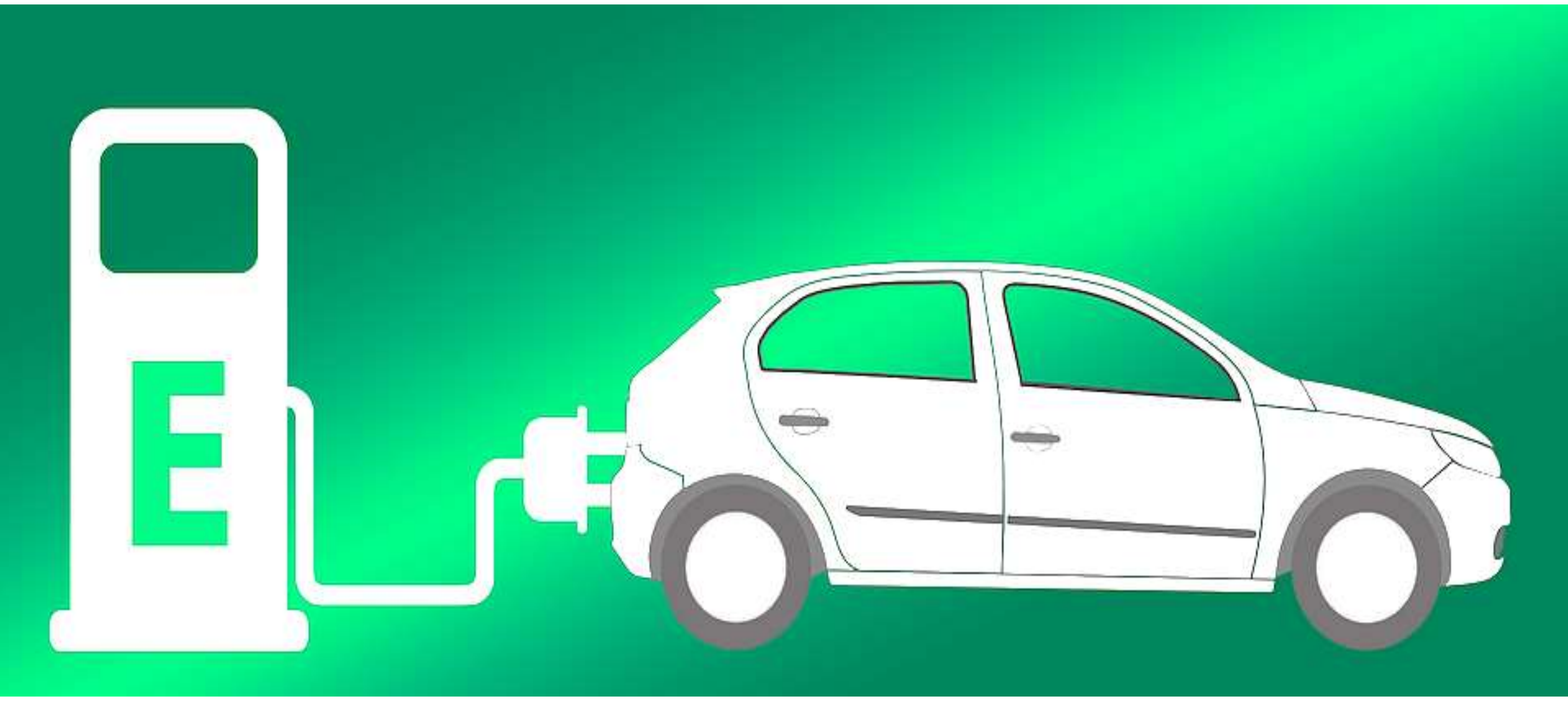
eGUTS



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List of abbreviations

AC - Alternating current
AFID - Alternative Fuels Infrastructure Directive
AG - Action Group
CS - Charging station
B2B - Business-to-business
CAN - Controller Area Network
CCS - Combined charging system
CNG - Compressed Natural Gas
COM - Communication of the European Commission
DC - Direct Current
DSO - Distribution System Operator
EC - European Community
eCS - Electric vehicle Charging Station
EEA - European Energy Agency
E-REV - Extended range electric vehicles
ETS - Emission Trading Scheme
EU - European Union
EV - Electric vehicles
HEV - Hybrid electric vehicle
ID - Identification
ISO - International Organization for Standardisation
IEC - International Electrotechnical Commission
LEV - Light electric vehicles
LNG - Liquefied Natural Gas
LPG - Liquefied Petroleum Gas
LPT - Local Public Transport
OCA - Open Charge Alliance
OCPI - Open Charge point interface
OCPP - Open Charge Point Protocol
PA - Public Authorities
PEMS - Portable Emission Measurement System
PEV - Plug-in Electric vehicles
PLC - Power Line Communication
POS - Point of Sale
RDE - Real Driving Emissions
R&D - Research and Development
RFID - Radio Frequency Identification
RSP - Regional Stakeholders Platforms
SMS - Short Message Service
V2G - Vehicle-to-grid

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Introduction

eGUTS project, with 21 partners and 9 demo regions involved, where were 7 Pilot Actions installed, represented in its two and half years of activity a rich environment to perform analyses, tests, development and proposals on eMobility related aspects. Interoperability and standardization, in particular, covered a relevant part of the efforts, being considered as key aspects to boost a mass rollout of Electric Vehicles (EVs) in Danube region.

The aim of this document is to present an overview summarising the results of the activities carried out on this topic, both within the dedicated Work Package (WP) 3 “DTP Standards & Strategy”, and in other more technically-focused WPs (WP4 “eMobility in DTP Cities”, WP5“eSolutions for DTP” and WP6“Pilot Actions in DTP”). Then, to synthesize and present to a wide audience the main results, findings and suggestions that emerged from that entire working process.

In parallel with that, an analysis process was carried out, starting from the study of the existing situation and then collecting issues and problems that have still to be tackled, according to the most relevant stakeholders in the field. Gaps and inconsistencies were pointed out in view of future interoperability and indication of the needs and route towards the necessary standardization activities was drawn.

The main results coming from these activities can be then divided in three big areas and summarized in three comprehensive recommendations.

The first recommendation refers to the awareness that, according to eGUTS experience, an effective communication among the actors will represent a crucial aspect, but that the communication interfaces still remain quite an open issue. The lack of standards and relative choices came strongly out of the State-of-the-art analysis process and should therefore be object of an intense work in the very next future. The effort is to start ensuring an easy and “universal” charging to drivers, thanks to a definitive physical interoperability (plugs/sockets) and to concrete choices towards roaming features (identification, authorization, IT interfaces), and then work to progressively include eMobility in the wider concepts of smart grids, through smart charging and reverse flow solutions.

The second recommendation expressed can be seen as the best “mean” to facilitate a quick and effective progress of the just mentioned standardization roadmap. The need for agreement in standardization and regulation phases is clear and it generates a strong demand to create a cooperative environment. This way, it would be easier to rapidly identify issues, solve them with the best technical solution and agree on their common application.

The last aspect, articulated in the document as some dedicated “recommendations”, expresses the concern that new eMobility initiatives start immediately setting up an up-to-date and “interoperable” infrastructure. Precise and well-focused indications for Public Administrations and Municipalities willing to install a charging infrastructure are provided, with a particular attention to standards and ICT features.

After two and half years of activity of eGUTS activity, it can be stated that e-mobility today is a dynamic and fluid environment, where relevant changes happened and will happen quickly. According to the acquired experience, a correct combination of the three just described aspects would give a powerful stimulus to standardization and, as a consequence, to the eMobility market.

Please notice that in order to comply at best with the aim of this document, which is to provide some effective “recommendations” towards interoperability, the report and its three macro-areas are thought and written with a specific attention for the “target group” they refer to. Despite of the fact that reading the whole document will obviously give the best overview on the topic, it can be said that different kind of readers could find more focused information in different sections of the eGUTS STANDARDS.

Rationale

Four years ago, as the eGUTS Project started as concept, eMobility was just something more than a sprout. Few car models were available on the market mainly due to retrofit solutions and to some "first-mover" car manufacturers. In parallel, a low number of charging stations was installed in European cities, with high predominance of low-power technology.

Today, after less than a lustrum, the situation has radically changed. Nowadays a large number of car manufacturers include a "zero emissions", pure electric model, or, at least, a Plug-In Hybrid model in their catalogue. The number of electric vehicles (EVs) sold in Europe is constantly increasing and, even if with remarkable differences among the countries, the market share is reaching some units, with an impressive 15% peak in Norway. The charging infrastructure development is going hand in hand with this evolution with an increasing trend towards high-power and fast charging technologies.

But this doesn't mean that all the problems are solved, far from it. Despite the considerable developments, eMobility is still struggling against its typical hurdles, i.e. costs and functionality. Although first effects of large scale production, technology improvements and economic competition are contributing to some cost/price-reduction, electric vehicles are still very expensive if compared with homologous fuel-based vehicles. In addition to that, functionality intended as allowed range and charging ease-of-use and availability are still unsatisfactory for many potential users. The combination of these two aspects represents both a significant barrier for a real mass-market deployment and, at the same time, a stimulating challenge for research, industrial and political activity.

It is interesting to notice that solving some issues immediately creates new ones. The best example of this phenomenon is the fact that allowing longer ranges to EVs, their domain becomes less and less local, introducing new requirements for interoperability. Interoperability is indeed becoming a relevant issue, closely related to standardization. The eGUTS project has worked on these aspects, dealt in more work packages, by the elaborated 5 Feasibility Studies from WP4, the eGUTS APP developed on WP5 and Pilot Actions installed in WP6, but in particular in Work Package 3 ""DTP Standards & Strategy"".

More in detail, the focus of WP3 activity, developed through several studies, surveys, workshops and Regional Stakeholders Platform Meetings, has been the identification of open issues in standards for the eMobility field, considering interoperability as the main objective to achieve. Comparing existing standards and regulation with present and near-future requirements, some relevant gaps have been identified and discussed.

The aim of this document is to synthesize and present to a wide audience the main results, findings and suggestions that emerged from the last two and half years of work, firmly believing that these could represent useful sparks for the eMobility roll-out.

State of eMobility

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. In order for this change to be significant, the share of EV's will have to increase worldwide and these EV's will have to be usable for a reasonable number of years and kilometres.

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 EV's and 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 at 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. 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 be 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 CO_2 emissions of 95 g/km by 2025. Most of these EV's will be produced in Italy, Germany, France and Spain, 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 industry, moving towards standardization of the electric mobility technology and infrastructure. 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 at all times, industry standards for charging, and universal standards for billing. Doing all of 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 a 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 changes that may have to be made are linked to human behaviour related to trip planning and driving behaviour 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 Vehicles

Electric vehicles (EV) are receiving significant attention as an environmental- sustainable and cost-effective substitute of vehicles with internal combustion engine (ICE), for the solution of the dependence from fossil fuels and for the saving of Green-House Gasses (GHG) emission.

