INNOVATION OUTLOOK – TRANSPORT SERIES

EV-smart grid integration
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*Keywords: intelligent transport systems, ITS, electric vehicle; EV; smart grid; EV-grid integration*
Executive Summary

The integration of electric vehicles with the energy system allows the use of vehicle batteries as a big distributed storage to balance the generation- and load-fluctuation. Batteries can charge power when renewable energies are present in the grid and feed it back into the grid later. Furthermore, electric vehicles help the energy industry to optimise the load management of their grids.

The market deployment of electric vehicles (EV) needs the preliminary preparation of the product environment. It is essential to upgrade electricity networks, install public charging stations and offer electricity charging services for EV users. The imminent EV market share growth implies commercial and technical challenges. The electricity grid will suffer from the impact of EV stock growth. To minimise negative consequences, it is crucial to prepare the integration of EV to grid. Automatic charging, connected charging, vehicle to infrastructure and vehicle to grid are some of the existing or planned solutions. All of these solutions in which ICT is integrated to transport is what we call intelligent transport systems (ITS).

Intelligent transport systems are marketed differently depending on the transport mode and sector specificities. The potential of ITS in the integration of EV in smart grids seem to be strong. In some European countries, ITS products concerning EV-grid integration are already available in the market. Nevertheless, their adoption is at an early stage of market penetration. Market trends show an active environment in which new partnerships are being set up, such as between electricity utilities and EV service providers.

In conclusion, ITS represent a high potential of opportunities for ICT companies. Alliances with traditional transport sector stakeholders are a viable strategy for improving the deployment of ITS. This integration is only possible if the technological, legal, and organisational environments are prepared prior to the general adoption of innovative ITS in the market.
EV-grid market

Market information

Since the beginning of the 20th century, with the arrival of the internal combustion engine (ICE) car and after countless attempts to revive it, electric vehicles (EV) seemed to be condemned to remain a museum piece. However, in the last decade, car manufacturers appeared to be determined to reintroduce the EV in the car market. Some of them took a prudential path, developing hybrid electric vehicles (HEV) while others preferred to take a chance launching 100% battery electric vehicles (BEV). Simultaneously, to encourage the acquisition of these vehicles, some governments implemented policies that aimed at removing market entry barriers. As a consequence, there is a progressive increment in the acquisition of these non-ICE vehicles in the European Union since 2004 (see Figure 1).

Even though the number of EV is nowadays increasing rapidly, not all of them are capable of being integrated into the grid. In order to ensure this integration, it is necessary to fulfil two requirements: one from the vehicle point of view and another from the grid side. Concerning EV, not all of them are capable of being plugged to the electricity grid, only PHEV, BEV and REEV. Concerning the grid, in Europe, most of them are capable of performing a basic management of the vehicle charging process through the installation of a specific battery charger.

As stated above, there are five main categories of electricity powered vehicles: BEV, REEV, HEV, PHEV and FCEV. For this application, only BEV, REEV and PHEV can be integrated to the grid in order to manage the charging and discharging process, using batteries as an energy storage system.

Currently most hybrid vehicles are HEV, not capable of loading batteries through the grid. Nevertheless, car manufacturers are gradually replacing all HEV models by new PHEV models, which can be plugged to the grid. Due to this technological tendency, PHEV will be available on the market in a few years only.
To have a better understanding of market evolution, Figure 2 shows the evolution of the battery electric and hybrid vehicle stock in the last decade for each country of the European T-TRANS project consortium (France, Germany, Greece, Italy, Latvia, Netherland and Spain) and the UK (considered as a non-negligible country for the European car market), as they currently cumulate nearly 60% of new car registrations in EU-27 (International Council on Clean Transportation ICCT, 2012). As stated, there has been an intense growth in BEV and HEV sales in the last decade after the launch of new models in the market. In Europe, for the countries studied, sales began to grow from 2003, with Germany leading the car stock, until 2008, when the Netherlands started having the higher stock of electricity powered passenger cars. The UK, being a non-negligible country for this market, has the highest EV stock in Europe (see Figure 2).

All these battery and hybrid vehicles represent the current size of the market for this study, even though most of them are not capable of being integrated into the electricity grid, as they are HEV and not PHEV or BEV. However, this figure gives us an idea of the market’s potential size for the new hybrid generations (PHEV), which are gradually replacing non-pluggable hybrids. The EV market share is still very small considering that only 0.7% of passenger cars sold in the EU in 2011 were hybrids and 0.07% were battery EV (International Council on Clean Transportation ICCT, 2012). However, this small share has presented a sustained growth rate for the last 5 years and pluggable hybrid technologies already available on the market allow the integration of such vehicles into the grid (see Figure 3).

