Deliverable 7.4

Year 1 Standardization Workshop - Gaps and recommended actions towards minimal features interoperable charging stations for EVs

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List of Abbreviations

ANSI	**American National Standard Institute**
BEV	**Battery Electric Vehicle**
BMS	**Battery management system**
CCS	**Combined Charging System**
CHAdeMO	**CHArge di MOve**
CP	**Charging point (used as a synonym to EVSE)**
Demo Reg	**Green eMotion Demonstration Region**
DoW	**Description of work (Annex I of Grant Agreement)**
EMC	**Electromagnetic compatibility**
ES1	**Demo Reg Barcelona/Malaga**
EVSE	**Electric vehicle supply equipment**
FG	**Focus Group**
GA	**Grant agreement**
GeM	**Green eMotion**
OCPP	**Open charge point protocol**
OEM	**Original Equipment Manufacturer**

PLC	**Power Line Communication**
PEV	**Plug-in EV**
PHEV	**Plug-in hybrid EV**
PLC	**Power line communication**
PWM	**Pulse Width Modulation**
RFID	**Radio-Frequency Identification**
SAE	**Society of Automotive Engineers**
SoH	**State of Health**
SoC	**State of charge**
V2G	**Vehicle to grid**
WP	**Work package**

Executive Summary

The present Deliverable 7.4 “Year 1 Standardization Workshop - Gaps and recommended actions towards minimal features interoperable charging stations for EVs” is the first one issued in the frame of WP7 Task 7.3 “Gap analysis of current status of technologies and standards”. In this task the gaps between technologies and standards (i.e., the lack of common standards) should be analysed and their criticality should be evaluated. In particular, aim of the first deliverable is, after having organized a workshop with External Stakeholders about standardization issues, to report on both inputs (i.e., the updated current status of technologies and standards in the Green eMotion Demonstration Regions) and outputs of the workshop (i.e., the synthesis of the main results and recommendations for alignment of the GeM demonstration projects with the EC M/468 mandate taken on by the CEN CENELEC Focus Group on European Electro-Mobility).

Actually, the Focus Group (FG), whose activity has been considered as reference all along the WP7 development, did perform a massive and excellent work, issuing in October 2011 a version 2 of a Final Report containing many useful recommendations toward the harmonization of standards in Europe. However, the FG experts could not reach the target shared vision about standards, in order to select the most suitable ones to be fully developed. Therefore, in the frame of WP7 the need to follow our own vision and path in the gap analysis toward the harmonization of standards emerged.

The analysis carried out during the arrangement of the External Stakeholder Workshop showed that two approaches can be followed:

- a “top-down approach” based on the Marketplace vision (as described by WP3 outcomes, and mainly by D3.1 and D3.3)
- a “bottom-up approach” based on selected simple feasible solutions.

It has been agreed that in the long term the first approach should emerge as the only possible solution to the complex framework of e-mobility. However, because of the complexity of this approach in terms of standardized technological solutions, the common GeM decision has been to select at first the easier “bottom-up” approach, in order to facilitate the rollout of e-mobility, by describing the gaps to implement specific solutions in the fastest possible way. Therefore, the minimum requirements for interoperable charging stations have been analyzed in two different cases, i.e.:

- InterCity - InterState or long distance travel
- City or short distance travel

This analysis was presented in the Standardization Workshop held during the External Stakeholder Forum in Brussels on May 10-11, 2012. The contribution and suggestions given by External Stakeholders and GeM partners both during and after the Forum are also integrated in this report.

In this Deliverable, **Chapter 1** presents the updated status of standards in the GeM Demonstration Projects. Such description is based on the “Data Logging Report” D1.2 issued by the Site Operation Manager IREC at the end of 2011 (Month 10). It is shown that the most implemented charging mode (according to IEC 61851-1 standard), is Mode 3 (up to 62.5% of

the charging points), followed by Mode 2 (supported by 26.7% of the charging points). The most implemented type of connector is Type 2 (according to IEC 62196-2). The rest of connectors types is almost negligible. However, there is a 19.3% of connectors in the Demonstration Regions that cannot be classified into the existing EV standards. The related issue cannot be neglected, since this percentage is high enough as to modify the conclusions about interoperability.

Chapter 2 reports on the agreed technological analysis of the expected charging infrastructure evolution. According to such analysis, the implementation of an infrastructure with minimal features, but still capable of allowing large interoperability all across Europe, is based on the installation of quick charging stations within the currently available petrol-service stations. There are no essential differences amongst the EU Member States.

Finally **Chapter 3** leverages the technological analysis carried out, documents the preliminary gap analysis in the two cases of long and short distance travels and gives some related recommendations toward interoperability.

Since the mass market introduction of EVs is proceeding fast, all presented gaps and recommendations should be addressed in the short term. Although most statements, options and solutions are valid for short as well as long distance travels, some specific recommendations to overcome the highlighted gaps can be given for the two cases and for the different technological areas:

a) ***long distance travels***

- To urgently define a specific standard that sets the rules to install quick-fast charging points.
- Vehicle/Charging Point: to develop and agree on a single charging interface allowing to charge with all existing charging methods (one-phase AC-charging, three-phase fast AC-charging, slow DC-charging and ultra-fast DC-charging).
- Communication: To promote the use of universal devices designed to communicate, which support Analog , PLC, Can and PWM interfaces with an extensive libraries on both sides (vehicle and external charger).

b) ***short distance travels***

- To define a few use cases/scenarios and associated data and interactions that enables all involved stakeholders and parties to test their part of the system stand-alone and later in combination with the total system.
- To define a minimal set of standards to be used in communication. Create a list of (detailed) issues to be solved and solutions or standards that can help in the solution.

Introduction

When the Description of Work of the Green eMotion Project was written, the work of the CEN CENELEC Focus Group for EV standardization (upon EC M/468 mandate) had just started. Because of the importance of this initiative, the Focus Group was taken as reference in the activity (WP7) devoted to the harmonization of standards in the Project. Therefore, according to the expected results and timeframe of the FG outcomes, it was planned to align the Project activities with the standards when they would have been fully developed, i.e. by April 2012. To this aim, an External Stakeholder Workshop had been planned, in order to summarize the alignment needs of Green eMotion with CEN CENELEC and also to collect further updated suggestions by the involved Stakeholders. Actually, the Focus Group did perform a massive and excellent work, issuing in October 2011 the version 2 of a Final Report containing many useful recommendations toward the harmonization of standards in Europe. However, in this moment of very quick technological developments the FG experts could not reach the target shared vision about standards, in order to select the most suitable ones to be fully developed.

Therefore, in the frame of WP7 it turned out to be necessary to follow an own vision and path in the gap analysis toward the harmonization of standards.

The analysis carried out during the arrangement of the External Stakeholder Workshop showed that two approaches can be followed: a "top-down" approach based on the Marketplace vision (as described by WP3 outcomes, and mainly by D3.1 and D3.3), and a "Bottom-up approach" based on simple feasible selected solutions.

It has been agreed that in the long term the first approach should emerge as the only possible solution to the complex framework of e-mobility. However, because of the complexity of this approach in terms of standardized technological solutions, the common decision has been to select at first the easier approach, in order to facilitate the rollout of e-mobility, by describing the gaps to implement specific solutions. The core of the proposed gap analysis will be the intermediate outcome of WP7, that is, to describe which standards are missing, which are available but not adequate or what it is recommended, so that the proposed solutions can be implemented in the fastest possible way. Therefore, the minimum requirements for interoperable charging stations have been analyzed in two different cases, i.e.,

- InterCity - InterState or long distance travel
- City or short distance travel

This analysis was presented in the Standardization Workshop held during the External Stakeholder Forum in Brussels on May 10-11, 2012.

During the Forum itself an interesting debate arose about the presented analysis and some suggestions were given, both by Green eMotion partners and External Stakeholders.

After the Forum some of the WP7 partners have also contributed to the preliminary gap analysis carried out, so that their points of views have been integrated in this report.

Therefore, in this Deliverable first the status of standards in the GeM Demonstration Projects will be updated, based on the most recent data available from the regions, i.e., from the Data Logging Report D1.2 issued by the Site Operation Manager IREC at the end of 2011.

Then the agreed analysis of the expected charging infrastructure evolution will be reported. Based on this, the preliminary gap analysis in the two cases of long and short distance travels will be documented and some related recommendations toward interoperability will be given.

Please note that much information regarding the status of standardization activities as well as the feedback from the different demo regions in the project can be found in D7.1 and D7.2. Information regarding technologies and standards related to electromobility is also clearly reported on those documents.

1 Updating of the review of technology and standards in the Demonstration Projects

For this preliminary analysis, T7.3 partners have managed the last report by IREC (D1.2, about Year1 Data logging), which collects and analyzes data up to end Dec. 2011 (Month 10).

Such data collection contains most recent data than the ones considered by WP7 in previous deliverables (in both D7.1 and D7.2).

The following analysis is focused onto European Interoperability for electromobility. For this reason, some items from D1.2 have not been taken into account, because of the lack of relationship with interoperability.

In a first step, notice that the information collected from the Demo Regions could be biased toward the main use of private company vehicles. Regarding the data collected in D1.2, just a 7,3% of the identified vehicles in the GeM project belongs to a private owner (individuals). Also, this kind of vehicle ownership appears just in one Demo Regions (IT1).

This analysis is also supported by the data about the vehicle use in the Demo Regions. Just a 16,2% of the vehicles in the Demo Regions has a private use.

The global analysis must take that into account. For this reason, the information showed in D1.2 could be not representative of the European situation in the future, but, anyway, the findings of the analysis will be a good initial overview of the technologies and standards linked to electro-mobility in Europe.

Additionally, another initial recommendation to bear in mind is to focus the analysis of the D1.2 data onto the “City or short distance travels” case study, better than onto the “Intercity – Interstates or long distance travels” case study. The data provided by WP1 will anyway allow also a more complete analysis, considering that several cities with different distances one among the others are present in the same Demo Region (DE2, Stuttgart and Karlsruhe (cities at 52 km); ES1, Barcelona and Malaga (cities at 770 km), ES2, Madrid and Ataun (Guipuzcoa) (cities at 420 km); DK1 and DK2, Bornholm and Copenhagen (cities at 160 km)).

Analyzing the data from D1.2, the focus of the Demo Regions on the short distance case is clear. Concerning the percentages of charging processes according to the charging point location, around 95% of the charging processes studied have been made in households and office parking (places associated to short distance travels). Coherently, concerning the percentages of consumed energy according to the charging point location, around 95% of the consumed energy has been consumed in households and office parking.

Taking these previous comments into account, additional findings could be extracted from D1.2 from the interoperability point of view.

Regarding the charging mode used by the Demo Regions (according to the IEC 61851-1 standard), at the current moment the report gives Mode 3 as the most implemented mode (up to 62.5% of the charging points use this charging mode), followed by Mode 2, supported by a 26.7% of charging points.

The most implemented type of connector in the charging points used within the GeM Demo Regions is Type 2 (according to the IEC 62196-2 standard). The rest of connectors types is almost negligible (Schuko: 5.7 %; Type 1: 4.7 %; Chademo: 0.2%). However, there is a 19.3%

of connectors in the Demo Regions (most of them in FR1 - 108 charging points - and 8 CP in IE1), which are not classified into the standard ones. The percentage is high enough as to modify the conclusions about this topic.