Electric vehicle (EV) is referred to as a vehicle that employs electric energy storage as its energy source and electric machines as its power source. Electric energy is a multisource energy type which can be obtained from many primary energy sources, such as traditional fossil energy sources (coal, petroleum, and natural gas), nuclear energy, hydropower, bioenergy, solar energy, wind energy, etc. With continuous depletion of petroleum resources and more and more concerns about environmental issues, it has been well recognized that electric vehicle is one the most viable substitutes to the current petroleum-fuelled vehicle. Electric vehicle also possesses other advantages of absence emissions, high efficiency, quiet and smooth operation, etc. With continuous progress on the technologies of chemical batteries, electric propulsion systems, and electronic control, electric vehicles are much closer to meeting a user's requirements than ever before.

Compared with petroleum fuels, the energy density of chemical batteries is much lower, which results in shorter driving range per battery charge. Long-time battery charging also causes incontinence to users.

At present, the battery- powered electric vehicles cannot challenge the petroleum-powered vehicles in terms of performance and use convenience.

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 but can also be integrated in the roadside environment, such as street lights, parking meters, even hidden beneath the pavement, etc.

It is up to the local authorities to decide on 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, 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.

One of the (still) facts of EV ownership is the associated range anxiety of users and the solution to this is having a wide adoption of charging facilities in places where there are cars. These charging facilities have to be easy to find, offer satisfactorily quick charging and, important in urban environments, they must offer short and medium term parking in order to be practical and to encourage EV adoption.

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 e-vehicle price, limited range, price of oil, availability of charging stations, 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 behaviour and uncertainty about future market players.

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 refuelling, 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.

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.

- 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. 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.
- Mode 3 (slow, semi-fast or fast charging): uses a special plug socket and a dedicated circuit to allow charging at higher power levels. 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 to the vehicle. An AC/DC converter is located in the charging equipment, instead of inside the vehicle as for the other levels.

One disadvantage of high-power, fast charging is that the stronger currents mean that more electricity is lost during transfer, i.e. the efficiency is lower. Moreover, fast charging can decrease battery lifetime, reducing the number of total charging cycles. Fast DC charging points are also around three 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.

Inductive charging

Electric vehicles can also be charged via induction. In this case an electromagnetic field is created in a primary coil, which transfers energy to a secondary coil integrated in the vehicle. 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 making the charging facilities and potentially even the charging process itself totally invisible to the user. 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 switch

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 or the next charging station, and will thus leave the car’s passengers stranded. This fear is based on the perception that there the charging opportunities along the route are insufficient. 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.

Light Electric Vehicles

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, maximum 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 quadricycles. 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 pedalling. They usually allow higher speeds, 45 km/h or more, but require registration and a driving licence 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.

While demand for electricity-driven buses, mopeds, scooters and motorcyclesis 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 725000 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.

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 in Europe but these networks are still going strong in many European municipalities and the DTP states are no exception to this. 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.

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. New developments in these technologies are not happening at a rapid pace anymore and the power lines that the vehicles require can cause some problems in the public spaces.

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 on-board 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 and are more expensive. With current technology and infrastructure, BEBs are only suited for short and medium range transport.

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 EV's. 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, and 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.

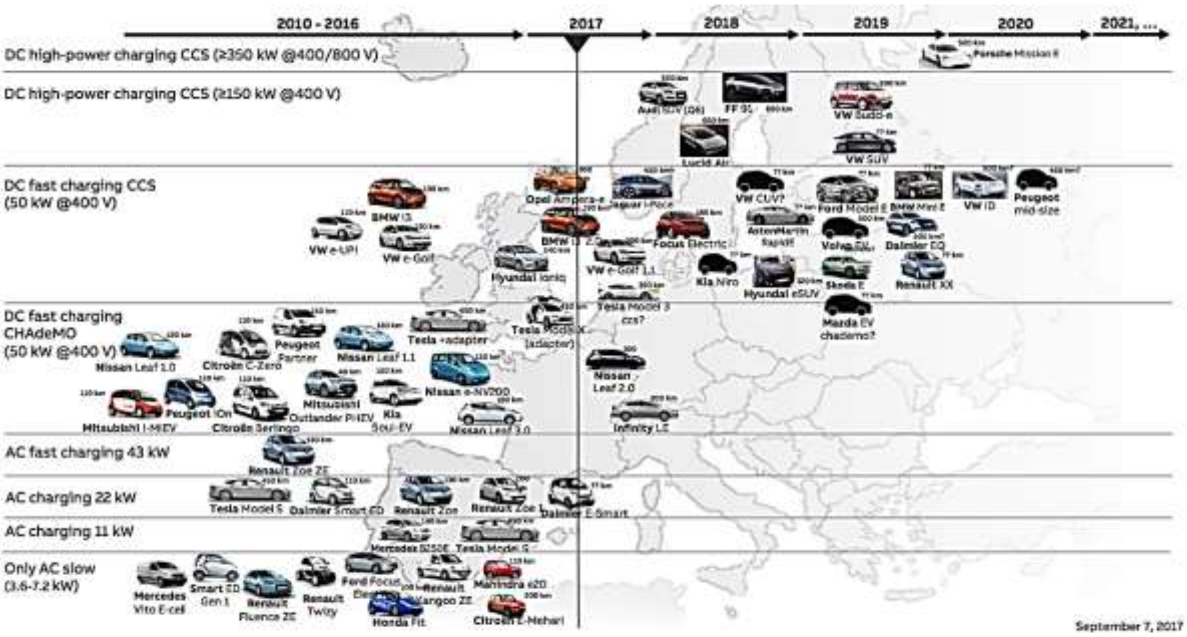
Of course the customer will be the key determinant for the commercial success of electric transport. Common standards will help to ensure the driver enjoys a convenient recharging solution across the European Union that will avoid a multiplicity of different cables and adaptors and/or retrofit costs 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 standardisation 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 analyse 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 scrutinised 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 commercialisation hurdles for this technology; given the uncertainty of the oil price, the right fiscal 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.



September 7, 2017

Figure 1. A map of charging technologies and some of the vehicles that uses 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 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 kilometre (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.

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.

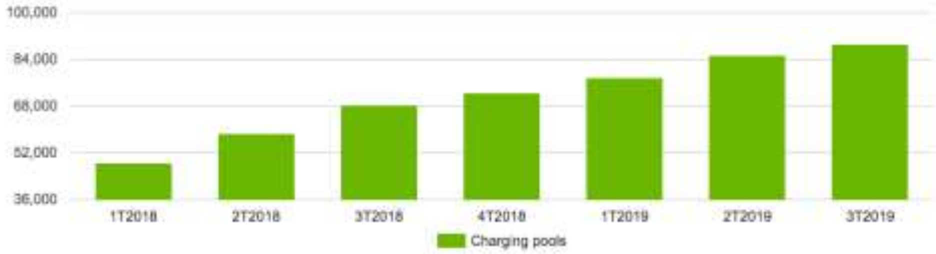


Figure 2. The rapid adoption of electric car chargers in Europe
Source: https://en.chargemap.com/about/stats

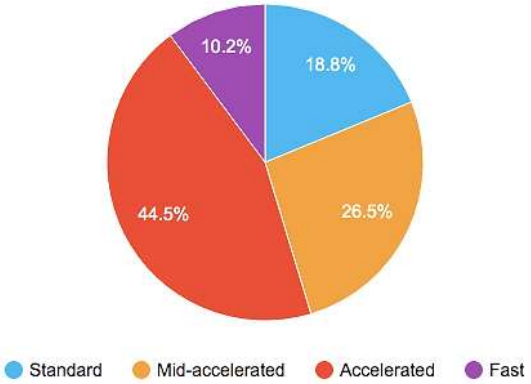


Figure 3. Distribution of plugs by charging speed
Source: https://en.chargemap.com/about/stats

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 neighbourhoods, 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 centres 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. 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 Republic	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%

Table 1. Countries statistics

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 goal 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.

Electrical Ratings of different EVs Charge Methods in Europe

The IEC 61851-1 Committee on “Electric vehicle conductive charging system” has then defined 4 Modes of charging, concerning:

- the type of power received by the EV (DC, single-phase or three-phase AC), the level of voltage (for AC in range between single-phase 110V to three-phase 480V),
- the presence or absence of grounding and of control lines to allow a mono or two-way dialogue between the charging station and EV,
- the presence and location of a device protection.

Charge Method	Connection	Power [kW]	Max current [	Location
Normal power	1-Phase AC connection	3,	10-16	domestic
Medium power	1- or 3-phase AC connection	3,7 – 22	16-32	semipublic
High power	3-phase AC connection	> 22	>	public
High power	DC connection	> 22	> 3,225	public

Table 2. Electrical Ratings of Different EVs Charge Methods in Europe countries

For the Mode 1 (fast charging) in DC two sub-modes of operation are then considered: DC Level 1 (voltage inferior to 500 V, current inferior to 80 A, power at 40 kW); DC Level 2 (voltage inferior to 500 V, current inferior to 200 A, power at 100 kW).

Three types of socket-outlets:

- IEC 62196-2 "Type 1" - single phase vehicle coupler – reflecting the SAE J1772/2009 automotive plug specifications – Yazaki;
- IEC 62196-2 "Type 2" - single and three phase vehicle coupler – reflecting the VDE-AR-E 2623-2-2 plug specifications – Mennekes;
- IEC 62196-2 "Type 3" - single and three phase vehicle coupler with shutters - reflecting the EV Plug Alliance proposal – SCAME.

Mode and type of plugs for EVs	private domestic socket	private dedicated E-mobility socket	semi-public AC	public AC	public DC

Power connection	≤3,0 kW / ≤3,7 kW 1-phase AC	Up to 22 kW	Up to 22 kW	Up to 22 kW	50 kW (CHAdeMo)*
Plug (Infrastructure side)	Domestic	IEC 60309-25 Type 2/Type 3	Type 2/ Type 3	Type 2/ Type 3	Yazaki (CHAdeMo)**
Charging mode	Mode 2	Mode 2 Mode 3	Mode 2 Mode 3	Mode 2 Mode 3	Mode 4

Table 3. Mode and Type of Plugs for EVs Charger in Europe countries

CHAdeMO protocol is a Japanese socket for the DC connection, with a maximum power level of 50 kW [not internationally standardised yet, http://www.chademo.com/]; CHAdeMO Association announced a major milestone as the CHAdeMO protocol is now officially recognized as an international DC charging standard by the International Electrotechnical Commission (IEC) alongside Combo plugs for U.S. and Europe and Chinese GB/T plug. CHAdeMO is officially recognized as international DC Charging Standard by IEC; "IEC 61851-23:2014, gives the requirements for DC electric vehicle (EV) charging stations, herein also referred to as "DC charger", for conductive connection to the vehicle, with an AC or DC input voltage up to 1000 V AC and up to 1 500 V DC according to IEC 60038. It provides the general requirements for the control communication between a DC EV charging station and an EV. The requirements for digital communication between DC EV charging station and electric vehicle for control of DC charging are defined in IEC 61851-24." "IEC 61851-24:2014, together with IEC 61851-23, applies to digital communication between a DC EV charging station and an electric road vehicle (EV) for control of DC charging, with an AC or DC input voltage up to 1 000 V AC and up to 1 500 V DC for the conductive charging procedure. The EV charging mode is mode 4, according to IEC 61851-23. Annexes A, B, and C give descriptions of digital communications for control of DC charging specific to DC EV charging systems A, B and C.

