7, the fuel tank feeds an engine which is coupled to a generator to charge the battery which provides electrical energy to a motor/generator to power the wheels through a transmission although a direct coupling can also be used.

The motor/generator is also used to recharge the battery during deceleration and braking.



Schematic of a Series Hybrid powertrain ***Source:*** http://web.mit.edu/evt/summary_powertrains.pdf

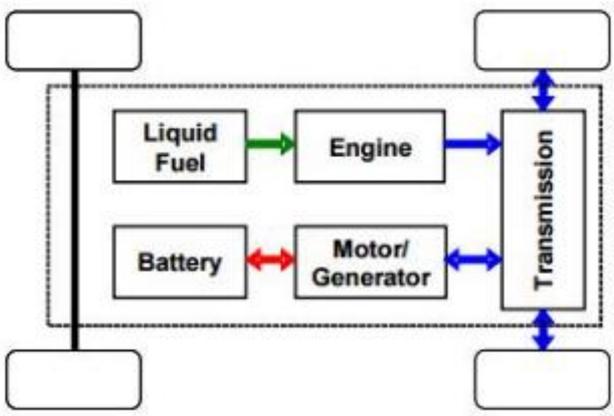
The Series Hybrid can operate in the following seven modes:

- Engine only traction
- Electric only traction
- Hybrid traction
- Engine Traction and Battery Charging
- Battery Charging and No Traction
- Regenerative Braking
- Hybrid Battery Changing

Although most Series Hybrids use an ICE, it is also possible to design a Series Hybrid using a Fuel Cell powered by hydrogen, creating a Fuel Cell Electric Vehicle (FCEV).

Parallel Hybrid Electric Vehicles

In a Parallel Hybrid, there are two parallel paths to power the wheels of the vehicle: an engine path and an electrical path, as shown in figure 8. The transmission couples the motor/generator and the engine, allowing either, or both, to power the wheels. Control of a Parallel Hybrid is much more complex than of a Series Hybrid because of the need to efficiently couple the motor/generator and engine in a way that maintains driveability and performance.



Schematic of a parallel hybrid powertrain ***Source:***

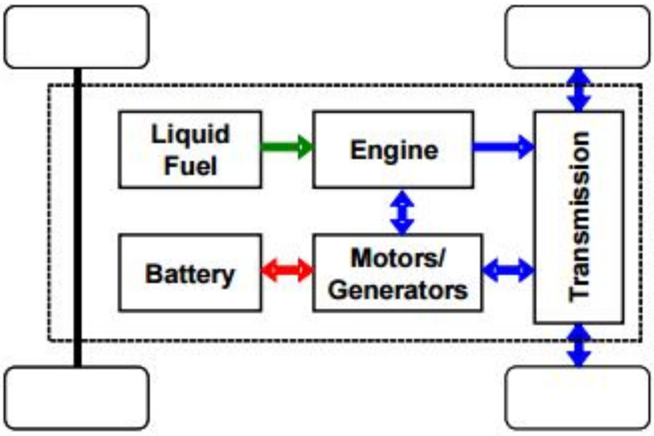
http://web.mit.edu/evt/summary_powertrains.pdf

The Parallel Hybrid can operate in the following five modes:

- Engine only traction
- Electric only traction
- Hybrid traction
- Regenerative Braking
- Battery charging from the engine

Series-Parallel Hybrid Electric Vehicles

A Series-Parallel HEV has both Series and Parallel energy paths. As shown in figure 9, a system of motors and/or generators that sometimes includes a gearing or power split device allows the engine to recharge the battery. Variations on this configuration can be very complex or simple, depending on the number of motors/generators and how they are used. These configurations can be classified as Complex hybrids (such as the Toyota Prius and Ford Escape Hybrids), Split-Parallel hybrids, or Power-Split hybrids.



Schematic of a series-parallel hybrid powertrain ***Source:***

http://web.mit.edu/evt/summary_powertrains.pdf

Plug-in Hybrid Electric Vehicles

A plug-in hybrid electric vehicle (PHEV) is an HEV that can be plugged-in or recharged from wall electricity. PHEVs are distinguished by much larger battery packs when compared to other HEVs. The size of the battery defines the vehicle's All Electric Range (AER), which is generally in the range of 50 to 80 kilometers. PHEVs can be of any hybrid configuration. Although no PHEVs are available on the market today, a number of companies have begun to sell conversion kits and services to convert a standard HEV into a PHEV by adding additional battery capacity and modifying the vehicle controller and energy management system.

