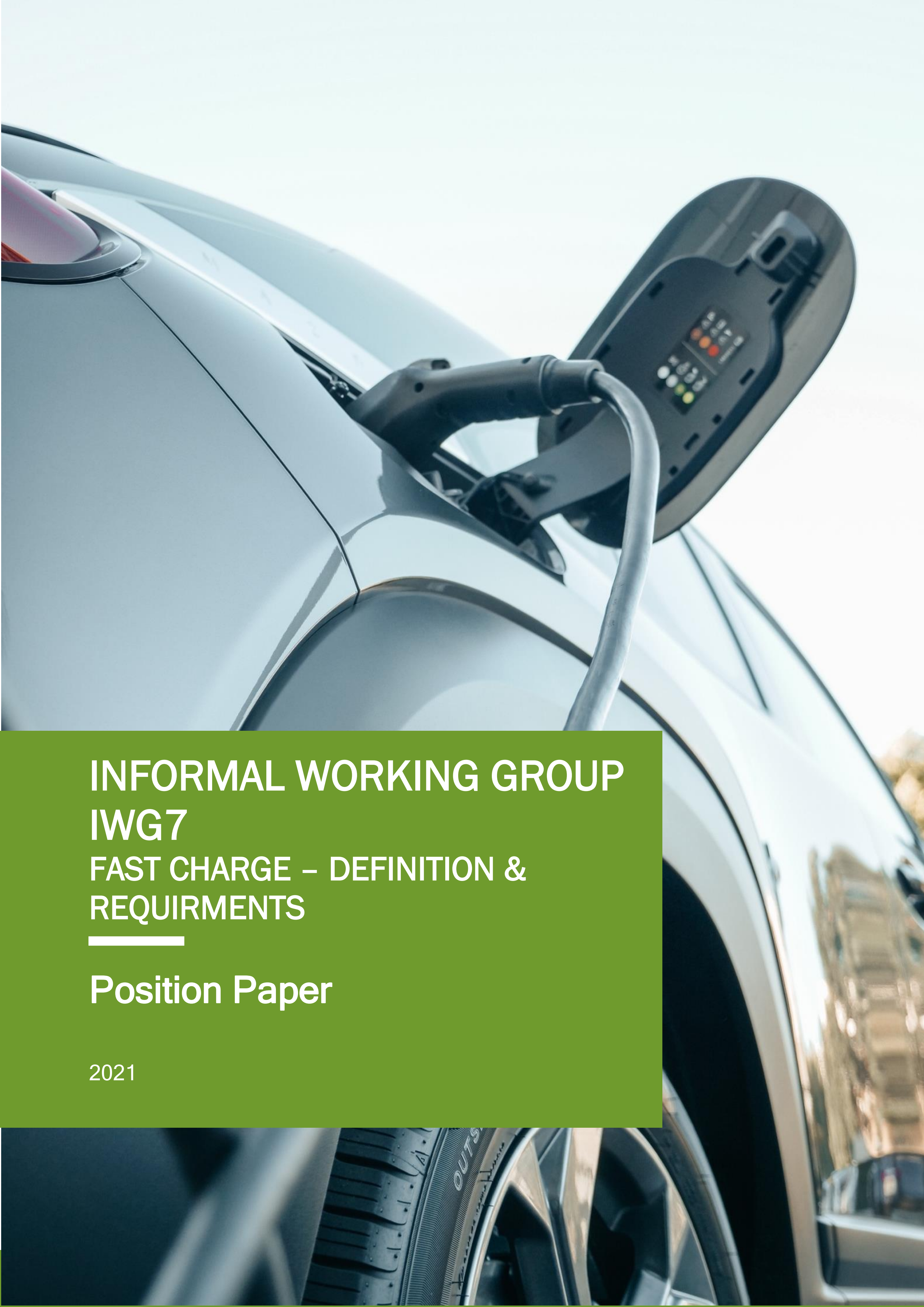

INFORMAL WORKING GROUP IWG7

FAST CHARGE – DEFINITION & REQUIRMENTS

Position Paper

2021

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Preamble

The Informal Working Group IWG7 is a subgroup of Working Group *WG5 Application and Integration – Mobile* of BatteRies Europe, the European Technology and Innovation Platform (ETIP) for Batteries, and is composed of public, private and research partners involved in battery research and innovation and in e-Mobility (

Table *5*).