Figure 2: BEV, HEV and PHEV passenger car stock evolution until 2012 by country. Data obtained from (International Council on Clean Transportation ICCT, 2013)

Figure 3: passenger pluggable EV stock by country (BEV and PHEV, with HEV not included). Adapted from (International Council on Clean Transportation ICCT, 2012) and from (Electric Vehicle Initiative EVI, 2013)
Smart grid penetration

The capacity of using electric vehicle batteries as a distributed storage system to balance generation and load fluctuation depends not only on the connectivity of the car and charger, but also on the capacity of the grid to manage charging and discharging processes. This capacity of the grid can be improved by having access to information about the local status of the grid, which is usually obtained from smart meters. That is why the “smartness” of the grid is measured by smart meter penetration. Thus, some countries in the EU began improving the “smartness” of the grid by installing smart meters, which aim at improving the local and regional management of the electricity grid (see Figure 4).

As presented in Figure 4 and Figure 5, Italy and Sweden lead the European Union in terms of smart meter penetration. Consequently, in these countries the grid operator can take more advantage of the integration of the EV and the grid, as it better knows the local status and needs of the grid and it has the capacity of performing local management.

Even if the smartness of the grid is measured through smart meter penetration, EV battery is loaded through chargers, which can actually manage the charging process regardless of smart meter penetration. Nevertheless, availability of information concerning the grid (provided by smart meters) allows an optimisation of the EV loading process, by taking into account the needs and limitations of the local grid. The efforts of local authorities and stakeholders to integrate EV into the grid can thus be measured by the penetration of EV chargers (Figure 6).
Public charging stations

The ideal number of chargers suggested by experts is one public charger and one private charger per EV on the road. These figures are being approached by Italy and Spain, countries where there are between 0.8 and 0.9 chargers per pluggable vehicle in circulation. On the other side, France has about 10 pluggable EV on the road for each public charger installed. The main reason for this is the rapid growth of EV stock in 2012 (Figure 3).

![Figure 6: Non-residential (public) charging stations installed in the country per registered pluggable EV (BEV, PHEV and FCEV) in 2012. (Electric Vehicle Initiative EVI, 2013).](image)

Market trends

Experts in the sector agree on the following market trends:

- EV market share is increasing due to new models availability and acquisition policies.
- HEV models are being replaced by pluggable PHEV models, which are integrable to the grid.
- EV autonomy is increasing, having a positive impact on the integration of EV to the grid, as battery loading management tends to have less impact for increasing autonomies.
- One-stop-shopping offers proposed by EV manufacturers include EV, battery renting, wall box installation, electricity supply and access to public charging infrastructure.
- EV-grid integration is in a premature state of market deployment. There are very few charging management services on the market due to the low EV penetration.
- Most of the already installed public charging stations can be remotely operated (on-off functions) and some of them can perform discharging (V2G). However, these functions are not implemented due to the low EV stock. Implementation of V2G and V2I is limited to pilots.
- Programmed charging is available on the market. In some cases, the charge can start automatically taking into account electricity tariffs.
- Governments are promoting policies to stimulate EV acquisition and use.
- DSO are interested in avoiding massive investment for improving the grid power capacity and consider eluding grid overload through EV loading management. In addition, EV introduces a new challenge in the sector: the mobility of consumption.
Market trends show that there is a slow but sustained growth in the battery and hybrid car market share in the last decade. The amount of these cars has already reached 1% and is continuing to increase. Two factors could explain this behaviour: the availability of new models in the market and the creation of policies that stimulate the non-ICE car acquisition.

Regarding the availability of new models in the market, 5 years ago it was almost impossible to find a BEV or hybrid vehicle in a car dealer. Today the situation has changed as almost every car manufacturer offers several models of electricity powered vehicle, especially BVE and hybrids (both HEV and PHEV).

Matching the market launch of new PHEV and BEV models, governments decided to set up new policies to encourage their acquisition. In some countries, such as France, these policies have had a strong impact on EV sales. The most important are presented in the following section “country profile” and based on (European Automobile Manufacturers’ Association ACEA, 2013).