Recognising that there is a need to offer customers a high-power charging possibility that allows them to recharge the EV battery within a limited timeframe, only the high power connection would satisfy this aim. Two technologies are at hand for high-power charging: DC off-board charging or AC on-board charging.

The European Automotive Industry is however promoting the combined charging system with the Combo connector, which features a single inlet for AC and DC charging on the side of the EV and can potentially deliver high-power charging of up to 100 kW in future. The Combo connector is currently under development and going through the IEC standardisation process.

EV Connectors

As mentioned in the overview, there are three main types of EV charging – rapid, fast, and slow. These represent the power outputs, and therefore charging speeds, available to charge an EV. Note that power is measured in kilowatts (kW).

Each charger type has an associated set of connectors which are designed for low or high power use, and for either AC or DC charging. The following sections offer a detailed description of the three main charge point types and the different connectors available.

Rapid chargers

Rapid chargers are the fastest way to charge an EV, often found in motorway services or in locations close to main roads. Rapid devices supply high power direct or alternating current - DC or AC - to recharge a car to 80% in 20-40 minutes. In most cases, the charging units reduce power when the battery is around 80% full to protect the battery and extend its life. All rapid devices have the charging cable tethered to the unit.

Types:

- 50 kW DC charging on one of two connector types,
- 43 kW AC charging on one connector type,
- 120 kW DC charging on Tesla Supercharger network.

Note: All rapid units have tethered cables

Rapid charging can only be used on vehicles with rapid-charging capability. Given the easily recognisable connector profiles – see images below – the specification for your model is easy to check from the vehicle manual or inspecting the on-board inlet.

Non-Tesla rapid DC chargers provide power at 50 kW (125A), use either the CHAdeMO or CCS charging standards, and are indicated by purple icons on Zap-Map. Both connectors typically charge an EV to 80% in 20-40 minutes depending on battery capacity and starting state of charge. The next generation of rapid DC units will increase the power first to 150 kW and then to 350 kW which will significantly reduce overall charging time.

Tesla’s Supercharger network also provides rapid DC charging to drivers of its cars, but use a Tesla Type 2 connector and charge at up to 120 kW. While all Tesla models are designed for use with Supercharger units, many Tesla owners use adaptors which enable them to use 50 kW rapid units fitted with a CHAdeMO connector. While these provide less power than a Supercharger, they are more common in the UK and elsewhere.

Rapid AC chargers provide power at 43 kW (three-phase, 63A) and use the Type 2 charging standard. They are indicated by green icons on Zap-Map. Rapid AC units are typically able to charge an EV to 80% in 20-40 minutes depending the model's battery capacity and starting state of charge.

EV models that use CHAdeMO rapid charging include the Nissan® Leaf, Mitsubishi® Outlander PHEV, and Kia® Soul EV. CCS compatible models include the BMW® i3, VW® e-Golf, and Hyundai® Ioniq Electric. Tesla's Model S and Model X are exclusively able to use the Supercharger network, while the only model currently able to charge on Rapid AC is the Renault® Zoe.

Fast chargers

Fast chargers, all of which are AC, are typically rated at either 7 kW or 22 kW (single- or three-phase 32A). Charging times vary on unit speed and the vehicle, but a 7 kW charger will recharge a compatible EV with a 30 kWh battery in 3-5 hours, and a 22 kW charger in 1-2 hours. Fast chargers tend to be found at destinations, such as car parks, super-markets, or leisure centres where you are likely be parked at for an hour or more.

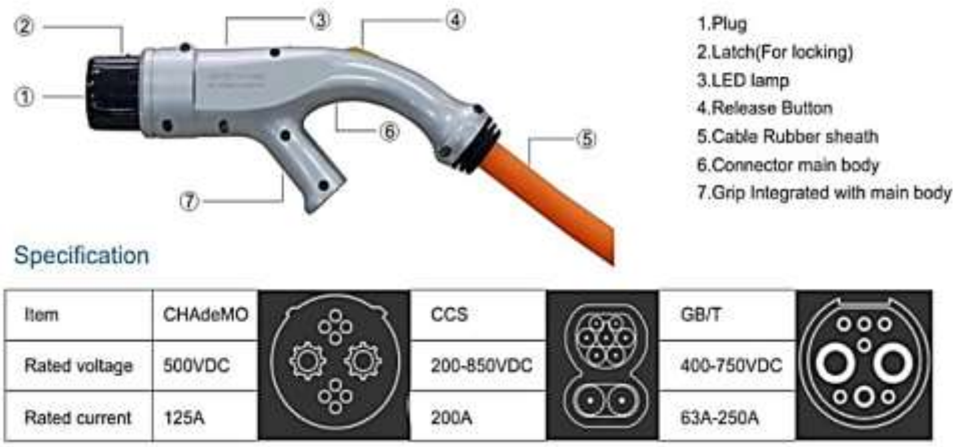
Types:

- 7kW fast charging on one of three connector types,
- 22kW fast charging on one of three connector types
- 11kW fast charging on Tesla Destination network,

Note: Units are either untethered or have tethered cables.

Fast chargers, all of which are AC, are typically rated at either 7 kW or 22 kW (single- or three-phase 32A). Charging times vary on unit speed and the vehicle, but a 7 kW charger will recharge a compatible EV with a 30 kWh battery in 3-5 hours, and a 22 kW charger in 1-2 hours. Fast chargers tend to be found at destinations, such as car parks, super-markets, or leisure centres where you are likely be parked at for an hour or more.

The majority of fast chargers are 7 kW and untethered, though some home and workplace based units have cables attached, usually with a Type 1 connector. The latter units mean only those vehicles that can use that connector will be able to charge on them; in contrast to the more common use of a driver's own connector cable. Untethered units are therefore more flexible and can be used by any EV with the correct cable.



Item	CHAdeMO	CCS	GB/T
Rated voltage	500VDC	200-850VDC	400-750VDC
Rated current	125A	200A	63A-250A

Figure 4. CHAdeMO connector

Charging rates when using a fast charger will depend on the car’s on-board charger, with not all models able to accept 7 kW or more. These models can still be plugged in to the charge point, but will only draw the maximum power accepted by the on-board charger. For example, a Nissan Leaf with standard 3.3 kW on-board charger will only draw a maximum of 3.3 kW, even if the fast charger is 7 kW or 22 kW.

Tesla’s ‘destination’ chargers provide 11 or 22 kW of power but, like the Supercharger network, are intended only or use by Tesla models. Tesla does provide some standard Type 2 chargers at many of its destination locations, and these are compatible with any plug-in model using the correct cable.

Almost all EVs and PHEVs are able to charge on Type 2 units, with the correct cable at least. It is by far the most common public charge point standard around, and most plug-in car owners will have a cable with a Type 2 connector charger- side.

The European Commission has decided that all electric vehicles must have installed the “Type 2” connector, as showed in figures 6 and 7:

This should resolve a central problem regarding EV charging stations: lack of interoperability. This connector can also be used in three-phase 400 V, having seven contacts in total. Type 2 connector can reach enough high values of charging power: up to 43 kW with fixed cable (63A/400V), up to 22 kW with detachable cable (32A/400V).

Figure 5. „Type 2“connector

The technological choice between on- or off-board chargers will be determined by what suits the EV on the market and the relative cost of both systems for the infrastructure provider. For the electricity industry, it does not matter much whether the conversion from AC to DC is done on- or off-board.

Slow chargers

Most slow charging units are rated at up to 3 kW with some lamp-post chargers being rated at 6 kW. Charging times vary depending on the charging unit and EV being charged, but a full charge on a 3 kW unit will typically take 6-12 hours. Most slow charging units are usually untethered, meaning that a cable is required to connect the EV with the charge point.

Types:

- 3kW slow charging on one of four connector types.
- Charging units are either untethered or have tethered cables,
- Includes mains charging and from specialist chargers, Note: Often covers home charging.

Slow charging is a very common method of charging electric vehicles, used by many owners to charge at home overnight. However, slow units aren’t necessarily restricted to home use, with workplace and public points also able to be found. Because of the longer charging times over fast units, slow public charge points are less common and tend to be older devices.

While slow charging can be carried out via a three-pin socket using a standard 3-pin socket, because of the higher current demands of EVs and the longer amount of time spent charging, it is strongly recommended that those who need to charge regularly at home or the workplace get a dedicated EV charging unit installed by an accredited installer.

All plug-in EVs can charge using at least one of the above slow connectors using the appropriate cable. Most home units have the same Type 2 cable as found on public chargers, or be tethered with the a Type 1 connector where this is suitable for a particular EV.

Connectors and cables

The choice of connectors depends on the charger type (socket) and the vehicle's inlet port. On the charger-side, rapid chargers use CHAdeMO, CCS (Combined Charging Standard) or Type 2 connectors. Fast and slow units usually use Type 2, Type 1, Commando, or 3-pin plug outlets.

On the vehicle-side, European EV models (Audi®, BMW®, Renault®, Mercedes®, VW® and Volvo®) tend to have Type 2 inlets and the corresponding CCS rapid standard, while Asian manufacturers (Nissan® and Mitsubishi®) prefer a Type 1 and CHAdeMO inlet combination. This doesn't always apply, however, with the Hyundai® Ioniq Electric and Toyota® Prius Plug-In being exceptions.

Most EVs are supplied with two cables for slow and fast AC charging; one with a three-pin plug and the other with a Type 2 connector charger-side, and both fitted with a compatible connector for the car's inlet port. These cables enable an EV to connect to most untethered charge points, while use of tethered units require using the cable with the correct connector type for the vehicle.

Examples include the Nissan® Leaf which is typically supplied with a 3-pin-to- Type 1 cable and a Type 2-to-Type 1 cable. The Renault® Zoe has a different charging set up and is comes with a 3-pin-to-Type 2 and/or Type 2-to-Type 2 cable. For rapid charging, both models use the tethered connectors which are attached to the charging units.

Charging Stations

EV charging stations European electricity companies, particularly distribution system operators (DSOs), are investing in the necessary infrastructure to stand- in a single European market for EV. European standards are indispensable to safeguard that drivers enjoy convenient EU-wide charging solutions that avoids a multiplicity of cables and adaptors and so retrofit costs. In June 2000, the European Commission issued a standardization mandate to the European standardization bodies CEN, CENELEC and ETSI (M/468) concerning the charging of EVs.