IWG7 is bringing together members who share common interest in fast charging solutions for transport, including passenger cars, commercial vehicles and flight applications, and is actively contributing and bringing its expert knowledge in the battery sector while focusing primarily on fast charging as an enabler for future transport applications.

IWG7 has agreed that, besides low range and high acquisition costs, especially the charging process (for example: interoperability, charging time, payment, availability) is one of the important enablers to help achieving the breakthrough of the electric mobility.

Fast and convenient charging is one of the means addressing especially this topic: the acceptance of e-Mobility can be drastically enhanced by enabling a perceivable reduction in charging times. As a further consequence, fast charging will enable new mobility modes for people and goods and support the transformation of mobility behaviour. Comfort charging like automated (fast) charging, bi-directional charging and other charging services will further accelerate this transformation due to higher convenience for the e-Mobility user and e-Mobility provider.

With this vision in mind, IWG7 is aiming at identifying all relevant stakeholders and their roles along the entire value chain of charging and fast charging. This begins by first agreeing on a definition of the term fast charging and the requirements for fast charging in the context of the activities of BatteRies Europe. Secondly, the group is identifying relevant research and innovation (R&I) targets/areas as well as the associated challenges related to fast charging faced by the battery R&I community, that need to be addressed to develop and support a competitive battery value chain in Europe.

Fast Charging will push new advanced battery material development to achieve higher C-Rates and higher charging performance while still ensuring lifetime and provide sufficient energy for range.

IWG7 is targeting fast charging of batteries used for transport in the timeframe 2030 and beyond.

The IWG7 is feeding actively its results into BatteRies Europe, ensuring an optimal cooperation with all other Thematic Working Groups, especially WG3 *Advanced Materials* and WG4 *Manufacturing & Cell Design*, as well as ensuring an optimal information exchange with cross-cutting issues and stakeholder.

The group is open towards new subjects, issues, players and stakeholders.

1. Motivation and Objectives

Some of the most important factors for increasing the acceptance of electric vehicles are to compensate for the shorter range compared to conventional vehicles, assure the availability of charging infrastructure itself as well as managing the time and ensuring the comfort of charging.

So fast charging is a very important enabler for electro-mobility, but most likely only for occasional charging. Thus, fast charging is considered to be opportunity charging:

- Daily needs can generally be met with classic slow charging, especially if the chargers are located where the vehicles spend most of their time
- Fast charging is a key enabler for long trips, especially for reduced-size batteries, that in turn directly benefit reducing the cost of electric vehicles

Users will have to accept that traveling on long trips will change, especially with smaller sized batteries that can be fast charged. A clear advantage of smaller sized batteries is the significant reduction of cost.

Charging is not needed everywhere, but only where it is useful, e. g. for long distance travel @public, @work or @home.

In order to build a comprehensive fast charging infrastructure, serving the growing number of customers, targeting 2030 and beyond,

- Technical requirements need to be identified, defined, standardised and met in terms of both vehicle, including battery, and infrastructure
- Effect of fast charging on batteries life time needs to be addressed
- Inclusion of all relevant stakeholders for this process is needed

2. Definition and specification for fast DC-Charging

It is expected that fast charging will be available in different power classes. The current standard for charging stations refers up to 500A enabling 350kW charging power. Companies like Fastnet or IONITY already build up a considerable number of High Power Charging (HPC) stations. Reduced local grid supply leads to reduced charging power. Charging power depends on the voltage level as well the current (P_{charge}=UxI). Therefore, higher voltage is supporting higher charging ratio (means energy charged into the car in specific time [E/t]). Current voltage classes at vehicle level are 400V and 800V. Because of less thermal losses (P_{loss}= RxI^2) higher voltage supports efficiency.

Fast charging is based on DC-charging. Different modes of transport and grid supply will foster different solutions, but efficiency will be key. In this regard DC Charging will also be considered for lower power charging in the future.