Regarding the integration of such vehicles with the electricity grid, the mass of “integrable” vehicles (BEV, REEV and PHEV) have not yet reached a critical amount to justify the operation of battery charging management systems. Nevertheless, most of the carmakers offer one-stop-shopping in which customers buy a BEV or PHEV that includes battery renting, wall box installation, electricity supply and public EV charging stations access. Complementary services such as remote access to vehicle information (e.g. SOC, charging station parking booking) are being offered to customers separately. At this moment, no service for battery discharging is available on the European market, as the current technological environment does not allow it. Even though some public chargers installed are capable of performing EV discharging, most of the EV models are not able to do so and the grid is not always capable of inverting the electricity flow.

On the other hand, smart grid deployment is promoted by authorities, often taking into account electric vehicle integration. The most important European projects are the following (see Figure 7):

- ADDRESS (Active distribution network with full integration of demand and distributed energy resources): Test with 400 customers and € 16M budget.
- GREEN e-MOTION: 9 electric mobility demonstration project with € 24.4M budget.
- ECOGRID: project involving 28,000 residential customers and 300 large customers, with 56MW of renewable generation and € 21M budget.
- GRID4EU: R&D pilot with 6 demonstration sites and € 54M budget.
Market barriers and incentives

Technological factors

The most relevant technological barriers affecting the integration of EV to grid have been overcome during the last years. Current charging infrastructure and electricity grids are capable of managing the EV loading process, performing such integration EV-grid. Some of the remaining technical barriers are related to EV production cost, autonomy, battery charging efficiency, battery discharging and reversed electricity flow capacity of the grid:

- **Vehicle cost**: With current technologies, plug-in hybrids and battery EVs are still expensive compared to an equivalent ICE car. This is due to battery cost.
- **Autonomy**: Technology does not meet users’ needs, as BEV autonomy is limited to circa 100km. Thus, public charging (conceived to mitigate autonomy limitation through fast charging) may not be compatible with EV loading management goals (to charge taking into account local grid requirements and needs).
- **Discharging process**: EV-grid integration is limited by the impossibility of discharging batteries. This is impracticable with some of the current grid infrastructure and EVs in the market. Furthermore, during the charging or discharging process, the energy losses are around 10% and 15%.
- **Battery lifetime**: If the battery is used to balance the grid by discharging, its lifetime is affected.

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*Figure 7: Four demonstration projects in Europe. Adapted from (Global Smart Grid Federation, 2012)*
Business factors

As the EV market share remains insignificant (less than 1% for BEV and hybrids in Europe in 2011) carmakers are not able to develop economies of scale for vehicles and batteries. Thus, EV prices remain considerably higher than prices of equivalent ICE. With a small penetration, the critical EV mass for setting up loading management cannot be reached. Thus, the most important business barriers affecting the integration of EV into grid are:

- **Economies of scale**: With a small EV stock, several stakeholders are not interested in setting up EV loading management services.
- **Battery business model**: There is no proven business model for the recycling and second life of EV battery. Thus, the residual value of a used battery is low, increasing the total cost of ownership.
- **EV loading management business model**: There is no proven business model for EV loading management, which is the key business element for the integration of EV to grid. Many issues remain unanswered: Who will pay the battery lifetime reduction? Why would EV users lend their batteries to the network and who will be paying for that? Who will pay the lack of autonomy for EV users?
- **Electricity network upgrade**: The upgrade of the grid requires important investments. Moreover, the mobility of electricity consumption introduces new technical and business challenges.
- **Additional services**: There is no proven business model for meeting users’ needs and increase value proposition through complementary EV services such as charging station tracking and booking.
- **Data property and management**: To manage EV loading taking into account grid requirements and needs, it is necessary to read, transfer and process information (EV battery state of charge, grid load, electricity production and consumption). Roles concerning EV-grid data management have not been clearly defined and there is a need of a vertical integration of such data.
- **Cost of infrastructure**: Not only for EV charging stations installation, but also for ensuring total EV integration to the local or regional grid (V2I and V2G). For achieving this, important investments are required (e.g. costs of Information Technology (IT) equipment for buildings energy management, smart meters, etc.). In addition to this, a smart home charger may cost about €300 more than a non-communicated one, which represents the annual cost of electricity consumption for a house in some European countries.

Social factors

Some experts are still convinced that the success of the integration of EV to grid strongly depends on social factors, such as:

- **EV drivers’ autonomy nervousness**: Even though approximately one third of passenger cars in Europe never travel more than 100 km in a single day, drivers’ nervousness is not a negligible factor. Pilot tests have shown that this nervousness is reduced with the presence of public charging infrastructure, which is not actually used to charge.
- **Charging habits**: Drivers are not used to charge EV every day and as a result, available autonomy is reduced.