Referring to the proposed classification of the four power levels for charging (Low Power charge ~ 3 kW, Medium Power charge ~ 22 kW, High Power charge ~ 43 kW and Ultra High Power charge ~ 100 kW), and grouping the data from D1. 2, the most implemented charging points show a Medium Power charge (~ 22 kW) with a percentage of 55.5 %.

The following power level in percentage of implementation is the Low Power Charge (~3kW) with a 44.1%. The other possibilities are negligible.

2 Charging infrastructure: context and perspectives

2.1 Range and charging needs

The population living in urban areas is continuously increasing. 80% of Europeans live in large cities, the great majority of people move less than 20 km a day and 80% of daily trips made by cars in Europe are less than 60 km long[1]. For most of the urban missions, Internal Combustion Engine Vehicles [ICEVs] cannot compete with Battery Electric Vehicles [BEVs] [2]. For urban missions or more in general for short distance travels, city BEVs (650-1000kg), small BEVs (1000-1300kg) and mid-sized BEVs (1300-1500kg) need two-three full charges a week that can be satisfied in the great majority of cases by slow charge approaches.

Ranges above 300 km can be easily covered with mid-size vehicles having 20 kWh battery packs when the speed is kept very low or low, e.g. constant at 50 km/h; but that is not a realistic situation. Long distance travels are usually characterized by an average speed close to 100 km/h with peaks at more than 140 km/h and a range over 300 km. Adopting the current technology, BEVs cannot cover these missions in a single charge and are likely not to be able to be cost competitive with ICEVS for another decade. However, most drivers experience high speeds and long ranges only occasionally, and could accept one or two fast 20 minutes recharges during the same trip in those few days of the year they need to travel longer distances. The possible inconvenience they could experience in those days is largely justified by the great benefits obtained during the rest of the year. When sold with the quick charge option, BEVs could become the first and only car for many families (more of 7% of BEVs amongst the new car sales by 2020 is very likely)[3,4].

2.2 Charging technologies future prospects

Standards need to take future roadmaps and developments into account and be open for upgrades and changes in both the vehicle and the infrastructure sides. An agreed technology roadmap, with associated actions through directives and standards, would indeed avoid the spread of non-rational solutions and the waste of public funding.

In a 5 to 10 years perspective most technology roadmaps envision:

- 50% to 100% increase of the energy density of the battery cells;
- the engineering of robust battery packs sustaining 5000-10000 full depths of charge with minimal degradation;
- 10% to 15% selling price reduction per year;

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[1] Gonzalo Hennequet, Mass Production of EVs: The Technological Challenge of RENAULT, Auto e-motion conference, 27 September 2011, Graz, Austria

[2] Most large OEMs seem to be aware of the new demand proposing e-bikes, motorcycles and LEVs of various kind having no rivals amongst ICEVs. See the note on: *cars21.com.* Urban mobility: small, light and electric, the way to go! 2011-09-28

[3] http://www.cleanfleetreport.com/clean-fleet-articles/electric-car-forecast-us/

[4] http://www.ev.com/knowledge-center/electric-vehicles-articles/14-million-evs-on-roads-by-2017.html

- low cost single or three phases AC-AC adapters and AC-DC inverters.

More in general, it can be said that the evolution of charging technologies depends on:

- power electronics - the overall complexity related to the infrastructure;
- the efficiency and the rationale behind the choice of an approach instead of others - cost of the overall infrastructure as seen from public institutions and Governments
- costs of the final user, possibly seen from a wider view than that based on a single charger and single car analysis and considering also the impact on the on-board complexity.

2.3 Quick charging

A schematic overview of charging infrastructures and of their related use is shown in the following figure.

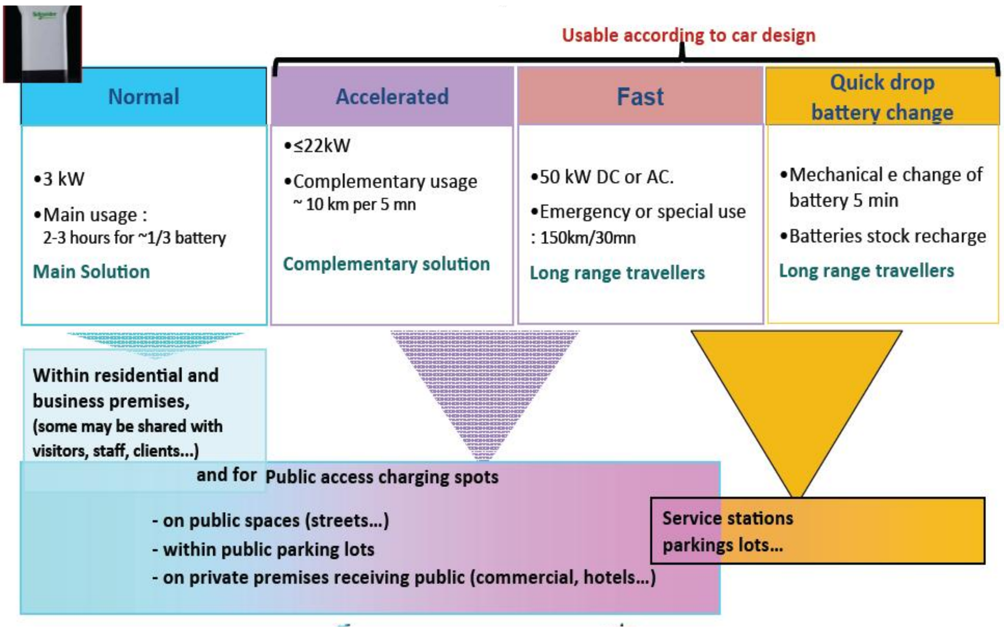

Figure 2-1: Types of Charging Infrastructures[5]

The two currently most sold BEVs (Nissan, Mitsubishi) allow both slow and quick charge. Both for commercial reasons and practical ones, quick charge cannot be considered an option. It is a need, not only for long distance travels, but also for vehicles purchased for urban or short travel missions. The availability of a quick charge infrastructure is now well acknowledged to influence

[5] Business markets around charging infrastructure, and their organization in view of a massive EV development, eRDF, EV Charging Infrastructure & Grid Integration, January, 2012, London

driver's behavior in terms of longer average distance travelled, reduced range anxiety and general improved feeling with electro-mobility. The figure below demonstrates the impact on drivers' charging behavior after the installation of only few quick chargers in an 8 km x 15 km highly populated area[6,7].

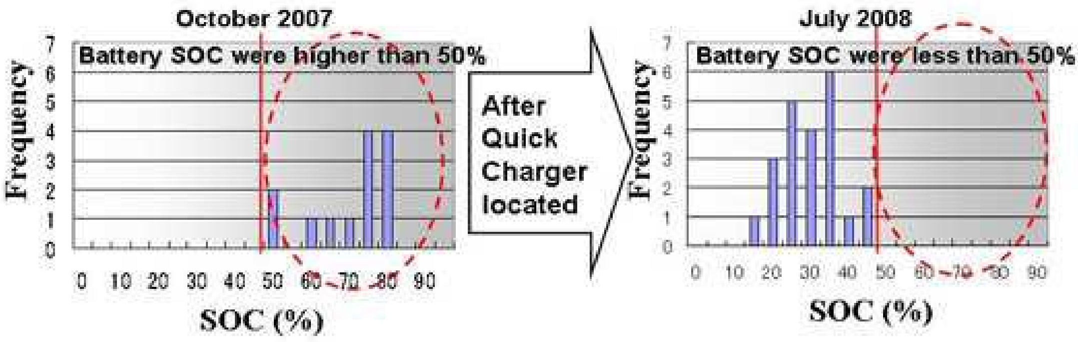

Figure 2-2: Difference in battery SOC at recharging before and after the introduction of quick chargers in Japan in 2007-2008

Quick-fast charging enhances business and consumer confidence in, and electric driving performance of, Plug-in Electric Vehicles [PEVs], making them increasingly attractive as a practical and reliable alternative to conventional vehicles.

The style of life imposed by modern society demands quick charge and in fact all forthcoming small and medium size vehicles incorporate it within their basic configuration. Before long, quick charge will become popular in city BEVs as well.

Also Plug-in hybrids could benefit from quick charging points. They are forecast at some 8-10% of the total car sales by 2020; they have a smaller battery pack (up to 16 kWh for serial hybrids), which is normally charged when travelling, by the on-board ICE. Charging Plug-in hybrids on highways, or more generally on long distance travels, is not such a critical issue, but when the driving mode is smartly managed (with ICE-off some kilometers before the charging point) there could be a considerable saving of gasoline. As PEVs (BEVs and Hybrids) popularity increases it is vital that fast/quick charging systems or either full or partial battery swap systems are incorporated into the standard infrastructure.

It has to be noticed that, whereas the different power levels for charging are universally recognized today (according to the already mentioned terminology: Low Power charge ~ 3kW, Medium Power charge ~ 22kW, High Power charge ~ 43kW and Ultra High Power charge ~ 100kW), no standard terminology exists (see Figure 2-3), not all vehicles are compatible with accelerated charging, and two different technologies (DC and AC) coexist for fast charging.

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[6] http://chademo.com/05_background.html
[7] See also**:** EV Charging Infrastructure Understanding Fast Charging, Verbund AG, EV Charging Infrastructure & Grid Integration, January, 2012, London: "*Public accessible fast charger serve as safety net for BEV drivers and show rather high acceptance and usage rates*".

Location	3 – 7kW	7– 22kW	22 – 50 kW	50 – 250kW
UK	Standard	Fast	Rapid	
Ireland	Standard	Public	Fast	
Japan	Home		Quick	
China	Standard		Fast	Quick
Other Suggested	Normal	Accelerated	Fast	Ultra fast
Eurelectric	Low Power	Medium Power	High Power	Ultra High Power

Figure 2-3: No Standard Terminology for the Charging Power Levels exists all around the world as well as all around Europe [8]

It has also to be reminded that quick charge stresses battery cells, limiting their lifetime and retained capacity; because of that, with the current state-of-the-art technology, quick charge is usually applied when the state of charge is in the range 30% to 80%, that is when the crystal structure of the electrodes is far away from the states of plastic deformation (permanent stress). Reservations remain about the long-term performance of Li-ion, however, commercial EVs are currently sold with battery packs covered by an eight-year/160,000 km warranty for a capacity at 80% of the design value **(**although a warning is given on the possible further reduction of the capacity when most charges are made by quick charge**).**The rapid evolution of battery technology pushes towards the planning of quick-fast charge infrastructures.

A further substantial reservation regards the impact of massive quick-fast charging on the grid. However, recent studies made in the Milano area have demonstrated that for quick charging stations directly connected to Medium Voltage MV lines or equipped with a 200 kWh buffer battery (and connected to the Low Voltage LV bus bar of a MV/LV substation), there will not be a substantial impact on the grid even if the 50% of the total passenger cars trips would be covered by electric vehicles. Besides, within the roadmap of quick charge technologies, it is possible to find economical solutions that can avoid the problem (see next paragraph). These technologies will rapidly spread in the forthcoming years.