According to the definitions in Article 2 of EU Directive 2014/94/EU a *normal power recharging point* means a recharging point that allows for a transfer of electric energy to an electric vehicle with a power less than or equal to 22 kW. This excludes devices with power less than or equal to 3,7 kW, which are installed in private households or the primary purpose is not recharging electric vehicles, and which are not accessible to the public; a *high power recharging point* means a recharging point that allows for a transfer of electricity to an electric vehicle with a power of more than 22 kW.

These definitions need to be updated to reflect the technological developments since 2014, focusing on what should be in place in 2030 and beyond.

The definition and specification of fast charging in contrast to standard and ultrafast charging depends on the application as summarized in Table 1 (see below). For future decarbonized mobility based on electric energy, fast charging is an enabler for both long distances and for raising the customer's interest for electrified cars due to higher charging ratio. But not every charging operation has to be ultrafast. An important amount of charging energy to the vehicle will be covered with @home- or @work-charging. In addition, public AC (up to 22kW) and DC (up to 50kW) charging stations will ensure a sufficient charging opportunity, especially but not limited to urban areas. Commercial Vehicles (CV) and public transport will rely on public charging infrastructure including ultrafast charging stations along their destinations and homebase. Pricing models depending on charging speed will also influence the charging behaviour. Ultrafast charging will in general be more expensive than charging with lower power. In the end it is the driver deciding which power suits best to his / her needs.

CV and flight applications have very specific requirements according to their application and geographical location. All of these requirements are depending on range as well as load. A heavy load will limit the vehicle range (due to the weight hindered for bigger batter packs); transport of goods with a lower weight will offer the possibility to include bigger battery packs, hence will support longer travel range and higher uptake of zero emission transport. Although using the same charging power, smaller batteries will see higher C-rates compared to bigger batteries.

Table 1: Definition and specification of fast charging depending on the application

Transport mode	Smaller batteries	Bigger batteries	Charging time
Passenger cars	45 kWh	90 kWh	< 20 mins
Commercial vehicles (urban)	45 kWh (vans)	400 kWh (heavy duty trucks)	< 30 mins
Commercial vehicles (long haul)	400 kWh	700 kWh	< 45 mins
Flight application	70 kWh	150 kWh	20 mins

Table 2: Definition/classification fast charging for passenger cars (L, M, N)

Charging mode	Power	C-Rate	Charging Rate	SoC
Standard charging	< 50 kW	< 1C	< 3 km/min.	< 90 % SOC
Fast charging	< 150 kW	< 3C	< 20 km/min.	< 80% SOC
Ultrafast charging	< 350 kW	> 3C	> 40 km/min.	< 70% SOC

Table 3: Definition/classification fast charging for commercial vehicles (LCV, HDVC)

Charging mode	Power	C-Rate	Charging Rate	SoC
Standard charging	< 150 kW	< 2C	< 5 km/min.	< 90 % SOC
Fast charging	< 350 kW	< 3C	< 20 km/min.	< 80% SOC
Ultrafast charging	>700 kW	> 3C	> 40 km/min.	< 70% SOC

Table 4: Definition/classification fast charging for flight applications (small VTOL aircraft)

Charging mode	Power	C-Rate	Charging Rate	SoC
Standard charging	< 150 kW	< 2C	< 3 km/min.	< 90 % SOC
Fast charging	< 350 kW	< 3C	< 8 km/min.	< 80% SOC
Ultrafast charging	>700 kW	> 3C	> 20 km/min.	< 70% SOC

These tables represent the current knowledge and views on fast charging with rough parameters. A deep analysis of the parameters shows that they are not completely consistent. More work will be required to develop an index or indices that will represent unique cases in a holistic way.

In summary 150kW charging power could already be the maximum but sufficient charging power for long distance travelling of passenger cars with relatively small batteries. 500A are expected to be a key enabler for an effective ultrafast charging infrastructure.