- **Cost of electricity**: Electricity price is a barrier. A typical passenger car runs between 50 and 70 km/day in average (Joint Research Centre European Commission, 2012). For a typical EV with a consumption of 13kWh/100km (i.e. Renault Fluence ZE, Citroen C0), that daily distance represents between 6.5kWh and 9kWh, which is approximately the consumption of an entire household, which is 11.3kWh/day in EU-27 on average, (Joint Research Centre European Commission, 2012). Then, owning an EV could double the electricity bill and this can become a social barrier.

- **Battery lending to grid**: Without economical compensation, an EV owner is not motivated to lend battery to the grid.

### Policy factors

The presence of infrastructure is more than necessary to reassure EV drivers regarding autonomy nervousness. Some governments decided to subsidise the deployment of public charging infrastructure to raise the attractiveness of BEV and PHEV. In contrast to this, other governments preferred to let the market drive this development, a decision sometimes seen as a policy barrier. Policies are an essential requisite to adapt the electricity network to charging and discharging processes. Other relevant policy factors affecting the EV-grid integration are:

- **Sub-metering**: In some countries (i.e. France), it is forbidden for private electricity consumers to have a second meter installed downstream the electricity meter. This limits EV loading management services deployment, as it is necessary to invoice independently EV and household consumption. Also in some countries only one electricity supply connection is permitted by property, which impedes the connection of a second meter for EV.

- **Personal information**: For managing EV loading, it is necessary to collect and process information (e.g. battery state of charge, EV location). Sometimes this is not compatible with local regulations. To overcome this, the contractual relation between actors becomes very complex. Thus, the adoption of a clear legal framework to manage this problem is needed in some countries.

### Organisational factors

- **Standardisation**: There is a lack of coordination between actors for infrastructure access homogenisation and for the development of a unique charging standard at a European level. This is one of the central requisites to ensure a European integration of EV to grid.

- **EV user centred efforts**: Private and public stakeholders are focusing their efforts in satisfying EV user needs and omitting EV-grid integration related problems.

- **Partnership and competition**: The roles of the actors on the market are not clearly defined yet. There is a lack of definition of the strategy vis-à-vis the relationship between the different actors (e.g. EV manufacturers have not yet decided if they are going to compete against utilities or if they will collaborate).
Market potential for 2020

The “smartness” of an electricity grid can be measured through smart meter penetration, as smart meters provide information about the local grid status and the penetration of EV chargers. Supposing that market development barriers are overcome, targets for 2020 concerning smart meter penetration seem to be promising in the studied European countries (see Figure 8).

Nevertheless, according to the vision of the main stakeholders of the sector, the concrete integration of EV to the grid seems to be highly dependent on the vehicle stock in a region. If the number of EV in a country or a region does not reach a critical value, most of the concerned stakeholders are not willing to put in place EV charging management systems and services. This means that for regions or countries in which the number of pluggable electric vehicle is low, the setup of EV battery loading services is not justified from the cost-benefit point of view: efforts and costs are fixed regardless the number of plugged vehicles, while benefits depend on vehicle stock. For the near future, some European governments have fixed clear goals concerning the EV stock (see Figure 9).

If the electricity grid in 2020 is smart enough to take control of the EV loading process, the potential source of storage is represented by the number of EV circulating in 2020. Some governments have established targets and others have performed estimations, concluding that EV stock will be around 6 million in Spain, France, Germany, Portugal and Netherlands in 2020 (see Figure 9). Considering national governments fulfil these targets and bearing in mind that 50% of new car registrations, including EV and hybrid registrations, in EU-27 in the last 10 years have been done in these five countries (International Council on Clean Transportation ICCT, 2012), the EU-27 EV stock is estimated about 12 million in 2020. In addition to this, considering a 25kWh typical EV battery, the...
total electricity storage capacity of such EV stock will be around 300GWh. In European OECD countries the total electricity generation in 2020 is estimated to be 3.360TWh/a (9205GWh/day) and 952GWh of installed capacity according to IEA forecast (source: revolution Greenpeace 2012). This means that EV storage capacity will represent 3.25% of the daily electricity production if the whole battery is available for storage, and 1.3% if only 10KWh of the battery capacity are used to store (equivalent to a typical daily use).

In 2020, about 1 charging station will be available for each EV on the German market (Electric Vehicle Initiative EVI, 2013). According to the opinion of other European stakeholders, for each EV in the market there has to be one wall box and one public charger installed.