The mandate stressed the need for interoperable plugs and charger systems to promote the internal market for EV and to discourage the imposition of market barriers. The Focus Group set up to respond to M/468 delivered a comprehensive and valuable report. However, given that the mandate objective was to achieve interoperability, not the adoption of a single connector, no recommendation has been made with regards to the choice of the AC mains connector. As a consequence, two types of connectors have been assessed as appropriate for the European situation.

Energy Storage Systems for EV Charging Stations

One of the major challenges for EV charging stations, especially the public one, is to reduce charging time. As seen in the International standards, this aim can be addressed by increasing the rate of power transfer: the fast charge method corresponds in Europe to the maximum value of power (50-100 kW). When a large number of EVs are charged simultaneously, problems may arise from a substantial increase in peak power demand to the grid. Addressing this peak power requirement may increase the generation cost of the energy, as well as the cost of the distribution and public charging infrastructure.

The integration of an Energy Storage System (ESS) in the EV charging station cannot only reduce the charging time, but also reduces the stress on the grid.

A suitable comparison among the various energy storage technologies applicable for this scope is among electrochemical storages (batteries), electromechanical storages (flywheels) and electrostatic storages (ultra-capacitors).

The batteries are electrochemical storages that alternate charge-discharge phases allowing storing or delivering electric energy. The main advantage of such a storage system is high energy density, the main inconvenience is their performance and lifetime degrades after a limited number of charge and discharge cycling. This affects the lifetime for all application (from 100 to 1,000 cycles).

The flywheels are electromechanical energy storage devices, where energy is stored in mechanical form, thanks to the rotor spinning on its axis. The amount of stored energy is proportional to the flywheel moment of inertia and to the square of its rotational speed. The life of flywheels is greater than the batteries (up to 100,000 cycles) and the frequent charging and discharging does not adversely affect their life time.

Additionally, flywheels have a power density that is typically a factor of 5 to 10 times greater than batteries. A drawback of the flywheel technology is the time of reply to fast variations of required power: it is also proportional to the inertia of the system, so the gradient of the power in time is generally high.

The ultra-capacitors are electrostatic storage system, characterized by a very high power density, but with a lower energy density than batteries and flywheel. Ultra-caps have also the benefits of charging and discharging much faster than batteries, a longer service life and a higher the efficiency than batteries.

Another important issue in the comparison of these three storage technologies deals with the cost: the installation, maintenance and replacement costs of the batteries make them no so attractive as a feasible solution as stationary energy storage system; the installation cost of a flywheel is usually greater than batteries, but its longer life and simpler maintenance results in a lower total costs.

Comparing the different types of batteries shown in next Table:

Type	Energy Efficiency [%]	Energy Density [Wh/kg]	Power Density [W/kg]
Batteries Pb-Acid	70-80	20-35	25
Batteries Ni-Cd	60	40-60	140
Batteries Ni-MH	50-80	60-80	220
Batteries Li-ion	85-95	100-200	300-2000
Batteries Li-polymer	80-90	100-200	300-2000
Super-caps	90+	25-75	5000-20000

Table 4. Energy Storage Technologies

- **Pb-Acid** batteries, with a life time of 200-300 cycles, have high capacity, low volume energy density, low capital cost, long life time, but on the other hand they are characterized by low efficiency (75%), potential adverse environmental impacts;
- **Ni-MH** batteries, with a life time of 100-200 cycles, a very high energy density;
- **Li-Ion** batteries have a very high efficiency (95%) and energy density, and high number of life cycles (3,000-5,000);
- **Li-Polymer** batteries have lower energy density than Li-Ion ones, but they are not flammable as Li-Ion and so offer more safety;
- **Ni-Cd** batteries have low energy density (40-60 Wh/kg), low efficiency (60%) and suffer of memory effect.

At these technologies it is necessary to add the Sodium-Sulphur (Na-S) batteries that, with a life time of 2,000-3,000 cycles, have a very high energy and power capacity, high energy density, but they are characterized by high production cost and safety concerns, that make them not commercially sustainable at the moment. The most common technology for batteries used for EV application is Li-Ion battery, with energy capacities included between 5 kWh to 53 kWh.

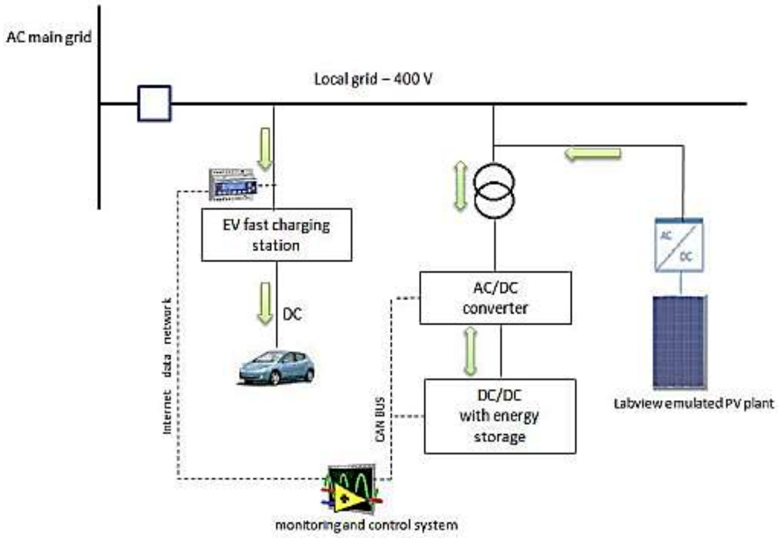


Figure 6. Scheme for the integration of the ESS with the EV charging station

The AC-bus scheme is generally preferred, because the AC components have well defined standards, ans AC technologies and products are already available in the market. DC-bus based system profides a more convenient way to integrate renewable energy sources and also higher energy efficiency thanks the inferior number of conversion stages.

Charging infrastructure needs for electric vehicles

Whenever they are connected to the electricity grid, electric vehicles are dependent on a charging station - at home, at work or at a public charging station. As most of the charging will be carried out in private areas, distribution grids at the low-voltage level will be mostly affected by the uptake of electric vehicles. In the future, different options for load management should become possible concerning charging with normal and medium power in both residential and commercial areas.

At present, Today, more than 80% of EV charging is carried out at residential and workplace premises. Charging at home, parking lots near home and office buildings every time the vehicle is parked during the day and night is often the most convenient and cost-effective solution. AC charging with normal/medium power opens up more possibilities for smart charging than DC charging.

By 2030, as owning an EV will become more commonplace even for those drivers without the possibility to have a charging point installed at their home, it is expected that the demand for (semi-) public charging will rise. The lack of access for home charging i.e. parking facilities such as private garages or driveways is a practical limitation which can differ from country to country, rural versus urban, or even from district to district.

Compatibility between EV and the charging network

An EV owner who is not in a hurry can always connect a battery to their home's electricity supply. The same applies at work, and they can charge between when they arrive in the morning and leave in the evening. However, fuel-powered cars have been so successful because they reduce travel time between cities. Whether or not the electric car is a success will, therefore, depend on its performance over medium and long distances. To offer the same service, it must be possible to charge an EV in roughly the same amount of time it takes to fill up a fuel tank – a maximum of ten minutes, which requires fast charging stations. These facilities are created by electricity distribution companies, regional authorities, motorway concession owners and EV´s manufacturers. The majority of the latter group quite rightly believe that the vehicle and the charging stations are two crucial parts of the same product. Tesla is a famous example.

EV´s manufacturers have a common interest to ensure that there are a large number of fast charging stations along roads and motorways which can be used by all types of electric vehicles. Consequently, they just need to sit down to define the technical features and communication protocols applicable to all charging points. This would be simple – if manufacturers hadn't already defined multiple standards, whether individually or in small groups. And as each of these standards is protected by a collection of patents and proprietary protocols, the collective benefits of adopting unique specifications disguise royalties which would benefit the company or group of companies whose standard is adopted.

De jure and de facto standards

There are essentially two solutions to break the deadlock. The first is that a political or professional authority - a standardisation organisation such as Cenelec - obtains a de jure solution from manufacturers, with the benefits shared to compensate those whose technical solution was not chosen, and who must, therefore, adapt their technology. To an extent, the initial game is made cooperative, by adding a stage where the benefits are shared among the participants in the agreement.

In the other solution, the current war becomes a war of attrition, resulting in a de facto standard - the winner's standard. If one of the competitors convinces a sufficient number of buyers that their technology is superior, their charging network grows more quickly than other manufacturers, and this continues to reinforce its appeal, as any person buying a new EV will prefer to opt for this network. That was how the combustion engine prevailed over the electric engine over a century ago.

The choice between them is left to the market and will depend on the different National regulatory frameworks. Today the only standards available at European level, dealing with the charging system, plugs and sockets, are contained in the IEC 61851. The actual standards provide a first classification of the type of charger in function of its rated power and so of the time of recharge, defining three categories here listed:

- Normal power or slow charging, with a rated power inferior to 3,7 kW, used for domestic application or for long-time EV parking;
- Medium power or quick charging, with a rated power from 3,7 to a 22 kW, used for private and public EV;
- High power or fast charging with a rated power superior to 22 kW, used for public EV.

Voltage Classes for eMobility

A look into the automobile's history shows that many of the first non-horse-drawn carriages were fitted with an electric drive. The fact that history was shaped by internal combustion engines in the following decades can be attributed to the extensive development efforts that helped overcome the engine's initial susceptibility to breakdowns and awkward handling, making it a practical solution for long distances. Following intensive research and development in the field of electric mobility, we now know that this innovative technology not only addresses environmental concerns, it also significantly increases driving dynamics and driving pleasure. This suggests that powertrain electrification will continue to increase and attract the interest of a growing number of buyers.

Renewed interest in e-mobility or hybrid technology - and hence electric drives - has its origins in eco-political objectives. The introduction of all-wheel drive hybrid vehicles demonstrated that significant speed values and hence impressive acceleration values can be achieved with two different drive technologies (thermal motor plus electric machine) working in parallel. This provided the impetus that was needed to develop e-mobility to its current stage. Any marketing expert knows that if you make driving more fun, you will attract more buyers; a sales argument which tips the balance even in the face of possible additional costs.

The 2015 CO_2 emission targets set by the European Commission under the Kyoto Protocol are virtually impossible to meet with traditional internal combustion engine technology. Moreover, non-compliance will result in fines if the average CO_2 emissions of a manufacturer's fleet exceed its limit values. Hybrid technology can help address this risk since it enables CO_2 emissions to be reduced by 10 - 20 percent on average based on the New European Driving Cycle. The European Commission also envisages a target of 'zero emissions' for European city and town centres in the future. This requires the use of vehicles that can be driven exclusively by electrical power, at least for shorter distances.