3. Research and innovation targets

The IWG7 has identified so far the following R&I areas:

Customer and Operator perception

The perception of customers and operators is the key to drive acceptance of e-Mobility and charging need to be the centre of technological and business developments. Saying this, we need a global picture covering the uniqueness of local markets whilst being able to develop global concepts and industrial drivers, including:

- Transformation of customer focus and resilience of old models.
- New mobility models and how to make them attractive (for the transition phase).
- On-demand charging power provision (variable power according specific situation needs).
- Understanding the efficiency losses and their effects and improve the awareness of customers and operators on this topic: higher power will generate higher losses due to internal resistance and therefore, will come at a price (more losses due to internal resistance)
- Dynamic pricing depending on the power needs.
- Data related topics, including the generation of data, the ownership of data and the usage of data.

All these research areas will need to be investigated in close cooperation with the other BatteRies Europe Working Groups as well as the other stakeholders involved. Research needs based on this paper will be elaborated within ETIP working groups.

C-Rate

Understanding the relationship between C-Rate and fast charging is key for any target (and limit) setting, research and development for fast charging. C-Rate describes the percentage of time needed to reach the nominal capacity of the battery with respect to 1C achieving 100% SoC in one hour. Currently average C-Rate (over the capacity range) is up to 1C. For the future we expect 1C up to 3C as usual for BEV as an average C-rate during the entire charging time.

Materials and cells design for fast charging

Materials and technologies to a build battery from cell and pack design to the overall system evolve quickly, leading to an increase in battery performance as well as to enabling changes in charging behaviour and options. Therefore, charging solutions to be developed have to include but not limited to the topics of different cell generations (current li-ion, advanced li-ion, solid state), semi-conductors, power electronics, and cable materials.

Each available technology should be linked to the best fitting application, considering their limitations, advantages and performance (including lifetime) towards fast charging. Eco-design and manufacturing should be specific for fast charging applications.

Thermal management and cooling solutions

Fast charging is recommended at moderate temperatures which leads to the need for internal thermal management for cells, modules and packs and active cooling measures for vehicles at charging points. In addition, battery performance at different temperatures is highly dependent on the used technology. Accordingly, the thermal management and cooling solution should fit very well each used technology.

Internal resistance of cells and battery packs result in thermal losses and have to be kept low. According to the thermodynamic laws of physics, increasing the power will increase the instantaneous thermal losses in the quadratic. The integral losses can be estimated based on the combination of ELT (a physical quantity used to compare the power capability and thermal losses of the cells - capacity and voltage independent) and C-Rate (**Figure 1**).

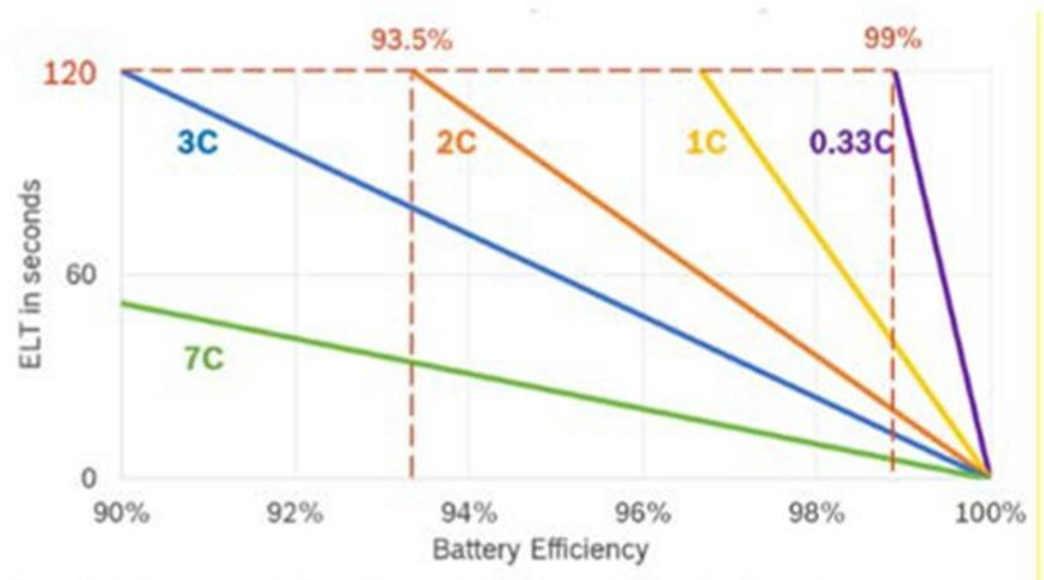

Figure 1:*Electrical Loss Time (ELT) as a function of the mean battery efficiency expressed in percentage © Bosch*[1]

Exchange of cooling fluid between infrastructure and vehicle is only relevant for very special use cases like very high performance and should be avoided in general.