Even though most European governments have established goals in terms of EV market penetration, the landscape for public charging stations is difficult to predict for 2020. An estimation from the national platform for electromobility (see Figure 11) considers that the number of public charging stations in urban areas will nearly double the number of private chargers for 2020. The total number of charging stations in Germany will be around 940 000 (Green eMotion Project, 2012).

This figure could be useful to estimate the number of chargers installed in other countries of the European Union, which would be proportional to EV stock.
A power-interest matrix shows the most important stakeholders and their implication in the EV-grid integration (Figure 12). The “players” are the most influential stakeholders, they are interested by the market and they have the power to influence it. The “context settlers” are unaffected by the conditions of the market, but they are influential, engaged in the debate. The “subjects” are interested by the issue but have no power to influence the debate in the market.

Figure 12: Power vs Interest stakeholders’ matrix. Power is the ability to influence the behaviour of the market, while interest is the engagement the stakeholder has within this market. Closer the core business of the organisation is in the market, higher will be the interest. A high power or high interest is represented by a higher number (value 5).
The responsible actor for investments related to the smart grid and the EV supply equipment deployment is usually the EV service provider (EVSP) or a public investor. Sometimes the EV service provider is a subsidiary of the electricity utility. These investments are indirectly paid by the EV user and electricity consumer when consuming electricity, but sometimes with a subvention from public authorities, especially in this early stage of market development. This figure also presents the electricity flow, with its related cash flow.

*Figure 13: EV-grid integration financial scheme*
The current status of the EV-grid integration differs from one country to another. This is due to the appreciable differences in the electricity market structure, the legal framework and consumers’ behaviour and needs.

**France**

France is one of the European leaders in terms of EV stock. Stakeholders consider that the EV related services market is very promising. However, the EV stock is still considered to be not big enough to justify the deployment of EV charging management services. Stakeholders’ roles are not yet clearly defined on the EV-grid market. The EV-grid integration issue does not seem to be a priority for most of the French stakeholders. Nevertheless, some new entrants such as international IT companies seem to have an increasing interest in this subject. The intelligence of the French grid is augmenting as the smart meter penetration is increasing. This will allow, in a near future, a better control of the local grid and the implementation of bidirectional electricity flow (V2G). Nevertheless, sub-metering is not already allowed, which can be problematic for the deployment of EV loading services. In addition, EV charging stations penetration is very low, as only one public charger was available for 10 EV on the road in 2012. Some pilot projects integrating EV to the grid have been performed regionally, and some of them including renewable energy but there are no commercial offers with these services. Communication EV-grid is an overcome barrier, but the next step is to be able to connect them to the grid and, after that, bidirectional electricity flow will be possible. In French public policy, vehicles emitting less than 20gCO₂/km benefit up to € 7000 in subsidies, limited to 30% of the vehicle purchase price, increased with the cost of the battery if it is rented. BEVs are also exempt from car tax. Hybrid vehicles emitting 110gCO₂/km or less benefit from a subsidy of € 4000 and they are exempt from car tax during the first two years after registration (European Automobile Manufacturers’ Association ACEA, 2013).

**Germany**

Germany is one of the leaders in the European market in terms of EV stock. German car manufacturers have started launching new EV models as it is considered a promising market. As in other European countries, basic charging services are available for EV customers, but not services concerning the loading management. Regarding German public policy, BEVs are only exempt from the annual circulation tax for a period of ten years after their first registration (European Automobile Manufacturers’ Association ACEA, 2013). This may be the main factor influencing the growth of the EV market, which is clearly lower than in France. As presented in the previous paragraph, the French government is incentivising EV acquisition with strong subsidies and thus EV stock in 2012 almost quadrupled the German one (Electric Vehicle Initiative EVI, 2013).

**Greece**

Concerning EV acquisition public policy, it is less stimulating than in other European countries, being limited to the exemption of registration tax for BEVs and hybrids (European Automobile Manufacturers’ Association ACEA, 2013).
**Italy**

In some regions of Italy, local EV loading management services are currently available. This management is usually limited to the control of a group of chargers installed together, maximising charging speed while taking into account local grid capacity. Nevertheless, other EV loading management services are not currently being proposed in Italy. With a small EV penetration, the key Italian stakeholders are not willing to invest in the deployment of charge management systems. With almost one public charging station available for each EV, Italy is one of the leaders in terms of public EV chargers penetration (in 2012). Utilities are only offering basic charging services such as the installation of wall box and access cards for the public infrastructure. Grid operators consider that the gap between the peak and off-peak price of electricity is too small to incentive automatic EV loading management. The main market barrier perceived by stakeholders is the absence of attractive incentives for EV acquisition, which are limited to the exemption of the annual circulation tax during the first five years for BEVs. After this period, they benefit from a 75% reduction of the tax (European Automobile Manufacturers’ Association ACEA, 2013). In addition to this, the national authority has not already established a clear legal framework, so the role of different stakeholders is not really well defined.