2.4 The charger: open points

2.4.1 Charger and traction inverter

From a technology point of view, since the late 80's the on-board motor-inverter used for traction has been proposed as basic component of the on-board AC-DC charger, that is, motor and inverter serving two functions[9]. Although technically feasible, it can be noticed that cooling during a continuous fast charge is much more critical than cooling an electronic drive when the motor is operating continuously at its nominal power. Besides, the couple motor-inverter is not

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[8] Fast Charging in eCar Ireland Project, ESB eCar, EV Charging Infrastructure & Grid Integration, January, 2012, London

[9] http://www.acpropulsion.com/products-reductive.html

asked to comply with the strict grid requirements, that is, in any case a charger must be designed with very different criteria than the motor and its drive.

Nevertheless, innovations in power electronics[10] have recently led some European OEMs and charging infrastructure manufactures to pursue the 3 phase AC charge at 43 kW that:

- applies connectors and inlets already defined and published in the IEC 62196-2standard,
- avoids a considerable part of the extra cost of the powered on-board EV charger by replacing it with the existing inverter on EV used in the reverse mode too.

2.4.2 On/Off board charger (i.e. AC vs DC charging)

The dispute whether to allocate the needed power electronics on-board the vehicle or in the infrastructure began with the advent of the first EVs and it is likely not to end within this decade. It is a matter that goes well beyond a mere cost analysis in that it is dealing as well with level of complexity in the vehicle, global efficiency, overall vehicle reliability and related maintenance. The analysis can lead to opposite conclusions when made either from the vehicle's point of view or the grid's point of view; besides, the conclusions differ when considering a single vehicle or a fleet of vehicles. When investigating whether there are less expensive alternatives that could provide nearly equal benefits, the business models of the operators acting in the value chain can push in opposite directions.

Cost is in any case the most crucial aspect and in that regard the single point fast DC charger has a higher cost than the AC fast charger. However, supposing that the single point chargers serve the same number of vehicles, for instance from 12 to 20 a day, the overall balance cost would suggest DC fast charging. DC fast charging allows the lowest on-board complexity, as well as the lowest vehicle cost and vehicle maintenance, because it only needs a low cost DC-DC filter onboard.

When referring to slow charge, the current trend is to demand the vehicle to be equipped with an on-board AC-DC inverter that communicates with the on-board BMS. It is agreed that charging modes 1 and 2 are the bridge before mode 3 will become the unified EU solution (slow and fast charge by AC-DC on-board power electronics). At the same time a mode 4 fast and ultrafast DC charge is envisioned.

At present, the Japanese ChaDeMo protocol (included in ISO 61851 standard), is the most widespread DC quick charging solution in the market, However, it can be foreseen that AC and DC slow and fast charging will still compete for several years and because of that a solution could be a global envelop inlet-connector coupler allowing both AC and DC slow and fast charging. In this sense, according to the most likely present solution, the vehicles could be provided with an inlet Combo2 coupler, even if they would consider only slow and fast DC charging or only slow and fast AC charging.

Slow charging points with an AC output will remain the most popular for several years and the availability of single functions lower cost on board-chargers up to 6.6kW will further consolidate this position in that several users may feel satisfied enough.

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[10] Luis De Sousa, Valeo Powertrain, EPE 2011 Birmingham.

The advent of renewable installations with an integrated storage system, the maximum power level achievable, the global efficiency and on-board simplicity will by the other hand push for external chargers with a DC output (for both slow charge and fast charge). DC charging could so be more and more applied for both floor and wall boxes (home-private and public, slow and fast charge).

With the advancement of low cost and very compact power electronics, the possibility to easy develop external low power charging point chargers will contribute to a growing competition between AC-AC and AC-DC technologies.

The dispute will remain alive for several years and the introduction of standards that would encourage one solution rather than the other may limit the roll-out of electro-mobility.

2.4.3 Public/Private charging

With cost reduction of both AC and DC fast chargers characterized by quick and easy installation - using widely available 3 x 32 A input, smart & ultra-thin design, simple floor and wall-mount connections - we will most likely see privates (petrol stations, hotel parking, company parking, commercial and office areas, supermarkets and houses) buying them without having to become affiliated with the electric vehicle charging networks, which sometimes apply complicated pricing schemes. In synthesis the freedom to install and set each own system and rules will be aimed at.

From the final user's point of view, the cost of a recharge will remain a big issue for many years. In fact, since 95% to 97% of the time a car is parked at home or work, the most logical condition is to slow charge there whenever it is possible, thus limiting the cost only to the electricity. On the contrary, considering that the owner of a quick charging station on a highway will be willing to cover his investment as soon as possible with a profit plus remuneration for the service in terms of availability and efficiency of the charge spot, the maintenance of the parking lot, the assistance (if any) during charging, in case of quick charging the cost of the electricity will probably be only a small part of the total cost.

Considering that both AC and DC fast chargers could allow the method of slow charge as well, their evolution will lead to a potentially large impact on the future of EV infrastructure, both public and private. The spread of quick charging points in conventional petrol stations, hotels, supermarkets and company parking will push toward decreasing new installations of slow charging points in public areas (which could become an issue for most municipalities and mainly city centers). From the opposite perspective, if quick charge will induce higher costs to the final user, there will be a spread of both wireless and wired slow charging points with most users motivated to radically change their "refueling" habits.

2.5 Battery swapping

The battery swapping concept (sometimes referred as battery switching or battery quick drop) is another "range extender technology" seen to facilitate long distance quick and easy travelling. The battery swapping itself takes 5 minutes without overloading the battery during the charging process.

When the battery runs low while driving, drivers are directed to the closest battery swap station via a driver support system. The battery swap station automatically swaps the depleted battery for a full one in a matter of minutes, allowing drivers to quickly continue on their way.

As battery density increases the locations of the battery swap stations could change, but the need should be status quo, as more BEVs are expected to be running on roads within the time frame of 10 years. In that time frame it could be possible to store in the stations small batteries for daily use and larger batteries for long trips. In this way, each car will not need to be provided with a big battery to accommodate only a few percentage of the user's trips.

2.6 Wireless charging

Resonant wireless charging is another quite interesting technology in that it simplifies life to the final user, yielding at the same time an efficiency around 90% from the main to the battery (whereas plate to plate efficiency can reach 98%). The limitations on the maximum transmissible power and more specifically on power density are likely to restrict the use of wireless charging to slow charging[11]. The technology has been proposed to provide continuous charging on highways when the car is in motion[12], but the cost of the related infrastructure appears to be prohibitive. There is a general consensus to consider wireless charging a promising optional solution to be added to the conventional conductive one.

2.7 Smart charging

The energy requirements for electric vehicles will challenge the current power grid as plug-in vehicle number continues to grow very fast. The charging of EVs represents a significant additional load on the grid providing both risks and opportunities for service providers and consumers. At a minimum, consumers want to access to a ubiquitous charging infrastructure that enables them to charge their EVs safely and quickly at the cheapest possible rate.

Energy Service Providers want to be able to push charging to off-peak hours to protect grid assets. Additionally, value-added services such as demand response/load control, pricing, availability, locating and reserving charging stations, reverse energy flow, and charge management can provide further benefits. To obtain a truly smart grid that can accommodate EVs and maximize the services and the benefits that EVs can deliver, it is necessary that communication among the various involved entities will be properly enabled. There are various communication requirements for charging of EVs under different use cases (home, commercial, public) and metering options, each with different levels of complexity.

With both AC-AC and AC-DC fast charging, the Electric Vehicles should be able to receive and respond to charge instructions based on the grid condition and the vehicle's battery state. With visibility into charging patterns, energy providers will have the ability to more effectively manage

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[11] Standard proposal for Resonant Inductive Charging of Electric Vehicles. Sebastian Mathar et al, Advanced Microsystems for Automotive applications 2012, pag.57-68, Springer edition, AMMA conference May 30-31, 2012, Berlin.

[12] Wireless Charging: The future of Electric car. Andrew Gilbert, Advanced Microsystems for Automotive applications 2012, pag 49-56, Springer edition, AMMA conference May 30-31, 2012, Berlin.

charging during peak hours. Adding a layer of agility (intelligence) to the PEV charging process will help make charging seamless for consumers, while ensuring the electricity source is reliable and the infrastructure is stable. Combining grid and vehicle data (cloud based software platform) allows creating an individualized charging plan for BEVs batteries. By utilizing in-vehicle communications system, the electric vehicle can interact with utilities and with the grid, creating a direct channel for sending and receiving usage information that could improve local grid managemen[13]t.

A database EV platform could moreover collect historical EV charging data and create a profile that can be used to monitor and forecast the location and duration of EV charge loads. For example, it could be possible to determine how many EVs are plugged in one neighborhood and the time it will take for each to reach a full charge. This can allow utilities to optimize grid operations and help reduce the chance of outages - a possible concern as the number of EVs increases.

2.8 Communication and IT aspects

IT mobility platforms installed either in the vehicle or at the infrastructure end, comprise entire software platforms that are useful for different stakeholders, e.g. consumers, utilities, car sharing operators etc., effectively unifying them in one portal. Simplified, four areas feed into the platform:

- EV consumer services: charging station access and location, state of charge, smart charging,
- EV back-end services: grid load monitoring, forecasting, billing, V2G,
- connected vehicle services: real-time traffic, dynamic POI, Internet radio, social networking, live TV, diagnostics etc,
- multimodal transport services: car-sharing reservation and location, multimodal transport reminders, etc,

These platforms can offer mobile access via the smartphone and use multiple technologies to satisfy customer needs.

The most important areas for IT companies are demand management and forecasting, which will allow catering for smart-charging during off-peak times.

Several aspects have to be taken into account:

- Roaming and billing: the challenge is to integrate all data for billing purposes, consider cross-border charging and roaming type agreements, feeding all information into one overall billing system;
- Predictive analytics and demand forecasting: IT companies must work with utilities to provide them with predictive analytics and forecasting software that monitor the number

[13] Detailed information on local grid management can be found in Green eMotion's Deliverable D4.2 Recommendations on grid-supporting opportunities of EVs

of devices plugged in the grid and the power consumption so that demand can be managed effectively;

- Smart charging: companies have started to offer home management systems that provide smart charging options for EVs.
- Energy Storage and Management (V2G): once EVs become mainstream beyond 2015, and since they are parked for 90%+ of the time, they can act as energy storage devices which can be used to extract energy during peak hours and charge during off peak hours

OEMs are willing to create their own cloud-based mobility platforms in order to allow:

- Communication between the smart center and the driver related to battery charge, plugging-in reminders etc.;
- Remote diagnostics, unscheduled maintenance alerts, scheduled maintenance task;
- Communication among the car, the OEM and the dealers.

The standalone direct AC-DC quick charge procedure, which is currently the most deployed fast charge method, will lead, together with the AC-AC quick charge one, EVs, charging stations, grid operators and OEMs to move towards a higher and higher level of cloud based mobility platforms.
Public charging has different communication requirements including the need to quickly and easily locate, price compare, and reserve charging stations on the fly. Additional complexities are also introduced due to the need to authenticate, authorize, and bill the user (especially when crossing over different service territories), though it could be easily managed by RFID pre-paid or post-paid systems.

Because of that complexity, it can be said that the direct AC-DC and AC-AC quick-fast charge procedures in the near term could suffer a serious competition because of the introduction of low cost and scalable battery storage modules, which offer minimal features and, more precisely, minimal dependency from the network of interested operators.

2.9 Charging interfaces standards

The evolution is leading to a single charging interface at the vehicle allowing to charge with all existing charging methods: one-phase AC-charging, three-phase fast AC-charging, slow DC-charging and ultra-fast DC-charging.