Module and pack system design

The specific design and performance of the battery will define the needed cooling system directly linked with the C-rate in use. Additionally, the design of the battery pack itself will make possible the further use of battery within a second life application when cell and module dismantling will be required. In this regard, new directives will come on the design specifications of the battery pack.

Voltage should be addressed in “system design” (nominal 400V - 1200V).

Charging management systems

Charging management systems and platforms are important tools to meet/steer the demands of the EV-market. They are one of the most decisive factors to optimize the grid connections to the charging stations, i.e. by short-term and long-term demand prediction for charging and provision.

It is important to grow the infrastructure at the same pace as the EV market. This is a challenge since the two markets have very different factors that influence the decisions for implementation. Thus, in a strongly increasing EV-market with strongly increasing power demands, comprehensive, reliable and highly scalable systems are mandatory to cover the

[1] Á. W. Imre, "Towards High-Performance Powertrain Solutions," in *Advanced Automotive & Industrial Battery Conference*, Mainz, 1/31/2018
V. Döge and Á. W. Imre, “Charge Transport in Energy Storage and Conversion Devices”, Diffusion Foundations, 2018, Vol. 19, pp 1-17

needs of the market in the future. In the future scenario, more mature and more novel battery technologies will need to co-exist. Hence, the charging management system will need to be smart enough in order to define the correct strategy for each battery technology.

One more option for large (fast) charging pools are stationary batteries. They enable higher charging power ability while not depending on the grid. Secondly this stationary storage system can help to stabilize the grid and reduce costs for charging.

Roaming and interoperability, including regulatory aspects

Interoperability means each car can charge at each charging station. As stated above: besides low range and high acquisition costs, the tedious and not interoperable charging process is one of the three major hurdles that have to be overcome in order to achieve the breakthrough of the electric vehicles.

One of IWP7's vision of interoperable fast charging is to ensure full transparency and interoperability for any car and any charging station to guarantee availability of free and operable charging spaces including charging power as a parameter for consistent planning. Or in other words the "ultimate goal" is to get the amount of charging that an e-Mobility customer really needs, at the right time (access), the right spot and the right charging power. Even if this expectation is very high and not always met at conventional fuelling stations, it would help to define new analysis tools and schemes to achieve it.

EU-wide we see the strong need to accelerate the deployment of a reliable interoperable charging infrastructure in all relevant places - at home, at work and on the street. This will only be successful, if all user behaviours and needs for charging are fully investigated and understood as well as secondly established.

Cross border charging opportunities have to be established across Europe and ensure charging independently of the car, the country and the energy provider; roaming must support the driver's needs at both national level and EU-wide.

Regulation today shows a lot of grey and non-harmonized areas when it comes to interoperability of charging solutions (Source: CharIN). Only a harmonization of regulation for the operation of charging infrastructures, a universally valid legal framework and changes in the energy sector in Europe can drive interoperability and a reliable charging offer.

Standardized and certified calibration, especially for DC-charging, high power charging and improved efficiency during charging are mandatory. Furthermore, interoperability needs to be pushed while also improving safety and liability topics.

The challenge for small batteries will not necessarily be in the daily-life usability for CV and PC, the biggest challenge is to make them also work for the occasional long trip without too much inconvenience. Smaller batteries should be optimized for daily use but also capable of longer trips that might take place 3 to 5 times per year. These further effects the research targets.

Dynamic solutions are not considered in the timeframe 2030.