Best practices

Europe is close to the wide scale adoption of electric buses after successful implementation of a multitude of pilot project in many European cities, including many from the DTP states. While there are still some undecided variables regarding the charging strategy and charging hardware, a set of good practices can be summarized as seen below.

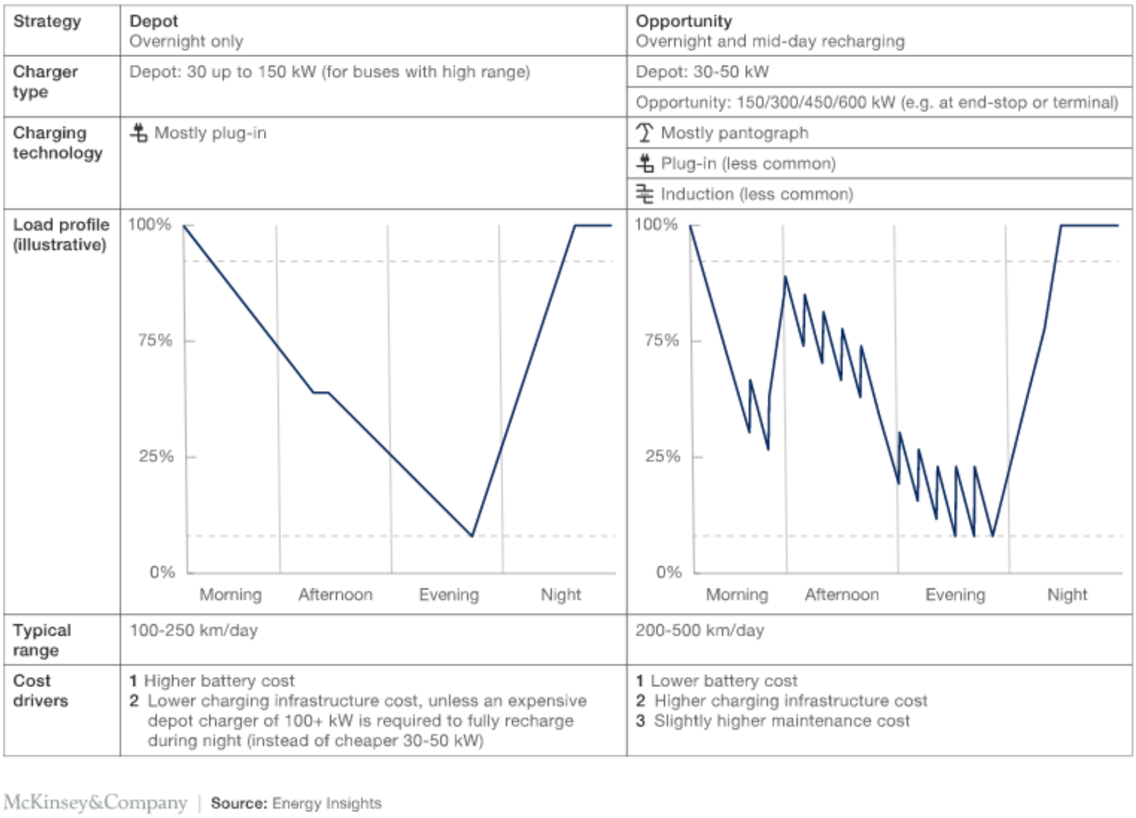
To date by far the largest successful deployment of eBuses has been in China where there are over 300.000 operational as of this moment. Europe is nowhere near those numbers but it will start to catch up rapidly in the following years. Commercial roll-out has started in most EU and DTP states, following the years of pilot project implementation.

Electric buses have two distinct advantages: no exhaust emissions on the consumer side and lower total cost of ownership (TCO) over the life of the vehicle, as demonstrated also in this project's feasibility study on electric buses. The low TCO is due to a significantly lower cost per kilometer compared to diesel alternatives, despite the overall higher cost of acquisition due to the price of batteries.

The benefits are clear both in regards to total costs and air pollution but countries must promote the adoption of eBuses by setting ambitious targets. A good example is the Netherlands, where 100% of public transport buses will have to be zero emission vehicles by 2025. The interest of all stakeholders at the regional level (cities, provinces, manufacturers, other stakeholders) was confirmed by the signing of the European Clean Bus Deployment Initiative. Fuel cell buses can also be clean if they run green hydrogen but we will not focus on this solution due to its lower physical efficiency and increased need for land when compared to solar panels or wind turbines.