Until recently, the majority of hybrid drives came from Asia. Market-driven competition paved the way for this technology to be adopted in vehicles inside and outside Europe. This resulted in an engineering boom that coincided with the availability of high-voltage components already used for military and aerospace applications, by industry and for traction systems (tramways and trains, etc.). But these components far exceeded automotive requirements and did not match the prices envisaged by the carmakers. Although these components were initially installed in early non-Asian hybrid vehicles, they have been gradually replaced by more suitable components that had first to be specified, developed and manufactured.

Today, a wide variety of high-voltage components is available that meet the technical requirements at prices that seem to be acceptable to the automotive industry. Hybrid drives are thus likely to become more attractive in terms of pricing in addition to their dynamic driving benefits.

In view of the evolving hybrid mechanisation of passenger and commercial vehicles it can be assumed that the architectures illustrated below with the options currently available will be used in the majority of vehicles in the near future.

- Traditional 12/24 volt level for all current vehicle and convenience features
- 48 volt level for one to five kW consumer installations and application in mild hybrids for boost and energy recuperation functions up to max. 12 kW
- High-voltage level for hybrid and electric vehicles for boost function, energy recuperation and electric driving greater than 12 kW

Technical Introduction

In view of the dedicated efforts of the auto- motive industry to implement powertrain electrification, the question arises as to whether the necessary applications are technically feasible, given the voltage levels that will be needed. Whilst voltages in excess of 12/24 V have previously been reserved for industrial and household applications, the voltages required for the electric drive power in passenger and commercial vehicles are several hundred volts higher.

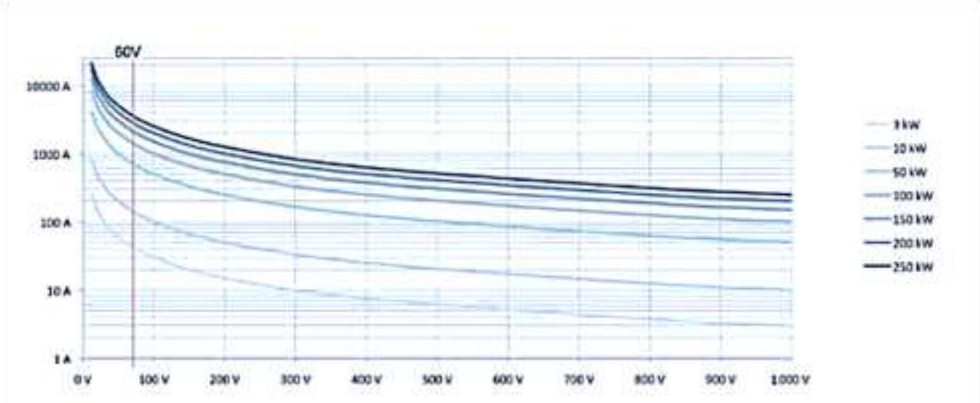


Figure 7. Engine and battery current – system voltage
Source: Lenze Schmidhauser

Moreover, functions that are currently mechanically powered in thermal drive systems must be electrically operated in the future, decoupled from rotational speed and torque and hence from the state and behaviour of the internal combustion engine (if present). While the VDE has standardised almost all established voltage levels, there is currently no valid standard available for voltage ranges greater than 60 V DC in vehicles.

Common voltage levels of 12/24 volt are still used for supplying most of the vehicle and convenience features and will continue to do so in the future.

The choice of voltage levels for the different electric and hybrid drives is determined by the relevant application within the electrical powertrain, resulting in great variation and individuality.

The electrical architectures and their physical implementation are also adapted to the relevant requirements of the powertrain. Standardising them would make a genuine difference in terms of costs.

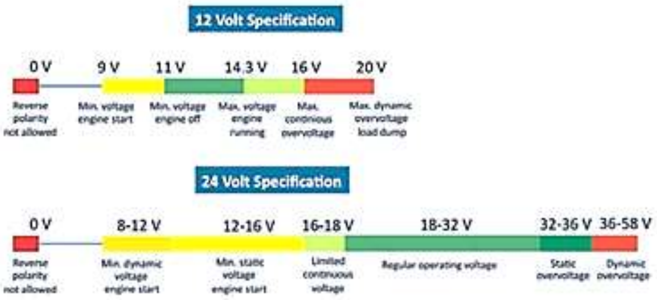


Figure 8. Voltages in the 12/24 volt on-board system
Source: ZVEI

Higher voltages - and hence lower currents - provide cost benefits primarily in terms of energy distribution (connectors, cable cross- sectional areas, etc.). Lower voltages are preferably used for battery technology due to lower costs since the number of cell connections can be reduced, making battery management less complex.

A holistic approach must be taken to the selection of (cost) optimal voltage since it cannot be satisfactorily resolved from the perspective of components alone.

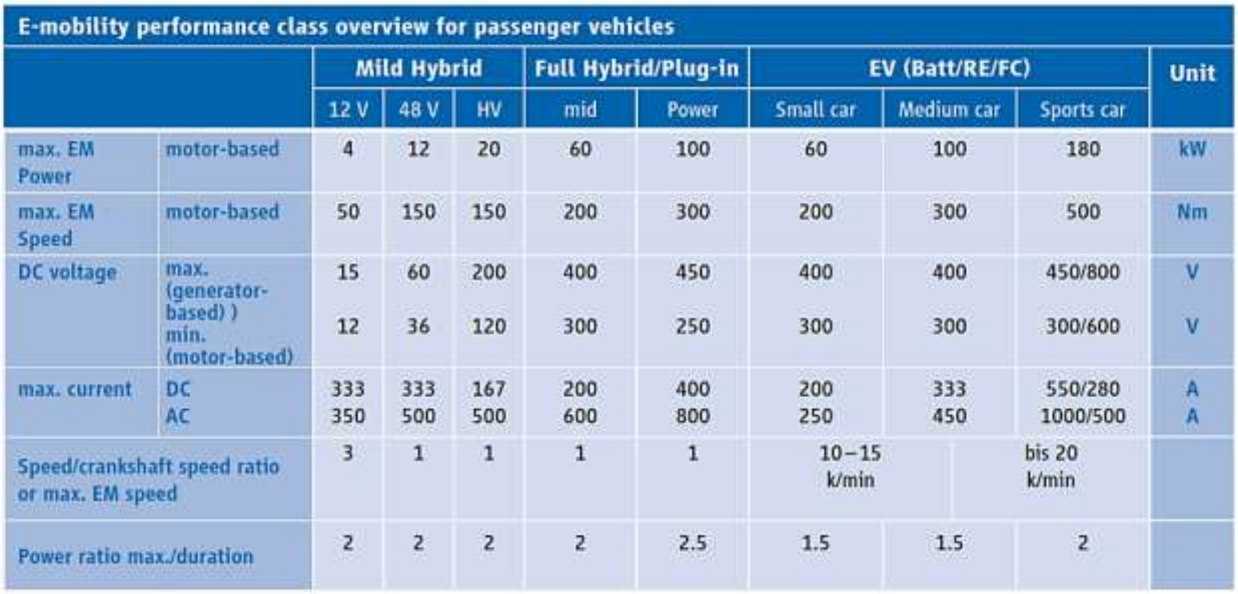
While electrical drive components in industrial applications are designed with expensive spare capacity/redundancy reserves in terms of their installation space and continuous load, this is not an option for the cost-aware and high-volume car manufacturing industry. The electrical architectures and their physical implementation are currently adapted to suit individual vehicle requirements. Standardisation will help to optimise costs, but it will take some time before the automotive industry agrees on standard structures and components based on practical experience.

It is clear that high voltages are required to transport power in the 100 kW range that keep the current values within reasonable limits during the actual transfer process.

Electrical power transmissions of this size for stationary or mobile applications such as trains or forklifts have been operated and maintained by trained electro-technical personnel to date. However, lay persons gain access to this technology when it is transfer- red to passenger cars. Therefore it is necessary to ensure they are protected from accidental contact with dangerous voltages. This applies to normal vehicle operation and maintenance. Even in the event of an accident, safety must be ensured.

High Voltage

Electrical powertrain performances of more than 12 kW are now reserved for the high- voltage range, whereby the voltage level required is based on the currents to be transmitted of approx. 250 A. While battery voltages of up to 400 V are envisaged for passenger car hybrid technology, voltages of up to 850 V are planned for commercial vehicles. These voltages lie within the voltage class B. The high-voltage level is max. 60 < U ≤ 1500 V DC, 30 < U ≤ 1000 V AC rms.

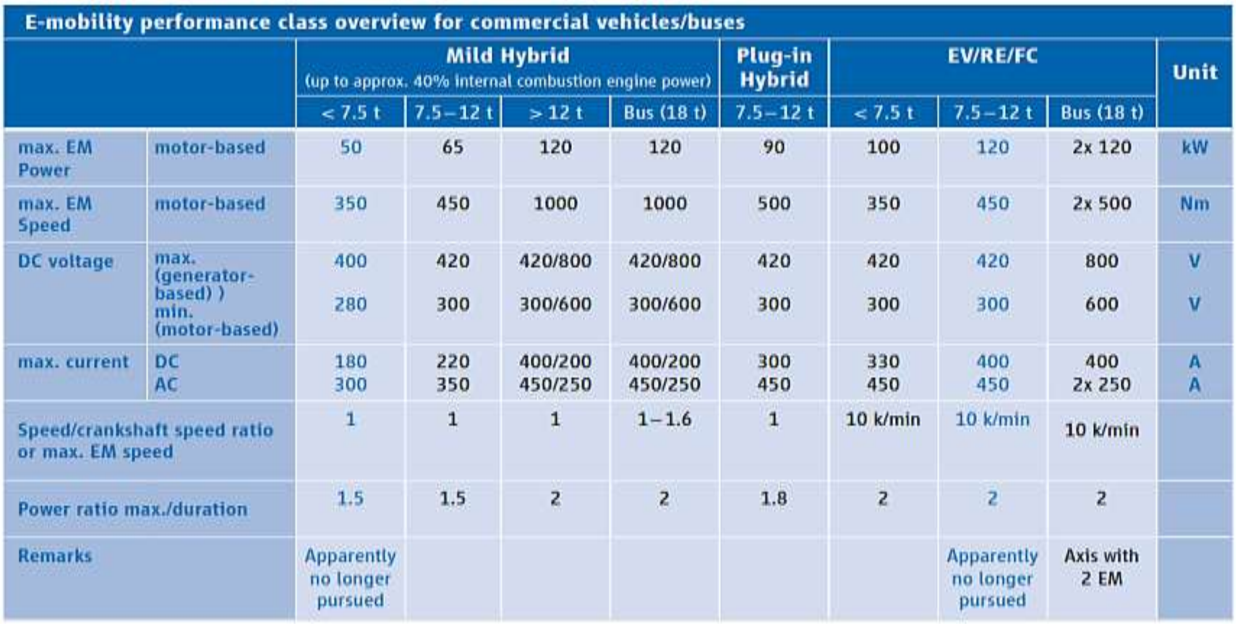


E-mobility performance class overview for passenger vehicles

		Mild Hybrid			Full Hybrid/Plug-in		EV (Batt/RE/FC)			Unit
		12 V	48 V	HV	mid	Power	Small car	Medium car	Sports car	
max. EM Power	motor-based	4	12	20	60	100	60	100	180	kW
max. EM Speed	motor-based	50	150	150	200	300	200	300	500	Nm
DC voltage	max. (generator-based))	15	60	200	400	450	400	400	450/800	V
	min. (motor-based)	12	36	120	300	250	300	300	300/600	V
max. current	DC	333	333	167	200	400	200	333	550/280	A
	AC	350	500	500	600	800	250	450	1000/500	A
Speed/crankshaft speed ratio or max. EM speed		3	1	1	1	1	10–15 k/min		bis 20 k/min	
Power ratio max./duration		2	2	2	2	2.5	1.5	1.5	2	