Advanced charging technologies (ACT)

Advanced charging technologies comprise battery management products for connected and automated charging (including robot charging), bi-directional charging, advanced battery monitors, as well as i.e. cloud-based monitoring and management solutions serving the ground support equipment, etc.

There are a lot of opportunities but not yet standardized and not yet sufficiently challenged and used, i.e. to avoid multiple charging connectors or to implement intelligent charging management solution with multiple outlet charging system (e. g. parking garage @work).

Framework for business model

Scenarios for charging have to be developed for various loading conditions in parking space, in public areas or in specific installed charging infrastructure

- Fast and standard charging.
- Fees for parking and regulation.
- Data as a shared business model, as well as location-related services.
- Stationary and mobile local energy storage providing services to the grid, CPO, customers, fleet operators.
- Access to and acquisition of land for charging infrastructure.
- Charging service on route.
- Connection to the grid (local, regional, national, European).

4. Challenges

IWP7 has identified challenges for fast charging:

- Establish solutions for EV drivers to experience charging as good as fuelling an ICE today especially in terms of availability, convenience, performance and costs of the necessary fast charging infrastructure
- The pending action of public authorities to set up the legal framework supporting interoperable e-Mobility for a “seamless” automated charging
- The missing capability of energy suppliers, DSOs, and TSOs to roll out new and effective business models in the EV charging-infrastructure
- The need to have investors to enter the charging-infrastructure-sector
- Develop a roadmap including recommendations for charging technologies / solutions that will be established and shared with all relevant stakeholders along the value chain of electric mobility
- Smart schedule charging should be provided in the charging stations
- Further standardisation activities are still needed to harmonise fast charging capacities.

The so far identified technical challenges for fast charging are:

- Fast and ultra-fast charge is only sensible for certain SoC Levels (table 2-4)
- Fast charging should be established also for small batteries and lower voltage levels
- Fast charging should be also applicable for aged batteries

Besides these directly linked challenges, we see a lot of cross cutting topics, e. g.

- Simulation, starting from microstructure scale up to battery design level, including thermal simulation
- Testing
- Validation

5. Stakeholders

(Fast) charging is a system approach involving:

- End customers, i.e. private customers and fleet operators
- Business owners, i.e. filling station operators and owners of shopping locations
- Charging Chain ensuring interoperability, roaming and billing.
- EU, national and regional policy stakeholders, representing the interests and the benefits electric vehicles and their fast charging offer to society and the environment (executed by standardization efforts, electric urban freight, etc.)
- Industry (transport, automotive, chemistry/raw materials, manufacturing, design, recycling, energy, network operators, etc.)
- Research institutes and universities, dealing with (advanced) materials, (smart) technologies, infrastructure and new business models.
- Environmental organizations regarding the case of high waste energy losses.

Stakeholders from various industries and organizations, not necessarily used to work together, increasingly offer service options to EV users, to other industrial stakeholders from the EV value-chain and to society as a whole.

6. Organisational

Table 5: Participants and contacts

Organisation	Name	
Asfinag/CEDER	Manfred	Harrer
AVL	Thomas	Traussnig
BMW Group	Franz	Geyer
CEA	Simon	Perraud
Cidetec	Oscar	Miguel
DG MOVE	Alexander	Verduyn
E.DSO	Florian	Gonzalez
EGVIA/AVL	Josef	Affenzeller
EGVIA	Lucie	Beaumel
EMIRI	Marcel	Meeus
ENTSO.E	Norela	Constantinescu
Robert Bosch	Ian	Faye
Iberdrola	Miguel	Garragori
KIC InnoEnergy	Ilka	von Dalwigk
IONITY	Dominik	Ziriakus
MAN	Jose	Campos
PSA	Nicolas	Leclere
Renault	Patrick	Bastard
SAFRAN	Thierry	Rouge-Carrassat
	Guillaume	Cherouvrier
TNO	Steven	Wilkens
	Bogdan	Rosca
Volvo AB	Mats	Rosenquist
VUB	Maitane	Berecibar
Vrije Universiteit Brussel	Joeri	Van Mierlo
VW	Stanislav	Severov
ZODIAC	Christian	Oeser