The shorter range of eBuses in comparison to diesel buses is a critical issue that will require the collaboration of municipalities, transport providers and manufacturers in order to find the most effective solution for specific local characteristics. There are two main charging methods: overnight charging in the depot and constant recharging throughout the day mixed with daytime charging, called opportunity charging.

Opportunity charging is not yet 100% reliable and workable in the long term by itself due to technical and practical issues such as the balancing requirements of batteries. As such, overnight chargers usually have a power between 30 and 50 kW and are called "depot chargers". Superchargers over 150 kW are used for constant recharging throughout the day, and combined with overnight charging they form the opportunity charging strategy.

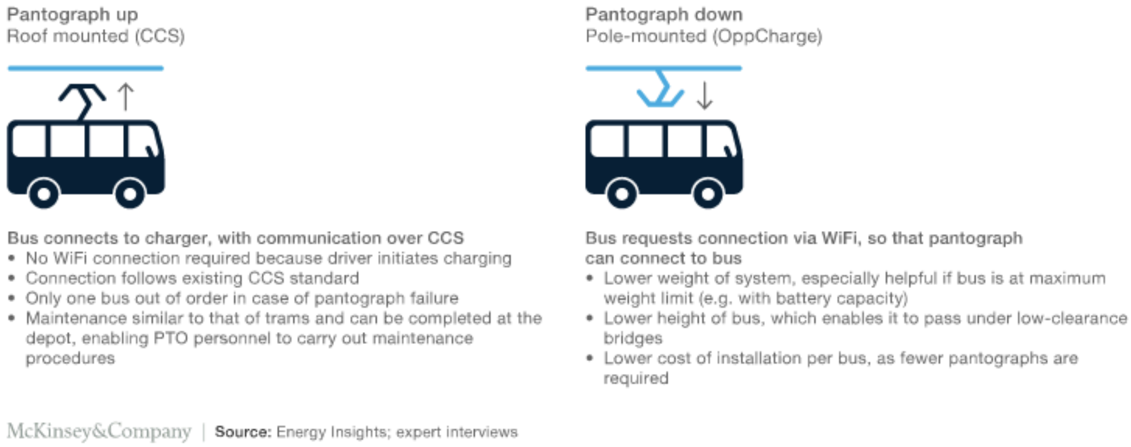


Strategy	Depot Overnight only	Opportunity Overnight and mid-day recharging
Charger type	Depot: 30 up to 150 kW (for buses with high range)	Depot: 30-50 kW Opportunity: 150/300/450/600 kW (e.g. at end-stop or terminal)
Charging technology	Mostly plug-in	Mostly pantograph Plug-in (less common) Induction (less common)
Load profile (illustrative)		
Typical range	100-250 km/day	200-500 km/day
Cost drivers	1 Higher battery cost 2 Lower charging infrastructure cost, unless an expensive depot charger of 100+ kW is required to fully recharge during night (instead of cheaper 30-50 kW)	1 Lower battery cost 2 Higher charging infrastructure cost 3 Slightly higher maintenance cost

Main differences between opportunity and depot charging
Source: https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-european-electric-bus-market-is-charging-ahead-but-how-will-it-develop

The main technical options for the physical charging of eBuses are plug-in, pantograph and induction charging and they have advantages and disadvantages depending on the charging strategy that is used. Depot-only charging works well with plug-in charging as this is the simplest and cheapest option. For opportunity charging pantographs are to be employed in certain places along the route, ideally in some or all of the bus's stations. Induction charging works similar to cars and is more expensive and difficult to operate and results in the lowest transmission efficiency.

Pantograph charging has no standardized form but the most common options are pantograph-up and pantograph-down. Some manufacturers such as Volvo or ABB only focus on pantograph-down but others use both depending on the situation. Both have advantages and disadvantages and can in fact coexist.



The two pantograph solutions and their advantages
Source: https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-european-electric-bus-market-is-charging-ahead-but-how-will-it-develop

Due to the lack of standards for the charging infrastructure it is advisable to combine tenders for the eBuses and the chargers or they might otherwise not be compatible. Another option, after the definition of standards the tenders can be split into buses and chargers in order to simplify the entire process. Lower values for the tenders will also enable more companies to participate, potentially driving the price down. Chargers also have a longer life than buses so the contract renewals will happen at different times if possible. There is however one more argument to be made for a single tender: a single supplier will increase hardware compatibility and negate any errors in the laid out standards, increasing the probability of perfect functioning of the system.