The relevant standards in this field are the following:

Existing standards:

- **IEC/EN 61851-1 ed.2 2011-04**: Electric vehicle conductive charging system -Part 1: General requirements;
- **IEC/EN 62196-1 ed.2 2011-08**: Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements;
- **IEC/EN 62196-2 ed.1 2011-10**: Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for A.C. pin and contact-tube accessories.

- **SAE J2293:** Energy Transfer System for Electric Vehicles
- **ISO/IEC 15118-1 Ed.1**: Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition;
- **ISO/IEC 15118-2 Ed.1** Road vehicles — Vehicle to Grid Communication Interface — Part 2: Technical protocol description and Open Systems Interconnections (OSI) layer requirements; (pending just ballot, to be officially published on 2014)
- **ISO/IEC 15118-3 Ed.1** Road Vehicles — Vehicle to grid communication interface — Part 3: Physical layer and Data Link layer requirements; (pending just ballot, to be officially published on 2014)

Standards under Review:

- **IEC 61851-21**: Electric vehicle conductive charging system - Part 21: Electric vehicle requirements for conductive connection to an AC-DC supply;
- **IEC 61851-22**: Electric vehicle conductive charging system - Part 22: AC electric vehicle charging station.

Work in Progress:

- ISO/NP 15118-4 Network and application protocol conformance test
- ISO/NP 15118-5 Physical layer and data link layer conformance test
- ISO/AWI 15118-6 General information and use-case definition for wireless communication
- ISO/AWI 15118-7 Network and application protocol requirements for wireless communication
- ISO/AWI 15118-8 Physical layer and data link layer requirements forwireless communication
- **IEC 61851-23 Ed.1**: Electric vehicles conductive charging system - Part 23: DC Electric vehicle charging station;
- **IEC 61439-7 Ed.1** Low-voltage switchgear and control gear assemblies - Part 7: Assemblies for specific installations at public sites such as marinas, camping sites, market squares and similar applications and for charging stations for Electrical Vehicles;
- **HD 60364-7-722** Requirements for special installations or locations – Supply of Electric vehicle.
- **SAE J2847-3**: Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow)

With the advent of DC quick charging, the need to harmonize AC connectors would become less of an issue[14]. On the contrary, once sufficient infrastructure is in place, it may prove difficult to switch connector types, so **the harmonization effort for DC connectors is considered a gap to address in the near-term**.

[14] ANSI Standardization Roadmap for Electric Vehicles – Version 1.0 (April 2012)

3 Gap analysis

In the previous section we have provided an overview of the current situation and trends in the EV sector, and it has quite clearly emerged how and why the infrastructures for both short and long travels are expected to develop with quick charging technologies equipped either with an AC solution or with a DC one (according to IEC 61851-1 Standard: Electric vehicle conductive charging system - Part 1: General requirements).

The costs of infrastructure technology and installation, as well as EV costs**,** need to be minimized to bring the overall EV system life cycle cost in line with that of conventional vehicles. Costs will remain a critical issue before EVs will be produced in large scale like conventional vehicles.

As already mentioned in the Introduction of this document, two different approaches can be followed: a “top-down” approach based on the Marketplace vision and on “smart grid, smart chargers, smart vehicles, smart operators, smart OEMs…” interacting in a cloud based environment, and a “bottom-up approach” based on simpler feasible selected solutions. The first approach is characterized by a high overall complexity and related high costs for the driver and during workshops it arose how it will represent a reference both in the long term and in this phase of EVs rollout, but also that it could be made optional and not mandatory in the short term.

The bottom-up approach, indeed, with its gradual introduction of comprehensive, clear, and forwardly insightful standards and codes, could reduce the immediate risks and uncertainties for technology developers and can encourage competition facilitating new market entrants and private sector investments.

In the following paragraphs we analyze the infrastructure alternatives that are capable to allow interoperability for charging when travelling across Europe, trying to follow a quite practical and immediate approach and focusing on two different case studies, for long and short distance travels.

3.1 Case study: InterCity - Interstates or long distance travels

Long travels (most time associated to higher speeds) are usually run on highways or roads with restricted access such as city rings. It is universally recognized that with existing battery technologies only fast charging or battery swapping allows for an adequate range extension of BEVs.

3.1.1 Quick charging infrastructure

The most logical and economical recharge infrastructure is based on the installation of quick charging stations within the currently available petrol-service areas. There are no essential differences amongst EU Member States. Electro-mobility will be shared with conventional fuel based mobility for many years to come and petrol stations, which are more and more becoming service stations or rest stations, will not surely diminish in this decade.

Petrol - service areas are:

- Located where they are needed;
- Largely distributed all across Europe;
- Under control of an operator during the working hours, whether they are on highways or in cities or in small town (minimal risk of vandalism);
- Mostly video or personnel controlled at night;
- Served by an AC high power line. Most petrol stations are already supplied by a power line of several tenths kW and many of them are located in the vicinity (few hundred meters) of medium voltage power line[15]. Whether necessary, they can be upgraded to higher powers delivery with a minimal cost of the infrastructure or, for instance, adding battery storage modules;
- Provided of large parking places suitable to park enough cars for the fast charging scenarios and to install photovoltaic or small wind power generators;
- Well mapped on all automotive or personal device navigators (digitally easy to find). There is no need for a big change, set-up new maps or introduce new actors but only to update the existing maps,

The minimal approach is to add quick charging points to those stations already operating on gasoline, diesel and natural gas. A single charging station can be provided with several charging points outlet ports-conducting cables-connectors, so that several cars can be charged in parallel. Some safety criteria should be applied to avoid unsafe procedures. Considering that the pumps serving compressed natural gas are located at a safe distance (typically more than 30m) from the pumps serving gasoline-diesel, a similar criteria could be applied to charging stations.

The payment method might be carried out using cash during the working hours and by credit cards and by RFID authentication card related to an energy supplier/service provider contract in the other daily or night hours. When implementing a minimal feature solution we should consider that everywhere in the world people are used to pay directly by cash, by credit cards, pre-paid cards, post-paid cards, debit cards. With that, there is no need to change habits or introduce new standards. The same credit card reader can be used to manage the payment of gasoline, diesel, natural gas and charging (some countries have restrictions regarding sells of electricity, although selling a charging for a fix price will most likely be available through out Europe 27).

To provide an example, in the UK a network of AC-DC rapid charge points located in motorways service stations has been initiated to enable electric vehicle owners to drive the length of the

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G.Mauri, A.Valsecchi "*The role of fast charging stations for electric vehicles in the integration and optimization of distribution grid with renewable energy sources.*" CIRED Workshop - Paper – 227, Lisbon 29-30 May 2012.

country. The system is built based on the concept of “pay-as-you-go”, as opposed to subscription-based. Drivers only need to pay for the energy they need for their EVs[16]. The approach is then similar to the one people are used with conventional fuel based cars.

It can be noticed that in some nations the payment is allowed through an RFID embedded on a personal device (cellular phone) and this approach is likely to spread all across EU in few years. With respect to the charging stations available on highways, this will anyway not introduce any substantial changes.

As said, also battery swap stations could be an interesting solution. They could be installed along the main highway system where the need for energy is the most relevant and where the accessibility of the right grid supply is available.

A specific standard that sets the rules to install charging points and battery swap systems is urgently needed. Many existing and under development standards should be taken into account:

- **IEC 60364-4**: Low Voltage Electrical Installation;
- **EN60079-10**: Explosive Atmospheres, Classification of areas;
- **EN50014**: Electrical Apparatus for potentially explosive atmospheres. General Requirement;
- **EN50018**: Electrical Apparatus for potentially explosive atmospheres. Flameproof enclosure;
- **ISO/IEC 29123**: Identification Cards - Proximity Cards - Requirements for the enhancement of interoperability
- **ISO/IEC 14443**: Identification cards - Contactless integrated circuit cards

Work in Progress:

- **IEC 60364-7-722**: Low voltage electrical installations - Part 7-722: Requirements for special installations or locations - Supply of Electric vehicle;
- **IEC 61439-7**: Low-voltage switchgear and control gear assemblies - Part 7: Assemblies for specific installations at public sites for charging station for Electrical Vehicles.

3.1.2 Interoperability requirements

When studying the gaps to deploy a fully interoperable quick charge infrastructure across Europe to allow long distance travels, the key is the interface vehicle to charging point. Both for the vehicle and the charging point it is possible to define a set of requirements that would ensure the correct and effective operation of the charging process.

[16] UK first rapid charging network allows EVs to cross the whole country. EV21, 08 June 2012

Vehicle side

- **Battery management:** all battery types require some degree of management to optimize performance. In particular, Lithium Ion batteries are relatively expensive and do not tolerate abuse, so management is essential. Besides, the larger the pack, the greater the need for management.

  The Battery Management Systems "BMS" on the vehicle and the on-board or off-board charger must so communicate because the battery must be charged with a precise (I,V) profile function, which depends on:

  - Architecture chosen by the OEM (serial and parallel connection of the cells) with typical DC link ranging from 96V for some city cars to above 400V for larger vehicles
  - Temperature
  - SoC, State of Charge
  - SoH, State of Health (age)

  In the ideal interoperability context the BMS is a universal device designed to communicate with the quick charger supporting: Analog, Can (CAN2.0A, B and CAN Open, from 125 kbit/s up to 1 Mbit/s bus speed), PLC and PWM interfaces with an extensive library of chargers supported.

  Involved standards:

  - **SAE J2847-1**: Communication Between Plug-in Vehicles and the Utility Grid;

  Work in Progress:

  - **SAE J2847-2**: Communication between Plug-in Vehicles and Off-Board DC Charger;
  - ISO/IEC 15118-1 Ed.1: Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition;
  - ISO/IEC 15118-2 Ed.1 Road vehicles — Vehicle to Grid Communication Interface — Part 2: Technical protocol description and Open Systems Interconnections (OSI) layer requirements; (pending just ballot, to be officially published on 2014)
  - ISO/IEC 15118-3 Ed.1 Road Vehicles — Vehicle to grid communication interface — Part 3: Physical layer and Data Link layer requirements; (pending just ballot, to be officially published on 2014)
  - DIN 70121: Electromobility – Digital communication between d.c. EV charging station and an EV for control of d.c. charging in the CCS.
  - **IEC 61851-24**: Electric vehicles conductive charging system - Part 24: Control communication protocol between off-board DC charger and electric vehicle.
  - **ISO/IEC/PAS 16898**: Dimensions and markings of secondary lithium-ion cells for vehicle propulsion).

- **Connector**: a combined charging system that gives EV owners the ability to charge at most existing charging stations regardless of the individual power source is needed. This should integrate one-phase AC-charging, fast three-phase AC-charging, DC-charging at home and ultra-fast DC-charging at public stations into one vehicle inlet.

  The International Society of Automotive Engineers (SAE) has chosen the Combined Charging System (shown in Fig. 3.2) as the fast-charging methodology for a standard that incrementally extends the existing Type 1 - based AC charging. ACEA, the European association of vehicle manufacturers, has also selected the Combined Charging System with the type 2/combo plug as its AC/DC charging interface for all new vehicle types in Europe beginning in 2017. This universal charging interface is going to be adopted by Audi, BMW, Chrysler, Daimler, Ford, GM, Porsche and Volkswagen.

  Involved standards:

  - **SAE J1772**: Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler;

  Work in Progress:

  - **IEC 62196-3** Dimensional compatibility and interchangeability requirements for pin and contact-tube couplers with rated operating voltage up to 1.000 V d.c. and rated current up to 400 A, and rated operating voltage up to 690 V a.c. and rated current up to 250 A, for combined a.c./d.c.charging.