Table 5. Vehicle types and power categories considered (passenger)
Source: ZVEI

In the automotive industry, high-voltage refers to voltages above 60 V. The classification of voltages in extra-low, low, medium, high and extra-high voltage has its origins in plant and building services engineering, which is particularly evident in the detailed description of earthling and isolation conditions. Whilst this differentiation is helpful for industrial applications, when specifying vehicle voltage classes it is more useful to distinguish between low and high voltage. In this way, lay persons can easily recognise the increased risk associated with higher voltage. This is why the rated voltage of all energy distribution components is colour-coded orange specifying live components.



E-mobility performance class overview for commercial vehicles/buses

		Mild Hybrid (up to approx. 40% internal combustion engine power)				Plug-in Hybrid	EV/RE/FC			Unit
		< 7.5 t	7.5–12 t	> 12 t	Bus (18 t)	7.5–12 t	< 7.5 t	7.5–12 t	Bus (18 t)	
max. EM Power	motor-based	50	65	120	120	90	100	120	2x 120	kW
max. EM Speed	motor-based	350	450	1000	1000	500	350	450	2x 500	Nm
DC voltage	max. (generator-based))	400	420	420/800	420/800	420	420	420	800	V
	min. (motor-based)	280	300	300/600	300/600	300	300	300	600	V
max. current	DC	180	220	400/200	400/200	300	330	400	400	A
	AC	300	350	450/250	450/250	450	450	450	2x 250	A
Speed/crankshaft speed ratio or max. EM speed		1	1	1	1–1.6	1	10 k/min	10 k/min	10 k/min	
Power ratio max./duration		1.5	1.5	2	2	1.8	2	2	2	
Remarks		Apparently no longer pursued						Apparently no longer pursued	Axis with 2 EM	

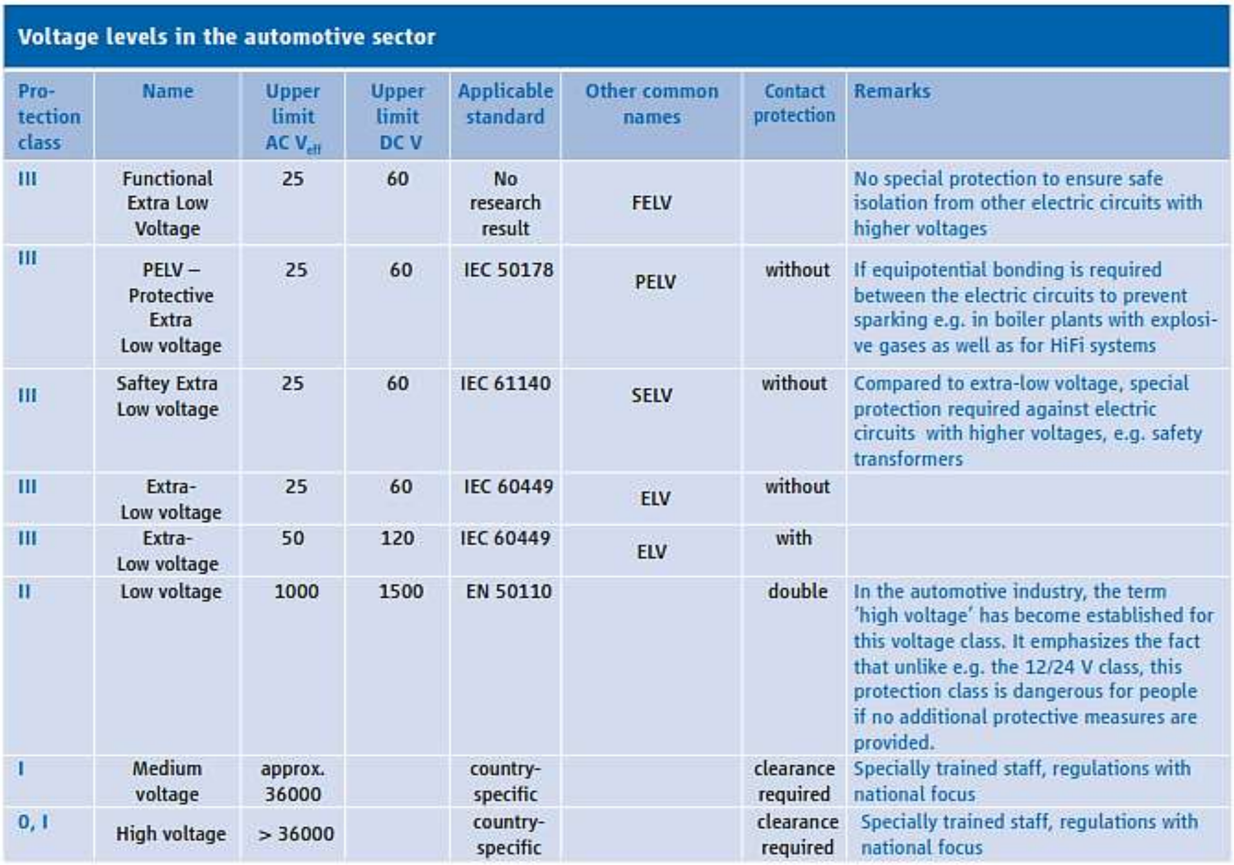
Table 6. Vehicle types and power categories considered (busses)
Source: ZVEI

Connection to charging infrastructure

Low voltage standards also apply to the entire charging infrastructure of e-vehicles and - in line with an agreement between IEC and ISO of 2011 - during the charging process to all electric circuits in a vehicle that are galvanic connected to the charging infrastructure. This kind of electrical isolation is only available in vehicles fitted with on-board chargers with galvanic isolation or in the case of inductive charging systems. No galvanic isolation is required for vehicles using DC charging. Consequently electrical isolation must be ensured by grid-side charging stations.

This would therefore suggest that a vehicle‘s HV system is always galvanic isolated from the power supply system. This is generally referred to as IT (isolated terra) system. The vehicle chassis is earthed during charging via the infrastructure in line with IEC protection class 1.

Only if both poles of electric voltage source/poles are touched simultaneously, does this result in an electric shock. In contrast to installation and building technology, isolation monitors can be used in vehicles to identify and eliminate potential risks when the first fault occurs before a second fault enables both poles to be touched.



Voltage levels in the automotive sector

Protection class	Name	Upper limit AC V_{eff}	Upper limit DC V	Applicable standard	Other common names	Contact protection	Remarks
III	Functional Extra Low Voltage	25	60	No research result	FELV		No special protection to ensure safe isolation from other electric circuits with higher voltages
III	PELV – Protective Extra Low voltage	25	60	IEC 50178	PELV	without	If equipotential bonding is required between the electric circuits to prevent sparking e.g. in boiler plants with explosive gases as well as for HiFi systems
III	Saftey Extra Low voltage	25	60	IEC 61140	SELV	without	Compared to extra-low voltage, special protection required against electric circuits with higher voltages, e.g. safety transformers
III	Extra-Low voltage	25	60	IEC 60449	ELV	without	
III	Extra-Low voltage	50	120	IEC 60449	ELV	with	
II	Low voltage	1000	1500	EN 50110		double	In the automotive industry, the term 'high voltage' has become established for this voltage class. It emphasizes the fact that unlike e.g. the 12/24 V class, this protection class is dangerous for people if no additional protective measures are provided.
I	Medium voltage	approx. 36000		country-specific		clearance required	Specially trained staff, regulations with national focus
0, I	High voltage	> 36000		country-specific		clearance required	Specially trained staff, regulations with national focus

Table 7. Voltage levels
Source: ZVEI

Interactions between different Voltage levels

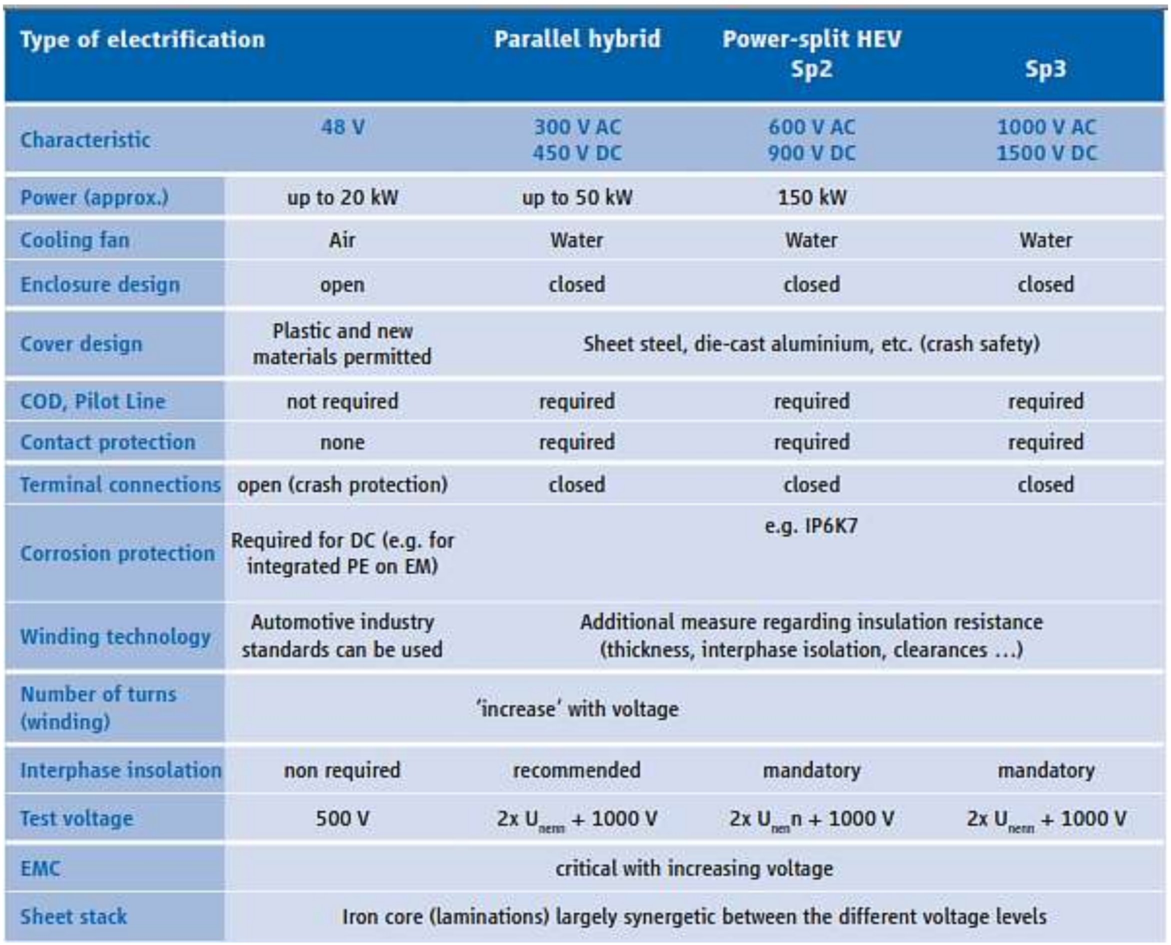
The different voltage levels used in vehicles must be able to operate separately from one another, independently and simultaneously. Standard fusing procedures must be used for the individual voltage levels to ensure cable and short-circuit protection. This can be achieved with safety fuses or electronic protection processes. In the event of faults occurring between two different voltage levels, careful consideration must be given to the design of protective circuits and detection systems and additional measures put in place if required.