Each municipality must look at the size and type requirements of the eBuses, specifics of the route, needs of passengers and other factors when defining technical specifications for these standards. If the know-how for this is not available within, it is highly advisable for the municipalities to employ outside consultants so that the long-term result is also (close to) the most efficient one.

While public transport operators are very cost conscious, there are a few reasons why they could deviate from the most cost-effective option. Most importantly, local factors such as weight limits and planning considerations could restrict charging options. Battery weight (and therefore depot charging) can be constrained by old bridges and similar obstacles, requiring opportunity charging to reduce weight. On the other hand, urban planning can mean limited space for opportunity charging, restricting eBuses to depot charging only, despite the higher cost.

Furthermore, early charging strategies will be dictated by eBus supply and standardization. Over the next three years, for example, early movers like Chinese BYD could continue to dominate the eBus market, with buses that currently do not support opportunity charging.

Finally, some PTOs prefer the flexibility to operate eBuses on different routes, so they are unlikely to optimize their charging strategy based on individual routes. This means even short routes could use opportunity charging, especially if the charging points used are going to be installed for the longer routes anyway.

Earl analysis shows a clear TCO advantage for opportunity charging on longer routes (>150 km/day), while shorter routes can be run most economically by using depot-only charging. This trend is expected to remain unchanged, because the main cost drivers—battery cost and charging hardware—have similar declining cost projections. However, operators can still opt for a less economic solution for non-TCO reasons, such as restricted operational flexibility.

As a result, we expect a mix of both solutions to prevail. Translating the strategies into a market for depot chargers and opportunity chargers, the amount of depot chargers will be significantly larger, with the main reason being that for opportunity charging strategies a depot charger is still required overnight. Furthermore, opportunity chargers are often shared among multiple eBuses, resulting in a lower installed rate and lower purchases of opportunity chargers.

While the quest for the most optimal charging strategy is most relevant to PTOs and PTAs, there are also implications for other stakeholders, ranging from OEMs and governments to utilities and oil companies. All those involved need to ask themselves a number of questions in order to ensure they are well positioned for the eBus roll-out.

Small capacity electric public transport

There are specific situations when public transport is needed at a scale smaller than regular buses or trams. Due to the shorter route requirements, semi-public access and private ownership, some of these vehicles were electrified even more than 10 years ago, when there were almost no other electric vehicles on private roads. The fixed routes, often on private land, can facilitate the use of both technologies that are currently changing mobility in Europe: battery electric propulsion technology and autonomous driving.

Because of their very specific use and the easier, cheaper electrification compared to normal buses, these types of vehicles are a market onto themselves. In no particular order, they are especially suited for these types of mobility:

- Airports
- Amusement parks
- Zoos
- First mile / final mile transport
- Transporting tourists along short routes
- Large hospitals
- University campus

- Resorts
- Industrial parks

One example for the implementation of such a program is Vienna, where two autonomous vehicles will provide free 'last mile' rides to citizens of neighborhood of Austrian capital. After testing the vehicles for a few month, the Austrian capital has made a decision to put them in use in one of the recently built neighborhoods. The buses were put into use starting April 2019 but they were however suspended temporarily after a woman using a phone and wearing headphones walked into the side of one of the buses, sustaining minor injuries.

Navya bus as used in Vienna
Source:https://www.thelocal.at/userdata/images/article/c737a9615ff901c824eb7e759c75cbd29c005cca6a06fc225e166f589351def0.jpg

Nevertheless, this new type of mobility will continue to expand because their operating costs are extremely low and their costs will only decrease with advancements in technology. In the near future these vehicles can completely change the paradigm of public transport service in residential and low-density urbanized areas.

Policies

After signing the Paris climate agreement in force, the EU is more than ever committed to a global transition towards a low carbon economy. Local and regional leaders have a key role in cutting carbon emissions by upgrading transport systems making them cleaner, more energy efficient and more sustainable.

Low-emission mobility brings significant benefits to our citizens whilst strengthening innovation and competitiveness of our industry. We therefore all need to support zero-emission transportation as the most effective and efficient form of public mobility in our regions and cities.

Through their combined efforts the signatories of the "Declaration of intent on promoting large-scale deployment of clean, alternatively fuelled buses in Europe" are committed to make the transition to clean, alternatively fuelled happen.