Figure 3-1: Global envelope Combo2 coupler[17]

[17] Final Report of the Focus Group on European Electro-Mobility (June 2011)

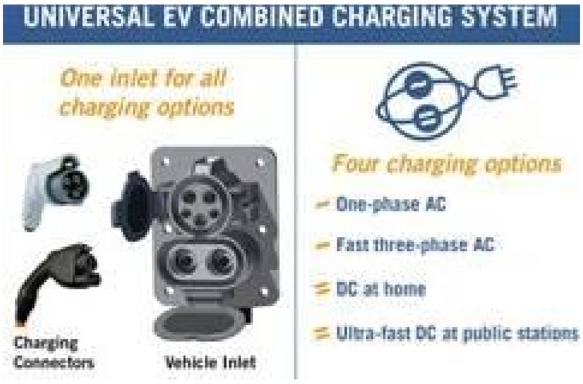

Figure 3-2: Combined Charging System chosen by SAE

Charging side

- **Communication**: similarly to what already said for the vehicle side, in the ideal interoperability context, the quick-fast charger module is a universal device that should be able to communicate with the on-board BMS via Analog, CAN, PWM, PLC interfaces (note: the CCS only refers to the ISO/IEC 15118 charging protocol solutions using PLC communications). An AC quick charger should adapt the PWM signal according to the availability of the grid during the recharge process and, through inputs of the BMS coupled with the on-board converting electronics, it should be able to tune the (I,V) loading curve accordingly. Actually, since ISO/IEC 15118 also applies to AC charging this requirement can be considered covered.
- **Variable output**: a DC quick charger should consider a variable DC output [50V, 500V] to satisfy the request of all type of vehicles adopting different DC battery links.
  The DC quick charger should be capable to deliver an (I,V) output curve as demanded by the on board BMS. Then it should be equipped with a library of charging procedures and (I,V) functions.
- **Plug**: quick charger socket outlet conducting cable.
- **Metering**: provided with an energy meter (each charging point within a charging station has to be provided with its own meter like for conventional petrol pumps).

3.1.3 Existing quick charging equipment

Several quick charging modes and power supply types are currently under considerations. A schematic visual overview is reported in *Figure 3-3*.

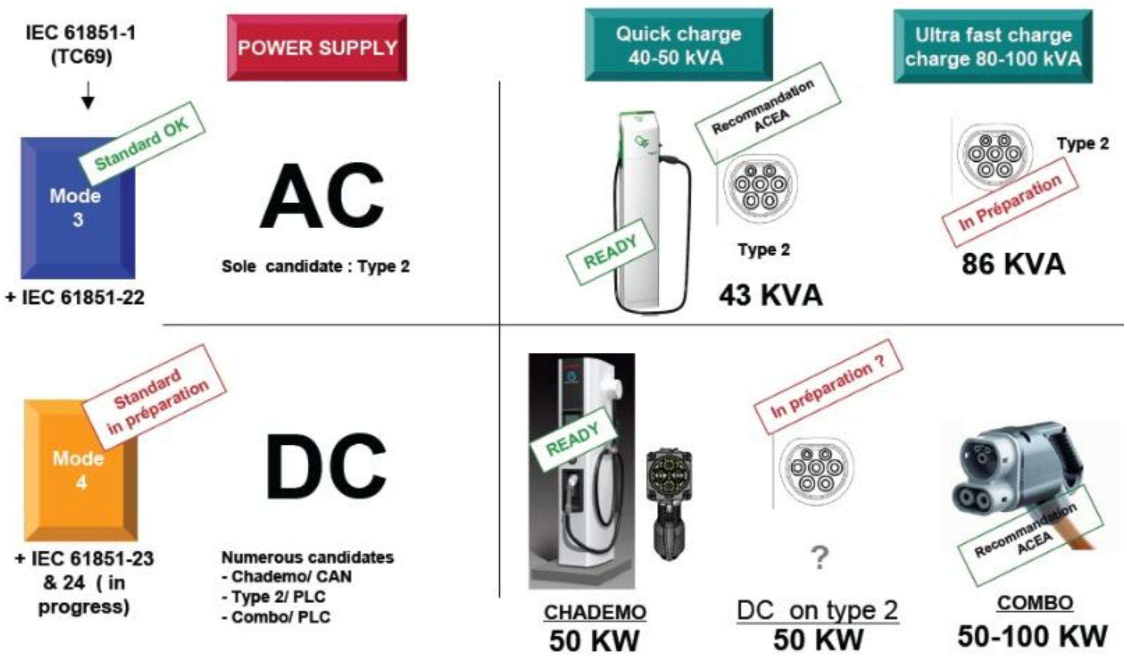

Figure 3-3: Quick Charge Charging Modes and Power Supply Types[18].

3.1.3.1 Three phases AC-AC charging point (mode 3)

- **Grid**: 3 Phase 16-32-63 A, 480 V up to 43 kW per each car or each independent charging point
- **Infrastructure**: It consists of a module of a variable three phase current output. The charging of several cars in parallel can be managed by the EVSE Operator backend system with a smart grid approach, avoiding critical issues for the grid. The infrastructure equipment is provided with a system that modulates the PWM signal according to the availability of the grid managed by the EVSE backend system. It is also provided with protection systems that are used to monitor ground connections or insulation of the charging circuit from the user. These systems monitor the infrastructure device as well as the vehicle through the conductive connection and the communication protocol ISO/IEC 15118, if any. The protection systems provide a smart control for the charging function and shutdown the infrastructure equipment in the event of a loss of the protective elements associated with that system of protection (ground or insulation).
- **Vehicle**: All of the power equipment, i.e. the AC-DC rectifier and power factor control as well as DC-DC current regulator, is located on the vehicle (mode 3). It requires liquid

[18] Solutions For Safely Harmonizing EV Charging Infrastructure To Deliver Interoperability Across Europe, Renault, EV Charging Infrastructure & Grid Integration, January, 2012, London

cooling when the rating powers are above 5 kW. On-board systems and controls are required to maintain the proper charge path such that AC voltages are not applied to the battery vehicle connector and vehicle inlet combination. Vehicle connector and vehicle inlet combination have the function to provide a conducting path and to assist the infrastructure equipment with safety checks, communication, and other aspects associated with safe recharging of the vehicle.

- **Communication and interfaces:** The protocol between BMS and on-board charger is provided by the OEM. A protocol between the on-board AC-DC inverter-charger and the external AC charger is the new standard ISO/IEC 15118; a sort of preliminary version of this protocol has been experienced since 2010 by Daimler, Enel and RWE.

Note: As already mentioned in section 2.4.1., when motor and inverter are used for traction only, each car needs to be equipped with extra expensive, volumetric, heavy and liquid cooled on-board inverter components. At a rate above 6.6 kW the AC-AC does not seem the most rationale and viable cost effective quick charge route, although Renault Zoe currently available for purchasing is equipped with a 43 kW charger on board. With the increasing numbers of EVs, the major issue will be to assure power quality with on-board AC-DC inverters-chargers. When motor and inverter are designed to be part of the charger system there is a considerable cost reduction of the on-board electronics but with associated drawbacks. An effective global cost-efficiency-maintenance saving related to the manufacturing of the motor and its drive serving as well as a charger needs to be demonstrated at large.

GAPS

- **Power Quality**: the increasing number of electric vehicles charging at slow charge has caused concern over their combined effects on the power quality and reliability of electric utility grids. Power Quality Requirements (e.g. harmonics emission) for chargers are needed in terms of requirements together with more stringent test procedures, to avoid possible problems arising from resonance phenomena appearing when several EVs are connected at the same point as reported in Green eMotion deliverable D4.2. “Recommendation on grid-supporting opportunities of EVs”

RECCOMENDATIONS

- Promote studies to evaluate the e-cars impact on the network .Promote the development of procedures to certify the efficiency of the adopted procedure of charging.

3.1.3.2 Three phases AC-DC charging point (mode 4)

- **Grid**: 3 Phase AC inputs 230 V, 480 V loaded up to 50 kW per each car or each independent charging point (with new requests above 100 kW). When two cars would be plugged in, the fast charger's 50 kW draw on the grid would be doubled to 100 kW if both cars were fast-charged at once; but although at a first glance the grid would appear to suffers the spikes, the simulations made for the Milano area [19]seem to demonstrate that the impact on the grid is negligible. When quick charge stations are directly connected to MV lines or when equipped with a 200 kWh buffer battery and connected to the LV bus bar of a MV/LV substation, even in the case 50% of the missions would be covered by electric vehicles, the grid will react well. More specific shared test is anyway needed.

- **Infrastructure**: It consists of a module of high DC variable voltage-current output. In controlled current charging, the insulating transformer and all the power equipment are located in the charging station. The quick charger can be used also as a slow charger and the charging of several cars in parallel is not so critical. The complexity of this AC-DC station leads to a much higher cost than an AC-AC fast charging station; on the other side, when considering a fleet of cars, the global added electronic cost in the cars having the on-board charger, when taken all together, is much higher than the added cost of the DC charging point.
- **Vehicle**: It does not require an in-vehicle inverter as the charger output is directly connected to the battery while controlled by the on-board BMS (although a safety filter is used to protect the battery). In the so called constant voltage the current to the battery is regulated on-board (preferred).
- **Communication and interfaces:** A smart and universal connection between BMS and quick charger is already available in DIN 70121, ISO/IEC 15118 and Chademo standards.

Note: A portfolio of fast chargers and multi-port base stations to be used along highways and offering a 15-30 minute “charge and go” service are rapidly spreading in Japan, USA and Europe. The ChaDeMo protocol, currently included in ISO 61851 standard, is largely the most applied, principally because of the push due to the Japanese OEMs and because of the lack of ready to use alternatives until the last year. AC-DC is globally more efficient than the AC-AC. The ChaDeMo is not the only possible AC-DC protocol nor should it be considered the a priori best fast DC charging method. In this direction a comparison with other fast DC charging methodologies should be encouraged[20]. The high peak power requirement of very fast charging can stress the local power grid and might increase the risk of power brown-or black-outs during peak demand if enough vehicles choose to charge at these times.

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[19] G.Mauri, A.Valsecchi, E.Fasciolo, S.Fratti “*Impact of fast Charging on MV e LV networks: scenario 2030 for the urban area of Milan*”, Convegno Nazionale AEIT, Rome - 12, 13 June, 2012 and G. Mauri, A. Valsecchi “*Fast charging stations for electric vehicle: the impact on the mv distribution grids of the Milan metropolitan area*” IEEE ENERGYCON 2012, Florence, 9-12 September 2012

[20] Martin Marz, Batteries and Smart Battery Management, presentation made at the PCIM Europe 2012 Conference Nuernmberg, 10 May 2012.

GAPS

- **Communications interoperability**: Communications interoperability is a critical component of a smart grid. In that direction within WPs 5 and 7 GeM proposes the contents of the interfaces for connection to the services, clearing house and Load Management. In particular, WP7 has been working in a New Work Item Proposal on the communication between EVSE and the backend systems..It has to be considered that due to the number of actors involved and services being offered, as well as the plethora of communications technologies in service, it is critical to standardize these communications as much as possible to provide ease of entry into the market, while also allowing widespread and consistent charging capabilities to drivers without adversely impacting the grid.