Whilst it is advisable to galvanic separate different LV voltage levels, galvanic isolation is imperative between HV and LV system(s). Maximum protection can be provided by spatial separation of the circuits to ensure as few physical contact points as possible, which eliminates the risk of a short circuit almost entirely. It is recommended that HV cables and connectors be colour-coded orange to provide a visual warning.

Charging voltage for DC fast charging

The battery voltage must be connected and adjusted to the relevant grid voltages to enable charging of electric vehicles. This task is performed by battery chargers built into modern electric vehicles.

Direct current fast charging is used today to speed up the charging process of electric vehicles. The charging station is directly connected to the vehicle battery. No on-board charger is required for this charging method. However, the charging stations must be able to adapt to the battery‘s voltage level and the key performance data required for charging (charging state, charging voltage, max. charging current) must be exchanged between the vehicle (battery) and charging station. The vehicle controls the charging process during this communication exchange, while the charging station controls current and voltage supply.



Type of electrification		Parallel hybrid	Power-split HEV Sp2	Sp3
Characteristic	48 V	300 V AC 450 V DC	600 V AC 900 V DC	1000 V AC 1500 V DC
Power (approx.)	up to 20 kW	up to 50 kW	150 kW	
Cooling fan	Air	Water	Water	Water
Enclosure design	open	closed	closed	closed
Cover design	Plastic and new materials permitted	Sheet steel, die-cast aluminium, etc. (crash safety)		
COD, Pilot Line	not required	required	required	required
Contact protection	none	required	required	required
Terminal connections	open (crash protection)	closed	closed	closed
Corrosion protection	Required for DC (e.g. for integrated PE on EM)	e.g. IP6K7		
Winding technology	Automotive industry standards can be used	Additional measure regarding insulation resistance (thickness, interphase isolation, clearances …)		
Number of turns (winding)	‘increase‘ with voltage			
Interphase insolation	non required	recommended	mandatory	mandatory
Test voltage	500 V	2x U_{nenn} + 1000 V	2x U_{nen}n + 1000 V	2x U_{nenn} + 1000 V
EMC	critical with increasing voltage			
Sheet stack	Iron core (laminations) largely synergetic between the different voltage levels			

Table 8. Drive unit concepts

Source: ZVEI

The ’CHAdeMO‘ interface is the incumbent standard originally developed by TEPCO in Japan. Technical data: 500 V, 125 A. In theory, it takes approx. 20 minutes to almost fully charge a 20 kWh battery. Some 1000 stations have now been installed in Japan. Several Asian vehicles are already equipped with this interface.

European car manufacturers have adopted the ’combo type 2‘ charging interface that sup- ports the combined charging system developed specifically for this purpose. This interface enables both AC and DC charging. The majority of European OEMs have agreed to use this interface for all electric vehicles from 2017. It is designed for voltages up to 850 V and currents up to 200 A.

The electrical performance can be increased by using higher current or voltage rates. The use of higher current rates to improve performance is determined by the system design, because higher current flows require the internal and external pin contacts (power modules and connectors) and cabling to have greater cross-sectional areas.

Since the current level cannot be increased above 250 A due to physical limitations, improved performance in passenger/commercial vehicles can be achieved with higher voltage rates.

Rules, Norms and Standardisation

Numerous standards apply to electric mobility, including those generated specifically for electric mobility applications. Examples include the standards for type 2 plug and socket systems and for electric cables in road vehicles for voltages above 60 V. There are many other electrical engineering standards that have not been specifically developed for electric mobility but are relevant due to their general nature. These include safety standards and standards relating to installation, for instance.

For example, as part of the activities of the German National Platform for eMobility (NPE), the DKE (German Commission for Electrical, Electronic and Information Technologies of DIN and VDE) has developed a standardisation roadmap and provided an overview of the relevant standards in the annex of the roadmap. The ZVEI‘s technical working group on standardisation maintains this list and updates it with information relevant to electric mobility activities. This additional information includes detailed descriptions of the relevant standard‘s content and status.

eMobility Standards

Which standards have to be considered for the e-mobility charging infrastructure?

The IEC 60364 Standard series consists of installation standards and therefore has to be used for fixed installations. If a charging station is not movable and connected via fixed cables, it falls under the scope of IEC 60364. IEC 60364-4-44, clause 443 (2007) provides information on WHEN surge protection is to be installed. For example, if surges can have effects on public services, commercial and industrial activities and if sensitive equipment of overvoltage category I + II are installed. IEC 60364-5-53, clause 534 (2001) deals with the question WHICH surge protection is to be selected and HOW it is to be installed.

Ensuring mobility - Protect the charging infrastructure and electric vehicles from lightning and surge damage according to the requirements of IEC 60364-4-44 clause 44, IEC 60364-7-722 and VDE AR-N-4100.

eMobility Standardisation bodies and other initiatives

The key importance of decarbonising road transport has seen the development of a broad range of initiatives promoting electric vehicles across the EU. These vary from developing service markets to standardisation, collection of eMobility data or analysis of how increasing shares of EV will affect the power grid. These initiatives have led to increased experience and learning in the field of eMobility that are being complemented by eGUTS.

The following section gives a limited overview of similar initiatives working on topics comparable to eGUTS. Many of these initiatives are cooperating with each other to foster a common approach and dynamic market for eMobility. Further synergies could be built between these initiatives in enhancing roaming services and further promotion of EU-wide eMobility.

Interoperability platforms

Ladenetz.de - Ladenetz.de is a cooperation between public utility companies that joined forces to enable roaming services between the charging networks of the individual utilities. With a single RFID card, customers can recharge their car at all publicly accessible charging stations irrespective of the operator. A new open protocol OCHP (Open Clearinghouse Protocol) was designed to give parties the opportunity to use their own system to connect to e-clearing.net, a platform initiated by Ladenetz. The 'Treaty of Vaals' was signed in 2012 to enable cross border roaming by Ladenetz.de, the E-laad foundation (Netherlands), BlueCorner, and Be-charged (Belgium), Estonteco (Luxembourg), Vlotte (Austria), ESB eCars (Ireland) and Inteli (Portugal). All connected players are using the OCHP interface.

Hubject - Hubject is formed by BMW Group, Bosch, Daimler, EnBW, RWE and Siemens. The joint-venture is operating an e-roaming platform that acts as a clearing house for network operators and service providers. E-roaming charging stations can be identified with an Intercharge symbol, allowing customers to access charging stations across borders on a contractual basis independent of the service provider. Customers can start a charging session by using a RFID card, smartphone app or plug & charge technology. Any network operator or service provider can join the platform and allow customers of network partners to use their charging stations.

Among the operators that have connected their charging stations to the Hubject network is also the GIREVE platform in France. In April 2014 there were 1,800 charging stations operated by Hubject's partners in Germany, and 150 charging points were connected to Intercharge in Austria. Hubject also recently announced that it has joined forces with the Swisscom Managed Mobility to expand its charging services to Switzerland. Hubject is also founding member of eMI3 and developing standards with eGUTS further.

GIREVE - GIREVE is a joint-venture by Caisse des Dépôts, CNR, EDF, ERDF and Renault to design and operate in France a platform for interoperability between EVSE operators and EVSPs. Its first task has been to create a charging spot repository in France (over 9,000 charging stations registered in mid-2014), on which base it will be possible to provide roaming services between operators. The first available service by the end of 2014 will be a search & find available charging spots according to given criteria, and allow access to a selected one for a customer having a contract with another service provider. GIREVE is member of eMI3 and has a working agreement with Hubject to focus on European standards.

MOBI.Europe - An interesting example is the Mobi.Europe project which focuses on supporting interoperability of electric vehicle charging between four pilot projects in Ireland, the Netherlands, Portugal and Spain. The partners decided to opt for a decentralised ICT infrastructure based on peer-to-peer connection between the pilots' managements systems. This solution can however allow for a future centralised solution if the business is driven towards that direction. Customers can charge their electric car on charging stations located in remote pilots by using the Mobi.Europe mobile application for roaming and charging. The app communicates with the user's own payment management system (PMS), which in turn communicates with the remote PMS to allow the use of operations.

CROME7 - Another joint project focused on cross-border travel was CROME (Cross-border Mobility for EVs) between the Alsace and Moselle regions in France and Baden-Wurttemberg in Germany. In this joint project with French and German industrial and research partners, the following overarching objectives have been followed:

- Performing a wide-scale cross-border field demonstration of mobility with EVs;
- Introducing fully public interoperable charging stations (EVSEs) ensuring easy access and charging of EVs all over the French and German CROME area;

- Investigating customer acceptance of eMobility and user needs regarding charging in the context of cross border mobility;
- Offering charging services enabling simplified identification and billing as well as charging spot availability and reservation;
- Testing and giving recommendations on the European standardisation of the charging infrastructure (plug, cable ...) and services (identification, billing, roaming ...).

Initiatives on eMobility data

European Electro-mobility Observatory (EEO) - In 2012 the European Commission launched the European Electro-mobility Observatory (EEO). The EEO aims to become the reference point for providing insight in the development of eMobility for national, regional and local policy makers and related stakeholders. Electromobility in the framework of the EEO covers full battery electric vehicles, plug-in hybrids and fuel cell electric vehicles as well as the corresponding energy delivery infrastructures. The project has started to gather data and information within its regions about its ongoing electro-mobility projects.