**Latvia**

The EV acquisition policy is based on the exemption from the registration tax for BEVs (European Automobile Manufacturers’ Association ACEA, 2013). The market is in an initial phase of development and the technological environment is in preparation phase, with only 10 EV public charging stations (with a total of 44 EV plugs) introduced in the whole country in 2012 (Uldis Putnieks, 2012).

**The Netherlands**

BEVs are exempt from the registration tax and from the circulation tax. Hybrids are also exempt from the registration tax if they emit less than 88g CO$_2$/km (diesel hybrid) or 95g CO$_2$/km (gas hybrid) and from the circulation tax if they emit less than 95g CO$_2$/km or 110g CO$_2$/km respectively (European Automobile Manufacturers’ Association ACEA, 2013).

**Spain**

85% of householders have flat tariff electricity supply contracts. Thus, EV load management is useless from the consumer’s economical point of view and it is even counterproductive as full EV autonomy availability could be negatively affected by EV loading management. With almost one public charging station available for each EV in the market, Spain is the EU leader in terms of EV charger penetration. Incentives for EV acquisition vary from one region to the other. Various regional governments, such as Aragon, Asturias, Baleares, Madrid, Navarra, Valencia, Castilla la Mancha, Murcia, Castilla y Léon, Cantabria, Catalunya, Galicia, Pais Vasco and Extremadura, subsidize the purchase of BEVs, hybrids and other non-conventional fuel vehicles (GNC, LPG) with € 2000 to € 7000. In Andalucia, the incentive can reach 70% of the vehicle’s price (European Automobile Manufacturers’ Association ACEA, 2013).
General conclusions

The integration of ICT in different transport modes is a key factor to improve efficiency, save costs and energy and decrease transport time. Different ITS are available today and many stakeholders are responsible for their implementation. This document presented a general analysis of the most relevant information for the integration of EV into smart grid market, proposed by the T-TRANS project.

Results show that the market seems promising and ICT will play a key role and is a necessary element to enter the market. Most of the market development technical barriers have been overcome and the different actors seem to be determined to build the technological and organisational environment.

As a conclusion, the ITS sector represents a high potential of opportunities for IT companies. Alliances with traditional companies in the transport sector are a viable strategy for improving the integration of ICT. Nevertheless, such integration is only possible if the technological, legal, and organisational environments are prepared prior to the launch of innovative ITS in the market.

Proposals: marketing strategies and technology diffusion

After having identified the main barriers for the integration of electric vehicle in the electricity grid, some strategies for improving this integration at European level are proposed:

- Lobbying at EU level to ensure the interoperability of EV and charging systems in different countries.
- Development of a standard for the interoperability of different actors in the value chain and for different technologies and communication protocols for ensuring an interoperable integration of the EV to the grid.
- Vertical cooperation: of electricity system operators (at different levels) with car manufacturers, energy service companies and other stakeholders involved in the value chain (through cooperation tools such as think tank, business clusters and associations) to enhance loading management products and offer user-oriented services.
- Horizontal cooperation: between different grid operators to develop information transparency at a European level, which encourages the development of an e-cloud space of information to manage EV loading process.
- Lobbying at EU level to push for standardisation and interoperability of loading management concerning charging infrastructure, grid and EV.
Annex: basic notions

Market definition and delimitation

To perform a general market analysis, it is necessary to define the targeted market. The market for this study is defined as the one that includes the integration of electric vehicles (EV) in a smart electricity network. As the “smartness” of the electricity network is not easy to measure, this survey is performed regardless of this level of “smartness” of the smart grid. This means that the market is limited to EVs that are connected to an electricity grid capable of managing the charging or discharging process (e.g. automatically starting and stopping the battery loading process to meet generation and load fluctuation). The analysis is focused on passenger cars and small transport cars, not including trucks or buses.

This study covers the European Union, with a special focus on: Spain, France, Germany, Greece, Italy, the Netherlands, Latvia and the UK.