RECCOMENDATIONS

- Use charge plans and flexible tariff models, which permits to create economic incentives for vehicles charging during off-peak times. It will also allow the DSO to provide charge schedules to the EV according to the available energy.
- Promote the combination of the direct AC-DC vehicle to grid connection together with the use of energy storage devices with on-site renewable energy generators.
  - PromoteCombined Charging Systems as possible alternatives to the ChaDeMo protocol but considering that in the first phase multi-standard (CCS/AC/CHAdeMO) quick charging stations are the most viable and practical solutions. It has to be noticed, in this sense, that by joining the Green eMotion project, different OEMs have worked together on EV quick charging infrastructure and come up with a practical multi-standard solution for the investors across Europe.

3.1.3.3 Grid to battery storage modules, Three-phase AC-DC input in battery, DC output

- **Grid**: Scalable, easy to manage constant loads, no need for high peaks. This fast-charge solution does not involve fluctuations in the power and it is then very unlikely it could be a trouble for the local distribution network operator. There is no need for a smart grid, but it could help stabilizing a smart grid.
- **Infrastructure**: It consists of a modular network system of battery pack sub-modules having an AC-DC inverter in input and a high DC variable voltage-current in output. It allows the charging of several cars in parallel (each requiring 50 kW or above) without inconvenience to the grid.
- **Vehicle**: It does not require an in-vehicle inverter because the charger is directly connected to the battery, while controlled by the on-board BMS.
- **Communication and interfaces**: A smart and universal connection between BMS and quick charger is needed.

Note: To use an energy storage system bridges the gap between the charging station demand and the power grid. There is no need for high smartness in the grid. The energy storage system suffers some efficiency drop and thus trades lower overall system efficiency in favour of higher peak demand capacity. The presence of the battery storage implies in particular 7% to 10% higher losses than in a typical AC-DC direct connection. Battery modules can be charged off-peak and used to charge vehicles directly. It is a quickly emerging technology with an ideal figure of merit in terms of scalability, cost, ease of installation, independency from grid and other operators, good performance. It is not commercially available with a smart energy management. It is typically implemented with high power Li-ion rechargeable battery although alternative technologies such as flow batteries, liquid metal batteries and sodium-sulfur batteries could also be inexpensive to implement on a large scale[21].

GAPS

- **Need to define procedures and general criteria to install larger battery modules in petrol stations**. Certain DC loads could be connected to a DC power distribution system which would then be connected to the electric power system using a single converter. There is a need to develop standards for VDC power distribution systems. It is not possible to directly connect an EV to a facility DC power bus because of differences between the EV battery voltage and the facility bus voltage. There is the need to precisely control the charging current into the EV battery and it can be easily done using a DC to DC converter, such as a buck-boost converter. It is important to develop requirements for high voltage DC power distribution systems and for the integration of distributed energy resources and DC loads with the system. A DC-DC EVSE could easily be used if the facility uses a DC power distribution system.

RECOMMENDATIONS

- Battery modules should be addressed to include power sources up to 600 volts DC.
- Pursue the development of efficient Power electronics to reduce the conversion inefficiency.
- Promote the technology to integrate-complement the direct AC-DC connection whenever it is possible.

3.1.3.4 Low voltage Photovoltaic DC - battery storage - to high voltage DC (similar for wind)

- **Grid:** usually off-grid until the battery module is full (the conventional DC-AC PV grid connection will remain in place until fed-in tariffs will be available).
- **Infrastructure**: scalable PV modules, scalable network of battery modules.
- **Vehicle:** it does not require an in-vehicle inverter in that the charger is directly connected to the battery while controlled by the on-board BMS,
- **Communication and interfaces**: A protocol between BMS and quick charger is needed.

Note: It is the most efficient use of renewable energy in that there is no need for a double DC-AC and AC-DC grid conversion (the efficiency of the grid and of the battery are comparable). It is a quickly emerging technology, which could be a recommendable complement to AC-AC, AC-DC standalone installations, and other AC-DC battery storage modules. It has the great

[21] https://www.appalachianpower.com/

advantage to be installed either on-grid or autarkic (off-grid) and it can be of interest for homes, hotel parking, rural areas and special users operating under emergency when all other lines are non-operating. Commercial solutions are available and amongst the emerging technologies DC-DC quick chargers appear particularly interesting because they do not necessarily require grid connection. With the rapid spread of renewable energies and with the forthcoming radical reductions of the fed-in tariffs, modular photovoltaic installations with an integrated battery pack are likely to become very popular. Amongst the techniques for quick charging, this technology is potentially:

- o Economic and gradually implementable in relation to the growing demand;
- o Efficient;
- o Easy to install;
- o Not impacting the grid.

GAPS

- **Proper standards**: both solar and small wind installations are subject to existing standards for PV and wind equipment. There is a need to adapt these existing standards to the case of petrol stations, in particular when battery packs are large and voltages are high.

RECOMMENDATIONS

- Include DC voltages up to 600 volts.
- Promote the implementation of modular approaches and related technologies.

3.1.4 Battery swapping

As already mentioned in section 2.5, an alternative approach to addressing the range extension issue is via a network of battery swapping stations. A battery swapping station is an electro-mechanical installation of robotics, electrical and mechanical drives used for the swapping of batteries for electric vehicles and that may include battery charging devices and telecommunication ports.

In 2007 Better Place promotes the solution of replace a depleted battery with a fully charged one in less than 5 minutes. The fully automated process removes the battery from the vehicle and moves it to a battery rack, so the battery can be charged in optimal conditions. A fully charged battery is then taken from the battery rack and inserted into the vehicle.
Better Place's business model was based on car owners paying a fee according to the number of miles they drive. The per-distance fees would have covered battery pack leasing, charging and swap infrastructure, cost of electricity, the revenue of investment and all the battery problems would have been handled by Better Place.

Where the battery swapping station can recharge the battery to a 100 % capacity in those 5 minutes, DC charging will do 0-80% in 20-30 minutes.
The scenarios show that the ability of managing swapping, storing, cooling and charging of batteries reduces the impact on the grid significantly (although the impact in any case does not seem to be relevant). This, however, does not mean that battery swapping should be prioritized

over fast chargers. They serve two distinct needs; fast chargers in city/urban locations for a "boost charging", just enough to cover range needed to get to e.g. the home charger. Battery swapping may be intended for longer trips, and the stations are often located by highway exits or other strategic sites for servicing customers on intercity travels. The question is whether a car designed and equipped with battery swapping should be equipped with electronic to allow as well conventional slow and fast charging.

Interoperability requires that all OEMs would accept the manufacturing of vehicles with the option of full battery swaps. Denmark is the first country within EU where the battery swap stations have been deployed. The deployment is made at the main highways with a distance of approx. 60 km from each other based on traffic simulations commercial needs. This has been done to ensure the maximum service level for long distance travelers.
After having installed battery switch stations in Denmark and in Israel, in May 2013 Better Place filed for bankruptcy due to high investment required to develop charging and swapping infrastructure and a market penetration significantly lower than originally predicted.
After two failed post-bankruptcy acquisition attempts, in December 2013 the assets were sold to Grngy, an Israeli energy company founded in 2008. .

GAPS AND RECOMMENDATIONS

- Petrol stations, which are typically privately owned, are not expected to install quite expensive swapping stations by their own. Amongst the quick charging methodologies, this one is the most engaging in terms of upfront cost of the infrastructure, standardization of components, infrastructure and vehicle design, thus making interoperability at Members States quite difficult. There is a need for international battery swapping standards addressing safety, energy needs, exchangeability, ready access, data and communication framework[22].

3.1.5 Wireless charging (Inducting or magnetic resonance)

Wireless charging is an emerging technology with increasing knowledge and a lot of research underway. Little experience is actually known at higher than 15 kW powers. The communication to be established in between the BMS-the on-board converter-charger and the external module is been addressed by ISO/IEC 15118. It is a relatively easy to deploy infrastructure for slow charge solutions and because of that it is attracting lots of interests. However, for quick charging it would require an expensive and bulky on-board converter and because of that does not seem to be a viable short term cost effective quick charge solution (like per the AC-AC). Wireless technology has been proposed to provide continuous charging on highways when the car in motion[23] but global efficiency would suffer a lot besides the cost of the related infrastructure appears to be prohibitive. It seems difficult to standardize emitters and on-board receivers capable to handle both low and high powers for all emerging wireless technologies.

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[22] http://publicaa.ansi.org/sites/apdl/evsp/ANSI_EVSP_Roadmap_April_2012.pdf; page 71
[23] Wireless Charging: The future of Electric car. Andrew Gilbert, Advanced Microsystems for Automotive applications 2012, pag 49-56, Springer edition, AMMA conference May 30-31, 2012, Berlin.

Involved standards:

DKE GAK 353.0.1: Berührungsloses Laden von Elektrofahrzeugen; Work in Progress:

IEC 61980: Electric vehicle wireless power transfer systems;

SAE J2847-6: Wireless Charging Communication between Plug-in Electric Vehicles and the Utility Grid;

SAE J2931-6: Digital Communication for Wireless Charging Plug-In Vehicles;

SAE J2954: Wireless Charging of EV & PHEV).

ISO/IEC 15118: Road vehicles — Vehicle to grid communication interface

GAPS:

- **EMC safety at high powers**. Research is underway at high powers. Each vehicle has to be equipped with an expensive on-board module conversion. Interoperability would require that all actors Member States, OEMs and charging stations owners would accept to adopt the same technology.

RECOMMENDATIONS:
There is no evidence that wireless charging could become the minimal feature implementation for an easy and low cost to deploy interoperable charge infrastructure for long distance travels.

3.2 Case study: City or short distance travels

This case study refers to the most common use of passenger cars, i.e. in cities or for short distance travels. It focuses into differences with the case study "InterCity - Interstates or long distance travels", since most statements, options and solutions are valid for short as well as long distance travels.

Several studies[24,23] seem to confirm the following:

- Public accessible fast chargers serve as safety net for BEV drivers and show rather high acceptance and usage rates also inside the cities (the most logical public location of fast chargers is in or around the city petrol-service stations).
- Public charging points should primarily support fast charging since slow charging is often not fast enough.
- All users need a dedicated charging point at home for charging during the night.
- Charging at start and end points of main trips (from home to work and back) defines the scope of usability of BEVs.
- Energy optimisation and management scenarios tend to assume a higher rate of connected EVs during the day and higher power levels.

[24] EV Charging Infrastructure Understanding Fast Charging Verbund AG, EV Charging Infrastructure & Grid Integration, January, 2012, London:

3.2.1 Typical use and charging needs

Technology evolution is such that from the charging point of view the distinction between short and long distance travels will be progressively less and less evident.
The most significant difference with the long distance travel case is that in short distances the EV user wants to charge on different types of locations, not only in public, but mostly at home/private/work. A typical situation of EVs use is represented in Figure 3-4 and Figure 3-5.