Joint Research Centre (JRC) - With more than 320 ongoing R&D projects, the European Commission's Joint Research Centre (JRC) builds on a rich experience of EV data collection and analysis. The projects can be found in the EV-Radar9, an interactive tool that collects and illustrates ongoing RD&D eMobility projects. The Green eMotion project has also helped to foster cooperation between IREC and JRC which has culminated in JRC Data Collection and Reporting Guidelines for European electro-mobility projects10. The report provides useful guidance to European mobility projects about what and how to monitor and report. It also gives a detailed description of the critical and optional elements needed for monitoring, as well as some ideas on quality control and data collection. The document is based on the Green eMotion internal report "Demo Regions Reporting Guidelines".

FREVUE and ZeEUS projects - FREVUE and ZeEUS are EU's two other flagship eMobility projects. In parallel to other activities they have started a data collection in order to assess the eMobility of freight vehicles and, respectively, electric buses. The last three meetings of the EU Electromobility Stakeholder Forum have taken place jointly with both these two projects in June 2013, June 2014 and February 2015.

Standardisation bodies and industry consortia

IEC - The International Electrotechnical Commission is the leading global organization that publishes consensus- based International Standards and manages conformity assessment systems for electric and electronic products, systems and services, collectively known as electro-technology. In the field of electromobility it is responsible for several important standards like 61851 "Electric vehicle conductive charging system", 62196 "Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles” and together with ISO for the 15118 “Road vehicles - Vehicle to grid communication interface”.

CEN/CENELEC - Together, CEN and CENELEC provide a platform for the development of European Standards and other technical specifications across a wide range of sectors. They work closely with the European Commission to ensure that standards correspond with any relevant EU legislation. CEN and CENELEC also cooperate with respectively the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) to reach agreements on common standards that can be applied throughout the whole world, thereby facilitating international trade. An important activity in the field of electromobility is the eMobility Ad Hoc group on Smart Charging (CEN CENELEC M/468 M/490).

eMI3 12 - As the Commission’s standardisation mandate (M/468) showed, standardisation is clearly important but it is not enough. Interoperability within and in between standards is needed to ensure that customers are truly able to park wherever they stop and roam outside their network. The eMobility ICT Interoperability Innovation, eMI3, an industry group which started with a small group of eGUTS partners to grow as a platform of over 40 stakeholders strives to achieve just this. The group aims to harmonize the ICT data definitions, formats, interfaces, and exchange mechanisms that enable a common language among all ICT platforms. Although eMI3 intends to facilitate and promote their implementation, its core objectives lie in the development, publication, sharing and promotion of ICT standards. The eMI3 group operates under the umbrella of ERTICO - ITS Europe.

SWOT analysis

INTERNAL FACTORS	
STRENGTHS (+)	**WEAKNESSES (-)**
• Reduction of emissions. • Less noise pollution. • Reducing congestion in city centres • 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 • 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 • Unlike trolleybuses, eBuses do not depend on a single route and can adapt to road closures • 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

An analysis of secondary literature has been carried out for the areas of users, economy, politics and legal. Key subjects regarding the development of electromobility have been developed in this context. The corresponding technological factors and developments have been detailed on the basis of the analysis of secondary literature.

STRENGTHS (+)	WEAKNESSES (-)
• Carbon-free travel possible • Electric vehicle can significantly support the smart home • concept, can be integrated in the smart grid • Low noise emissions • Fun to drive (acceleration) • High level of comfort in urban areas • Recharging activity can be combined with parking activity • (no separate re-fueling activity) • Low costs of operation and maintenance • Improved active safety • Ongoing standardization projects are supporting the process of overcoming various technical problems and the definition of safety questions	• Insufficient range for longer journeys • Days when vehicle is not available are a key decision making factor in the purchase decision • Interior air-conditioning is a limiting factor for the range • Long recharging times • High cost of purchase • Low maximum speed compared with equivalent conventional vehicles • Reduced mobile flexibility • Technology and rescue chain hardly tested in practice • Still a lack of convergence of standardization activities in different countries

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 Unlike trolleybuses, eBuses do not depend on a single route and can adapt to road closures 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

Recommendations for eMobility

The work carried out concluded quite clearly the situation on eMobility standardization activities and pointed out many interesting aspects. The undeniable power of eGUTS project is the participation in the project of a high variety of actors, including practically all the stakeholders of the sector, and this allowed obtaining many different points of view, generating a quite complete picture.

The experience gained through the intense interaction with experts, led to identify some key aspects, which can be translated as recommendations and suggestions for different actors. A summary of the standardization-related activity carried out is reported below.

As mentioned briefly in the Introduction, the first recommendation refers to the awareness that, according to eGUTS experience, communication among the actors involved will represent a crucial aspect.

An effective connection among actors will indeed lead to:

- Seamless charging experience for users;
- Complete control of the charging event in order to optimize the process smart grid/smart cities/V2G/V2H vision;
- Possibility to provide additional services.

These three points, combined with technological improvements in EVs components, will be the key to ensure a massive roll-out of e-mobility.

To achieve this goal is not trivial, as for “effective connection” is intended both a “physical” connection between the car and the charging station, and the ICT-based connection among all the other actors involved. The eGUTS APP insures in present at the developed stage only communication between eCars chargers, the short time not allowing also establishing the connection eCar – eCar charger too. In both cases there is highly the need for standardized solutions and for common choices/regulations. Interoperability becomes a central topic and while the physical plug/socket aspects are becoming less problematic, the communication interfaces still remain quite an open issue. The lack of standards and relative choices came strongly out from the State-of-the-Art with SWOT Analysis and should therefore be object of an intense job in the very next future.

The second recommendation tries to address the fact that in many cases the main problem is not to define new standards, but to choose one from multiple standardized versions (more regulation than standardization). Thanks to active debate with many stakeholders, including the European Commission (EC), it has been possible to identify which actors should be involved and which process could lead to effective choices and to regulation decisions. The best situation to enhance interoperability will be to have only one common solution, but this needs:

- Coordination among different research/industrial activities to point out the best technical solutions;
- Creation of working groups/alliances/partnerships among industries;
- Wide agreement on one solution by industries and stakeholders;
- Policy intervention through regulatory means (EC Directive or other).

The need for cooperation is evident, since there is no single entity that is able or can be appointed to solve the set of existing gaps. This cooperation can be searched in user groups, industry parties, different sets of actors and stakeholders or groups making choices on standards since in some areas multiple solutions are available. Having more coordination and some kind of centralized control, both inside the EC and inside the industrial world, would represent a really important achievement.

The third recommendation, at last, has the aim to stress the importance of starting immediately to deploy a "smart and interoperable" infrastructure. Many Municipalities are now starting to install charging stations but there is the real risk that "old" systems are put in place. It is really important that also small initiatives are seen as a part of a much more complex and integrated "system". In a few years probably EVs will often cross borders and the infrastructure developed since now on has to be able to charge them. The infrastructure has to permit identification and access through "up-to-date" methods (there are still systems accessible by physical keys). Charging stations have to be connected to some kind of marketplace and they have to allow roaming.

In terms of electrification, the recommendation are summarised in the table below.

Action	Recommendation
Take multi-stakeholder and market-specific approach	Develop a multi-stakeholder approach in electrification strategy Design internal organizations to ensure convergence of energy, urban and mobility planning objectives, Ensure city, regional, national policies support and reinforce each other: Build a national platform for electric mobility with city representation, Assess local characteristics to inform action: Assess current and projected local characteristics in terms of city infrastructure and design, energy system, and mobility culture and patterns
Prioritize high-use vehicles	Focus on electrifying public and commercial fleets, including mobility-as-a-service: - Introduce financial and/or non-financial incentives for high utilization vehicles, Complete electrification of public transport system - Secure funding for electric buses and infrastructure, and renew the fleet gradually through public procurement: - Collaborate with the public transport operator(s) to define the fleet electrification targets,

	- Involve electricity network operators and electricity, suppliers to enable smart charging and ancillary services at bus depots, Enable the integration of AVs: - Develop national regulatory frameworks that allow regions and cities to begin testing and introducing AVs - Investigate the impact of AVs on urban spatial and infrastructure planning
Deploy critical charging infrastructure today while anticipating the transformation of mobility	Focus on reducing range anxiety and promoting interoperability: - Develop fast-charging network through public-private funding to connect different cities, - Include standardization and interoperability in minimum requirements, Prioritize energy-efficient charging hubs with grid edge technologies and smart charging: - Locate charging hubs on the outskirts of cities, connected with public transport systems and alternative mobility means - Support the evolution of regulatory paradigms to enable new energy-related services, - Decide on the approach to charging mobility hubs: public, private or public and private cooperation Develop digitalized end-to-end customer experience to enhance access to charging services: - Create a national database of public charging points through public-private partnership, - Standardize and simplify the payment of the charging services

Table 9. Recommendations for electrifying mobility

Conclusions

Common standards for EU-wide electromobility

One of the main goals of the eGUTS project was to promote the mass roll-out of electric EVs in Danube Region and further, in the entire Europe. One of the most important ways to achieve this goal is to promote standardisation of eMobility. The use of “eMobility” instead of EV refers to the acknowledgement of the fact that EV largely depend on the charging infrastructure, which in turn depends on the electrical grid. Therefore, communication between the electric car, its charging infrastructure and the grid is the key achieving interoperability.

The main message on standardization issues and needs for standardization and interoperability would be the harmonisation of technology and standards for the mass rollout of EVs and PHEVs across Danube region.

To make the most of the impact and dissemination of eGUTS findings, activities focussed on three major topics. First, infrastructure represents a key area as it needed further research on harmonising the interfaces on communication between charging points and charging management system. The need to analyse these requirements and functionalities led to the elaboration of the eGUTS APP, offering a starting point for the standardization bodies on communication messages focusing on defining the minimum contents of this communication.

Second, a specific topic was defined on the activities carried out by eGUTS activities for identification and authentication of users and other topics in order to ensure full interoperability of electric vehicle with recharging infrastructure.

A major outcome of the standardisation work regarding EV technology is the perception and proof that the definition and determination of the range and thus the energy consumption of an EV is critical and not sufficient.

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 centres 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 behaviour. A new age of personal mobility is starting and it has already changed our cities.

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 eBuses supply and standardization. Over the next three years, for example, early movers like Chinese BYD could continue to dominate the eBuses 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 eBuses roll-out.

In conclusion:

- 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 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.

We have to notice that **the driver**, the final user of the whole complex system, is the most relevant and central actor but at the same time quite a “passive” actor with respect to interoperability and standardization aspects. The driver is the one expressing the needs and defining the minimal requirements, but his direct intervention in the process to comply with them is limited.

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