Products in the EV-grid market

Three physical elements compose this EV-grid integration market: electric vehicles, smart electricity grids and the integration interface.

Electric vehicle (EV)

![Electric vehicle types](image)

Figure 14: Overview of drive technologies. Adapted from (Nationale Plattform Elektromobilität NPA, 2012).

Smart electricity grid

A smart grid is an electricity network that uses ICT to monitor and manage the transport of electricity from the generation source to the consumers. A smart grid may be capable of coordinating the power needs of generators, operators, end-users and any other market stakeholder. The objective is to operate the system as efficiently as possible, minimising costs and environmental impacts, while maximising reliability, resilience and stability.
Current smart grid structure is evolving and new functionalities and technologies are being introduced (Figure 15).

A grid performing more functionalities could be considered with a higher level of “smartness”. Nevertheless, this “smartness” is usually quantified by the smart meter penetration (Dupont, 2010). A smart meter is a device that measures the consumption of energy and has four minimum functionalities: remote reading, two-way communication, support for advance tariff and payment systems, and remote disablement-enablement of supply (European Smart Metering Industry Group ESMIG, 2012). Thus, the proportion of smart meters existing in a country or a geographical area is used to assess the degree of “smartness” of a grid.

![Figure 15: Vision of the smart grid in the present and in the future. (International Energy Agency IEA, 2011)](image)

### Vehicle-grid charging device

<table>
<thead>
<tr>
<th>PORTABLE CHARGER</th>
<th>WALL BOX</th>
<th>CHARGING STATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used to charge battery of BEV and PHEV in a domestic electricity plug. It is a slow speed charger (needing more than 15 hours to charge a 25kWh BEV).</td>
<td>Used to charge EV at home. It is usually installed in private garages and it can perform medium-speed charging (8 hours to fully load a 25kWh battery).</td>
<td>Usually installed in the public street, it is capable of loading a 25kWh BEV in less than 3 hours (and up to 40 or 20 minutes for high speed chargers).</td>
</tr>
</tbody>
</table>

*Table 1: Three types of electric vehicle charger architectures.*
The third component of the market is the integration interface: the charging device and its software, which connects the electricity grid with the vehicle. Three are the typical architectures (Table 1).

The main functionality of a charger is to feed the EV with electricity. It can perform other functionalities, such as discharging battery to the grid, powering EV’s air conditioning and heating systems, managing charging and discharging, transmitting data about the state of charge (SOC) or other. Consequently, charging devices can be classified from the functionalities point of view in three types:

- **Manual charger**: it ensures the basic functionality that consists in supplying electricity to the vehicle’s battery.
- **Automatic charger**: similarly to the manual charger, it supplies electricity to the vehicle, but charge can be programmed in order to automatically start and finish the electricity delivery. A home charger (wall box) can be programmed by the EV user or the utility to recharge during the night, during peak-off tariff hours.
- **Connected charger**: its operation can be controlled or programmed remotely. It can also receive and send information through a communication network in order to perform more advanced functionalities.

The integration of BEV, REEV and PHEV to the smart grid is achievable through automatic and connected chargers. Automatic chargers can be preset so as to perform the loading of the battery during electricity low-demand periods of the day, which can be predicted by power producers and grid operators. Connected chargers instead can be reprogrammed and operated in real-time, instantly adapting the loading process to grid requirements and needs.

A functional description shows the needs that are being satisfied by each charger (Table 2).

<table>
<thead>
<tr>
<th>Function performed by EV-grid interface (charger)</th>
<th>Type of EV-grid charger</th>
<th>Needs of charger user</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual</td>
<td>Automatic</td>
</tr>
<tr>
<td>Manual electricity delivery</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Security for user / vehicle</td>
<td>✗</td>
<td>✔️</td>
</tr>
<tr>
<td>Programmed charging</td>
<td>✗</td>
<td>✔️</td>
</tr>
<tr>
<td>Peak/off-peak charging</td>
<td>✗</td>
<td>✔️</td>
</tr>
<tr>
<td>Data transfer to/from EV</td>
<td>✗</td>
<td>✔️</td>
</tr>
<tr>
<td>Data transfer to/from grid</td>
<td>✗</td>
<td>✔️</td>
</tr>
<tr>
<td>Remote operation</td>
<td>✗</td>
<td>✔️</td>
</tr>
<tr>
<td>Discharging (V2I and V2G)</td>
<td>✗</td>
<td>✔️</td>
</tr>
</tbody>
</table>