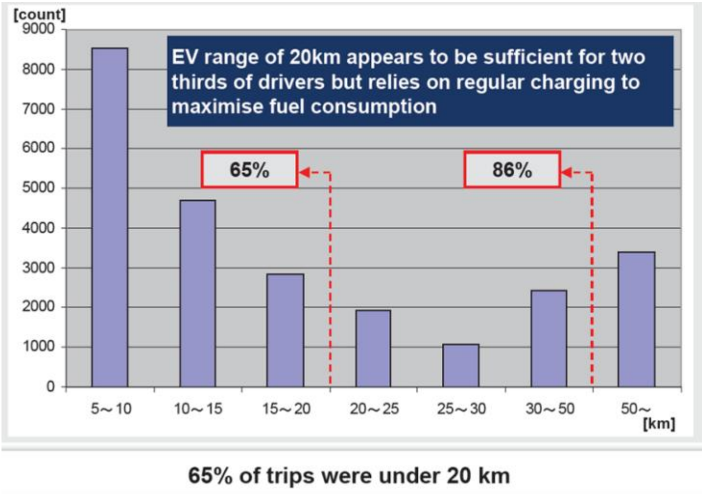

Figure 3-4: Distribution of Trip Distance[25]

[25] Toyota's Perspective on EV Charging Infrastructure & Grid Integration, Toyota, EV Charging Infrastructure & Grid Integration, January, 2012, London

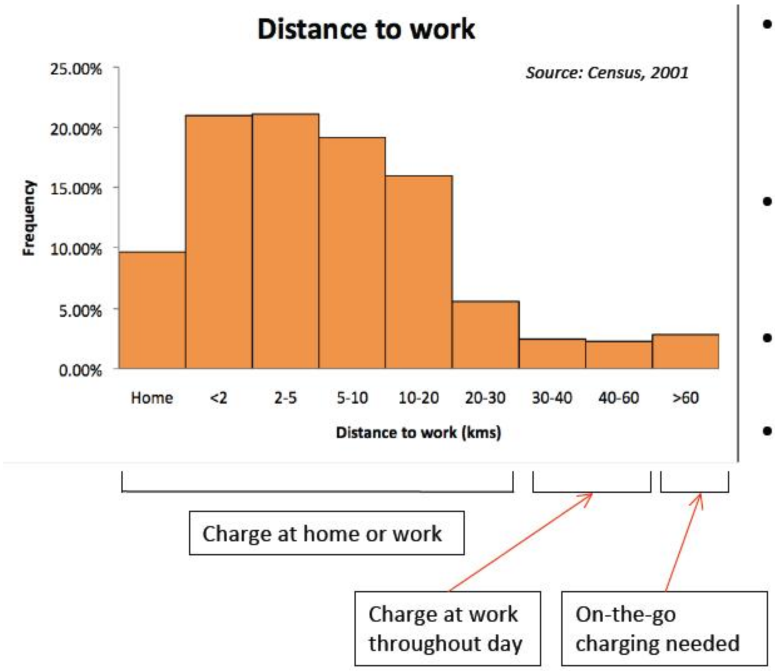

Figure 3-5: Distance to Work[26]

3.2.2 Charging stations required features

The case is quite different from the quick charging stations within the petrol-service stations as discussed in the long distance travel case. A payment infrastructure is available at petrol-service stations but not at most private/work or public locations. Since the energy amounts and its costs are relatively low, a credit card reader and printer are often too expensive. That is one of the main reasons why most charging systems will in this case require an EV user to have an identification that can be linked to a contract with an EVSP (EV Service Provider).

Let's consider a simple use case that could represent the Short Distance Travel case:

- Beginning: Car fully charged (and still connected to home charger)
- Disconnect EV, and drive to work
- Connect EV to charger at work
- Disconnect EV, and drive to city center
- Park at public parking place
- Connect EV to charger at public parking place
- Disconnect EV, and drive home
- Connect EV to charger at home

[26] Predicting EV Charging Patterns & locating public infrastructure, Aston University, EV Charging Infrastructure & Grid Integration, January, 2012, London

Let's assume the driver wants to charge and connect at all locations to keep his battery charged. This is a natural habit due to the current range anxiety even in short distances since there can always be unplanned longer trips. Then, this simplified case already reveals some different requirements per charge location:

- At home, payment is not needed since this connection is part of the user premises. In case the user has no private parking place the solution is to use a public charge spot;
- At work, the charging spots probably require at least identification to access; it could be free of charge if the employer is willing to pay the electricity, but in most cases the use of the charging infrastructure needs to be paid;
- At a public parking place, identification is required. Another simpler (pre-paid card) form of payment could be considered, but these do not enable other services as being mentioned next.

Besides these location type differences, there are other differences with respect to the quick charging stations:

- shorter travels means less urgent energy requirements, so also more flexibility available for smart charging (as well at home, at work and on public charging points). This implies the need of more communication with the grid, as also shown in the next figure on communication and smart grid.
- less energy means that the amounts to be paid are much smaller and at more (public) places so an efficient payment infrastructure is required.

These two points are even enforced when the flexibility of the EV will be used for grid services, so that in some cases the EV owner needs to be financially rewarded and compensated for his willingness to delay the charge (or, in the future, even accept a discharge by means of V2G).

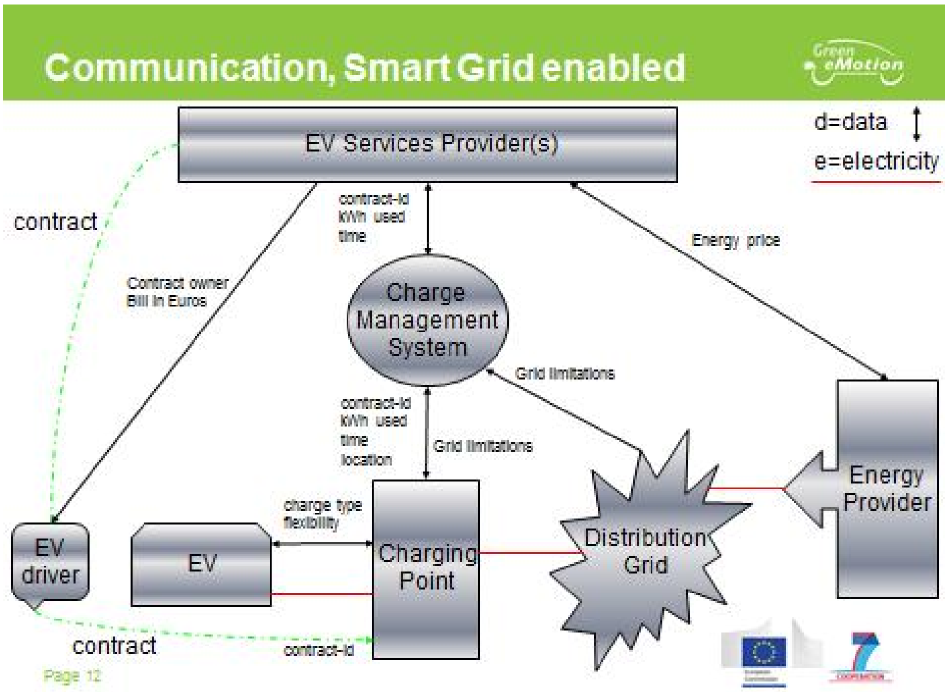

Figure 3-6: Communication, Smart Grid enabled for the short distance case

3.2.3 Slow AC charging point

Let's now address, for this short distance case, the same elements as done in the previous chapters:

Grid: For short distance case, fast charging is not required. We expect a grid connection between 3 and 10 kW (single or 3 phase).

Infrastructure: The charging points need to be able to communicate with a Charge Management System to exchange and verify the contract ID, and optionally to take grid limitations into account.

Vehicle: At first instance, no new requirements seem to be needed here, but some pilots already showed that flexibility available for smart charging is defined in a different way from the grid perspective than from the BMS system in the EV. Furthermore the user needs to be involved in defining input for flexibility. This requires preferably a standard user interface and standard simple parameters to fill in (this has already been covered by ISO/IEC 15118 after its approval).

Communication: Standardization and interoperability required as sketched in the picture above. In a Dutch case (http://e-laad.nl/), for example, they have agreed a protocol between CMS and Charging Points in order (as municipality) to be able to switch from CMS vendor while being able to reuse the installed hardware as Charging Points.

GAPS

It can be said that, while in the previously described "highway quick charging station" the interaction among the different involved actors could be considered quite low (no particular complexity on billing or identification, not much possibility for smart charging, etc), in the case of city charging there are several aspects that must be taken into account.

It is exactly on all these aspects, including identification, authorization, billing, interoperability, and so on, that Green eMotion is actively working. In particular, also in this same WP7 a survey on issues with EV standards have been carried on. Besides the generic plug/connectors standardization for physical interoperability, the wider part of the other emerged issues applies especially for the short distance case:

- Communications/standardization on protocols: required for exchange for identification and for smart charging. Currently eMI3 (a working group trying to harmonize the ICT data definitions, formats, interfaces, and exchange mechanisms in order to enable a common language among all ICT platforms for Electric Vehicles) is working in these protocols. Also, Better Place approved a New Work Item Proposal in IEC on these fields.
- User identification/authentication: standard mechanism and (physical) interface is required, but also privacy needs to be taken into account for user acceptability.
- Pan-European charging standard: especially in near border and for long travels in multiple countries a Pan-European standards is required to prevent that a system only works in a certain area/country or city.
- Payment interoperability on a business level: can the payments in one area easily be exchanged with the contract of EV users in another (their) home areas
- Interoperability and roaming: partly overlapping with the topics before. But more specifically addresses the roaming requirement from users and service providers. This is also identified as a gap by the ANSI: "Gap: Charging of Roaming EVs between EVSPs. There is a need to permit roaming EVs to charge at spots affiliated with a different EVSP"
  (see also: ANSI Standardization Roadmap for EVs Version 1.0 April 2012).

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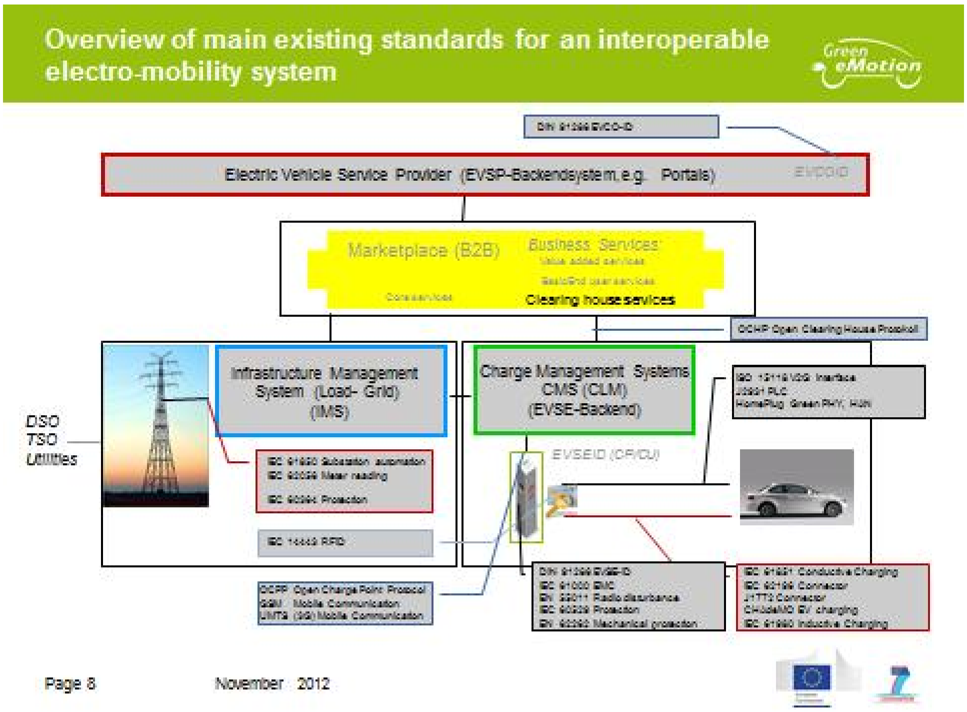

Figure 3-7: Possible communication standards

RECOMMENDATIONS

- The definition of a few use cases/scenarios and associated data and interactions that enable all involved stakeholders and parties to test their part of the system stand-alone and later in combination with the total system. This action was originally covered within WP3 of green eMotion and has been tranferred into eMI3 for further progress.
- Define a minimal set of standards to be used in communication. Create a list of (detailed) issues to be solved and solutions or standards that can help in the solution.