Signing up to the Clean Bus Declaration is easy and can be done online by any city, municipality, region, manufacturer of other type of stakeholder through a simple online form on the EC website.

The European Commission and the Committee of the Regions are facilitating the creation of a dedicated initiative for clean (alternatively fuelled) buses.

The Clean Bus Deployment initiative is based on the following 3 pillars:

1. *A public declaration* endorsing a common ambition of cities and manufacturers to accelerate roll-out of clean buses.
2. *Creating a deployment platform* where public authorities, public transport operators, manufacturers and financial organizations can come together with the aim to:
   - better exchange information,
   - better organize relevant actors and create coalitions,
   - leverage potential investment action
   - issue recommendations on specific policy topics
3. *Creation of an expert group* bringing together actors from the demand and supply side. This expert group will benefit from consolidated expertise on technological, financial and organizational issues.

The work on the Clean Bus Deployment Initiative started in 2016 when the Commission hosted a meeting with manufacturers, cities, transport operators, etc. in order to understand what the barriers are that need to be tackled in order to have more Clean buses into European cities. Since then several meetings have taken place, which have resulted in the 3-pillar based approach. The launch of the Clean Bus Deployment Initiative took place in Brussels on the 13th of July, during the plenary of the Committee of the Regions.

Future developments and conclusions

- High upfront cost still remains a major obstacle for rapid and comprehensive market adoption of hybrid and electric transit buses.
- Chinese market and Chinese OEMs emerging as major forces in the market. European OEMs increasingly developing global competitiveness and will benefit more in long term
- Distinct trend of vertical integration and Tier I supplier partnerships seen to emerge among Western and Chinese OEMs respectively.

- Uncertainty in government funding and incentives favouring hybrid and electric transit buses to continue. This is necessitating recalibration of business models.
- Growth in parallel hybrid adoption driven by price sensitivities in both developed and developing markets and economies of scale gained from truck market.
- Providing market-specific solutions and maintaining good relation with local transport authorities will be key to win in these markets. Developing global product platforms with flexible architecture to meet local specifications will help to keep check on cost and respond quickly to competition.
- Price competitiveness of parallels will continue pulling the market towards this technology. This is gaining momentum as BAE and Allison are gravitating towards offering parallel hybrid solutions in their portfolios. This will bode well for the market as it will ensure focused technology and market growth and evolution.
- Ultra capacitors and hydrogen fuel cells hold the potential to disrupt energy storage systems market and their superior power density can threaten expensive Li-ion technology. Li-ion and Ni-MH technology focused OEMs and suppliers must step up battery technology focused R&D to reduce prices faster than before.

4. SWOT analysis of electric mobility in the DTP area

INTERNAL FACTORS	
STRENGTHS (+)	**WEAKNESSES (-)**
• Reduction of emissions. • Less noise pollution. • Reducing congestion in city centers • Know-how in science and engineering exists in EU and DTP states • Simple technology • Public sees electrification as positive and necessary for the future • Reliability of EU and DTP electrical grid • Use of shared (light) electric vehicles increase creates less waste • Reduction of direct operating costs in comparison with conventional alternatives • High density of trolleybus systems in DTP countries • Better image for public transport operators	• High initial purchase price due to cost of batteries • Environmental unfriendly production of battery. • Some customers are resistant to change • Existing street infrastructure • Indirect environmental emissions. • Missing standardization in the field of charging technologies; • Electric vehicles are heavier (affects mostly light electric vehicles) • Limited range and longer charging times • Limited battery life span – necessity to replace battery sets approx. in the half of the vehicle life span

EXTERNAL FACTORS	
OPPORTUNITIES (+)	**THREATS (-)**
• Financial incentives in some countries • EU and DTP citizens want higher quality of life, less noise and better air quality • Electrification is a key component of a low carbon energy future • EU high-tech companies can create lots of added value • Security of energy supply by eliminating dependence on fossil resources from politically unstable regions in the world by using renewable sources of energy in Europe • switch of trolleybus systems to use modern trolleybuses equipped with battery for auxilary power supply • Light electric public transport can reach more places in an economically sustainable manner • More access in protected areas leads to development of tourism.	• Limited range and lack of charging stations specific for public transport electric buses. • Dispersed human settlement outside the major cities makes public transport difficult. • EU car industry has lost competitiveness because of late start in electric mobility • Value chain dependent on imports from Asia • Low oil prices • Competition from hybrids, hydrogen, alternative fuels

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