*Table 2: Functional analysis of the different categories of EV-grid integration interface existing in the current EU market.*
Another standard classification of charging devices differentiates them according to the safety level (International Electrotechnical Commission IEC):

- **Mode 1**: Neither the vehicle nor the grid are capable of ensuring human or material safety during the charge. The device is a basic adapter with an electricity input from the grid and electricity output for the EV.
- **Mode 2**: One of the connected entities ensures a minimum safety during the charging process. Portable EV chargers are Mode 2. They start the electricity supply to the car once the connection to the battery has been verified by the car and charger.
- **Mode 3**: Both the car and the grid ensure material and human safety before starting charging. This is the case for public charging stations, which monitor the state of the electricity supply from the grid and make sure that the connection to the vehicle has been correctly established before starting the electricity transfer.

The EV-grid integration can be done by any of the three modes. Nevertheless, functionalities performed vary and a full integration to the smart grid is only achievable by mode 3.

In addition to this, a classification of chargers from the installation location point of view is proposed (Table 3):

- **Private charger**: It is located in the end-user’s place. It is usually a charger installed in the wall of a parking place (wall box).
- **Semi-public charger**: It is situated in a commercial or private place but with public access, such as shopping centres or semi-public parking places.
- **Public charger**: It is installed in public parking or streets. The utilisation is normally limited to authorized users through an identification card.

These three types of charging interfaces are technically capable of integrating EV to grid, but functions vary depending on the charger model. Most of them perform functions that correspond to the “automatic charger”, being thus “integrable” to a smart grid. However, its implementation for public chargers could be opposed to their finality: to charge batteries as fast as possible. While the main purpose of public chargers is to ensure the maximum autonomy of the vehicle and reassure the driver, managing the charge to satisfy the grid needs could have a negative impact on autonomy.

<table>
<thead>
<tr>
<th>PRIVATE</th>
<th>SEMI-PUBLIC</th>
<th>PUBLIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>The charger is located in the EV user’s place, usually installed in the garage wall.</td>
<td>The charger is situated in commercial or private parking buildings accessible to public.</td>
<td>Charger is installed in the street or public parking.</td>
</tr>
</tbody>
</table>

*Table 3: Three types of charging devices proposed in this deliverable, according to place.*
References


European Automobile Manufacturers’ Association ACEA. (2013). *Overview of purchase and tax incentives for electric vehicles in the EU*.

European Smart Metering Industry Group ESMIG. (2012). *Position Paper on Smart Metering in the energy efficiency directive (COM 2011/370)*.


Green eMotion Project. (2012). *Deliverable 3.1 Business Analysis*.


**Acronyms**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEV</td>
<td>Battery Electric Vehicle</td>
</tr>
<tr>
<td>CS</td>
<td>Case Study</td>
</tr>
<tr>
<td>DSO</td>
<td>Distribution System Operator</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>EV</td>
<td>Electric Vehicles</td>
</tr>
<tr>
<td>EVI</td>
<td>Electric Vehicle Initiative</td>
</tr>
<tr>
<td>EVSE</td>
<td>EV Supply Equipment</td>
</tr>
<tr>
<td>EVSP</td>
<td>EV Service Provider</td>
</tr>
<tr>
<td>ESCO</td>
<td>Energy Service Company</td>
</tr>
<tr>
<td>FCEV</td>
<td>Fuel-Cell Electric Vehicle</td>
</tr>
<tr>
<td>HEV</td>
<td>Hybrid Electric Vehicle</td>
</tr>
<tr>
<td>ICCT</td>
<td>International Council on Clean Transportation</td>
</tr>
<tr>
<td>ICE</td>
<td>Internal Combustion Engine</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technologies</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electro-technical Commission</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technologies</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transport Systems</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Government Organisation</td>
</tr>
<tr>
<td>PHEV</td>
<td>Plug-in Hybrid Electric Vehicles</td>
</tr>
<tr>
<td>REEV</td>
<td>Range Extended Electric Vehicle</td>
</tr>
<tr>
<td>SG</td>
<td>Smart electricity Grid</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium Enterprise</td>
</tr>
<tr>
<td>SOC</td>
<td>State Of Charge</td>
</tr>
<tr>
<td>TSO</td>
<td>Transmission System Operator</td>
</tr>
<tr>
<td>V2I</td>
<td>Vehicle to Infrastructure</td>
</tr>
<tr>
<td>V2G</td>
<td>Vehicle to Grid</td>
</tr>
<tr>
<td>WP</td>
<td>Work Package</td>
</tr>
</tbody>
</table>

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