4 Summary and preliminary conclusions

4.1 Long distance travels

The implementation of an infrastructure with minimal features but still capable of allowing large interoperability all across Europe is based on the installation of quick charging stations within the currently available petrol-service stations. There are no essential differences amongst the EU Member States.

A specific standard that sets the rules to install quick-fast charging points is urgently needed.

The currently most used methods are both AC-DC, which demands a level of communication vehicle-charger-grid, and AC-AC 22kW combined with the incoming AC-AC 43kW.

The mass market introduction of PEVs is proceeding very fast. All gaps and recommendations discussed in this analysis should be addressed in the short term.

The introduction of low cost battery modules will reduce the problems related to load peaks and will increase the flexibility at the charging station where, with a minimal cost, several vehicles can be quickly charged in parallel thus eliminating the need to reserve the turn to recharge, but also future peak shaving and smart grid functionality needs to be taken into consideration. Because these systems are modular the expense of installation can increase with the growing demand thus reducing the upfront cost of the needed infrastructure. Until 2020 for the vast majority of charging stations the load on the grid can be limited to a continuous 20-24hours low-medium power of 25-30kW that, when complemented by a storage module of 100kWh, can meet the demand of 25% of the kilometers currently run in the Milano area. There is no real need to introduce new payment or billing standards in this case: a simple contract between the grid operator and the petrol station owner could solve the matter in those countries in which selling electricity is not subjected to limitations, since the EV user can pay as he is used to do." The increased demand of power would not be much higher (if it is) than the typical power already needed in a service station.

When addressing solutions based on some form of energy storage the smartness is related to the vehicle and the charger rather than to the grid.

The introduction of complementary PV battery modules or small wind towers is an option to recommend and motivate all across Europe.

Keeping in mind that the dispute AC versus DC slow and fast charge will continue for at least another decade, further technological recommendations are to promote the development of:

- Universal quick charger modules that should be able to communicate with the on-board BMS via Analog or PLC, CAN or PWM interfaces.
- AC quick chargers 22kW and 43kW are able to manage the PWM according the availability of the grid and the communication with the EV through ISO/IEC 15118 protocol,

The recently approved ISO/IEC 15118 have already covered the technical recommendations on:

- DC quick chargers having variable DC outputs [50V, 500V] to satisfy the request of all type of vehicles adopting different DC battery links,
- DC quick chargers capable to deliver an (I,V) output curve as demanded by the on-board BMS.
- A charging interface on the quick charger allowing to charge with slow DC-charging and ultra-fast DC-charging.

Concerning the different technological areas the following recommendations can be made after the analysis carried out:
Vehicle/Charging Point: While promoting the adoption of multistandard chargers (CCS/AC/CHAdeMO) in the short period, study and develop a single charging interface, like the already available combo 2 plug, allowing to charge with all existing charging methods: one-phase AC-charging, three-phase fast AC-charging, slow DC-charging and ultra-fast DC-charging. Promote the use of universal BMS devices designed to communicate with the quick charger supporting: Analog, PLC, Can (CAN2.0A, B and CAN Open, from 125kbit/s up to 1Mbit/s bus speed) and PWM interfaces with an extensive library of chargers supported. This communication is already covered by ISO/IEC 15118.

Communication: Promote the use of universal devices designed to communicate supporting Analog or PLC, Can (CAN2.0A, B and CAN Open, from 125kbit/s up to 1Mbit/s bus speed) and PWM interfaces with an extensive libraries on both sides vehicle and external charger (SAE J2931-1: Digital Communications for Plug-in Electric Vehicles; **Work in Progress**: ISO/IEC 15118 Series: Vehicle to grid Communication Interface (already approved and pending only ballot); SAE J2931-3: PLC Communication for Plug-in Electric Vehicles; SAE J2931-5Telematics Smart Grid Communications between Customers, Plug-In Electric Vehicles (PEV), Energy Service Providers (ESP) and Home Area Networks (HAN); SAE J2931-7: Security for Plug-In Electric Vehicle communications; SAE 2953: Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)). Due to the large number of communication possibilities we recommend using the recently approved ISO/IEC 15118 as communication interfaces with a defined but upgradable data model for the datum that is communicated.

There is a need to subsidize or promote the introduction of quick-fast charge stations along highways in petrol stations. On the contrary it will be very unlikely that petrol station owners will make the installation spontaneously before the market has grown.

For long distance travels along highways or city rings there is a need for properly trained personnel for the installation and maintenance of these fast charging stations. Essentially the rational implementation of a long travel interoperable infrastructure requires that highways and city rings owners-managers be part of the system.

4.2 Short distance travels

The most important existing standards as well as the recommended standards to be agreed or developed for the "near future" short distance travels are summarized in the next Table. The Table has been jointly filled in by CIDAUT and Endesa experts and refers to the situation in Spain. However, it can be also extrapolated to Europe, where the average situation is quite similar.

Location		Power nomination	Mains connection
Domestic	Household	Normal power	1-Phase AC connection
Semi-Public	Office Parking Fleet Parking	Medium power	1- or 3-phase AC connection
Public	Public Access Parking	High power	3-phase AC connection or DC connection
	Shopping Mall		
	Street		
	Petrol Service Station		

Figure 4-1: Classification of Charging Points, attending to their characteristics[27].

	Location		Mains connection	Plug	Charging Mode	Communic. EV - CP	Communic. CP - GRID	GeM (Spain)
Conductive Charging	HouseHold	Domestic	1-Phase AC connection	Schuko	Mode 1 / Mode 2	Not Applicable	Not Applicable	0.0%
		E-mobility dedicated	1- or 3-phase AC connection	Type 1 / Type 2	Mode 2 / Mode 3	IEC 61851-1 ISO/IEC 15118	Not Applicable	0.0%
	Semi-Public		1- or 3-phase AC connection	Shucko / Type 1 / Type 2	Mode 1 / Mode 2 / Mode 3	IEC 61851-1 ISO/IEC 15119	Not Required	98.4%
	Public		3-phase AC connection	Type 2	Mode 3	IEC 61851-1 ISO/IEC 15120	Authorisation	1.6%
			DC connection	CHADEMO	Mode 4	CHADEMO	IEC 61850-7-420	
Swapping Batteries			Not Applicable					0.0%
Inductive Charging								0.0%

Figure 4-2: Description of today's situation. Main existing standards (Spain).

	Location		Mains connection	Plug	Charging Mode	Communic. EV - CP	Communic. CP - GRID
Conductive Charging	HouseHold	Domestic	1-Phase AC connection	Schuko (only for Bike and Scooter)	Mode 2 / Mode 3	Not Applicable	
		E-mobility dedicated	1- or 3-phase AC connection	Single Plug (Type 2)	Mode 3	IEC 61851-1 ISO/IEC 15118	IEC 61850-7-420
	Semi-Public		1- or 3-phase AC connection	Single Plug (Type 2)	Mode 3	IEC 61851-1 ISO/IEC 15118	IEC 61850-7-420
	Public		3-phase AC connection	Single Plug (Type 2)	Mode 3	IEC 61851-1 ISO/IEC 15118	IEC 61850-7-420
			DC connection	Single Plug (combo AC/DC)	Mode 4	IEC 61851-24 ISO/IEC 15118	IEC 61850-7-420
Swapping Batteries			Not Applicable				
Inductive Charging			IEC 61980				

Figure 4-3: Recommended standards, for near future short distance travels in Spain, aligned with the Eurolectric recommendations for mass market deployment[28].

The main gaps toward interoperability highlighted by WP7, in documents D7.2 Monitoring and managing the collection of standardization issues and needs, and in D7.3 Gap analysis of current status of technologies and standards, those are the following:

- Communications/standardization on protocols: required for exchange for identification and for smart charging. Although currently, Identification is covered by the Better Place NWIP, by EVCOID EVSE ID in ISO/IEC 15118, Plug and Charge in ISO/IEC 15118.

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[27] [27]Facilitating e-mobility: EURELECTRIC views on charging infrastructure. EURELECTRIC Position Paper. March 2012.

Backend communication protocols must be aware that there is a need to transfer identification information and charge plans for smart charging. This is being considered in backend communication protocol workgroup 5 on eMI3.

- User identification/authentication: standard mechanism and (physical) interface is required, but also privacy needs to be taken into account for user acceptability.. This is an ongoing task from WP3 and WP7 that has been managed together with eMI3 in the form of a New Work Item Proposal for the standardization bodies it is explained in D7.5 Green eMotion actions to raise awareness on the standardization bodies and to promote standards.
- Pan-European charging standard: especially in near border and for long travels in multiple countries a Pan-European standards is required to prevent that a system only works in a certain area/country or city.
- Payment interoperability on a business level: can the payments in one area easily be exchanged with the contract of EV users in another (their) home areas. This is one of the main ideas beyond Green eMotion, the clearing house systems ad defined in WP3 of this project.
- Interoperability and roaming: partly overlapping with the topics before. But more specifically addresses the roaming requirement from users and service providers. This is also identified as a gap by the ANSI: “Gap: Charging of Roaming EVs between EVSPs. There is a need to permit roaming EVs to charge at spots affiliated with a different EVSP”. This Gap is being addressed by Green eMotion WP3 by defining a marketplace with a clearing house, this tool is being developed and will be tested during the project lifetime
- Due to the number of actors involved and services being offered, as well as the plethora of communications technologies in service, it is critical to standardize these communications as much as possible to provide ease of entry into the market while also allowing widespread and consistent charging capabilities to drivers without adversely impacting the grid. Communications interoperability is a critical component of a smart grid this issue is being addressed by WP3 and WP7 together with eMI3 and it will be detailed in D7.5 Green eMotion actions to raise awareness on the standardization bodies and to promote standards..

Some main preliminary recommendations can be given to overcome such gaps:

- To define a few use cases/scenarios and associated data and interactions that enables all involved stakeholders and parties to test their part of the system stand-alone and later in combination with the total system. The project has already performed this, the information has been included in D3.3 Services use cases & requirements description: Description of use cases and requirements of initial high value Marketplace Services to be demonstrated in first release following the ICT reference architecture and business analysis and D3.4 Services use cases & requirements description 2: Description of use cases and requirements of initial high value Marketplace Services to be demonstrated in the second release following the ICT reference architecture and business analysis. This is another of the gaps that is being addressed within eMI3 as a recommendation raising from GeM.
- To define a minimal set of standards to be used in communication. Create a list of (detailed) issues to be solved and solutions or standards that can help in the solution. This list was created in Task 7.5, together with WP3 and eMI3, the minimal contents of communication between EVSE and the backend systems have been included in a draft

New Work Item Proposal for the standardization bodies, as explained in D7.5 Green eMotion actions to raise awareness on the standardization bodies and to promote standards.