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NEW ACTORS AND BUSINESS MODELS FOR THE INTEGRATION OF EV IN POWER SYSTEMS

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AUTHORS

Michel Rivier	michel.rivier@iit.upcomillas.es
Tomás Gómez	tomas.gomez@iit.upcomillas.es
Rafael Cossent	rafael.cossent@iit.upcomillas.es
Ilan Momber	ilan.momber@iit.upcomillas.es

CONTRIBUTORS

Neil Downing	neil.downing@ricardo.com
Ed Bower	ed.bower@ricardo.com
Peter Miller	peter.miller@ricardo.com
Nora Hartmann	n.hartmann@consulting4drive.com
Sandro Fengler	s.fengler@consulting4drive.com
Colum Joyce	colum@imrworld.org
Belén Díaz-Guerra	bdguerra@ree.es
Vally Lioliou	v.lioliou@dei.com.gr

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Project Coordinator	PPC	N. Hatziargyriou	04/02/2011
Technical Coordinator	INESC Porto	J. Pecas Lopez	04/02/2011
Work Package Leader	COMILLAS	M.Rivier/T. Gómez	04/02/2011

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SUMMARY

Electric power systems are facing a major new challenge (and hence opportunity): the future massive integration into the electric grid of hybrid/pure electric plug-in vehicles (EV). “Mobile Energy Resources for Grids of Electricity" (MERGE) is a major EU-financed project to prepare the European electricity grid for the spread of electric vehicles.

This deliverable, being the first of three reports on regulatory issues for the efficient integration of EV, has the objective to focus on the new actors and business models involved arising at mass EV deployment.

This task provides a vision with a qualitative assessment of how power system participants will be affected by the deployment of EV. Finally different business models for retailers, aggregators, charging point managers, distribution system operators as well as transmission system operators are developed assessing the threats and opportunities for each agent under this new situation. The perspectives are complemented by the final EV user’s point of view as well as the automotive industry’s standpoint.

This report presents qualitative analysis of possible future arrangements of charging processes. It does not provide a quantitative assessment on probabilities of occurrence of these charging modes nor on the costs associated. It assumes that the deployment of EV will bring significant environmental advantages to the transportation sector of the future and therefore over the next decade there will be a strong effort to foster the market penetration by appropriate regulatory frameworks and legislative decision. In order to account for the timely scope and the likeliness of charging modes to appear, this report proposes two different stages of charging control alternatives: i) short-term modes based on uncontrolled or basic control modes, and ii) long-term modes where V2G applications are implemented.

Classifying these charging modes further by their location on private or public areas with private or public access several, two new agents are identified as critical for EV charging: the charging point manager (CPM) and the EV supplier-aggregator (EVS-A). Furthermore it is proposed, that DSOs are entities being the best option for developing public charging infrastructure because of the existing incentive regulation of natural infrastructure monopolies and the fostering of competition for retailing and aggregating services. In this case, as DSOs are regulated entities, the recovery of investments as well as the impact of charging infrastructures on the network is the critical issue to be taken into account by regulators.

In these arrangements, EV supplier-aggregators engaging in competitive activity based on supply contracts with EV owners that can be charged in different locations, mainly areas with public access. Charging point managers are electricity final customers that are allowed by legislation to supply charging services to EV owners on their premises, such as private parking areas. Battery leasing/swapping companies present other types of business models with different opportunities and threats associated to battery standardization among car manufacturers. IT-suppliers might play an important transversal role in linking different agents during the charging process. EVs charged during valley hours could benefit the integration of renewable energy, mainly wind, in systems with high penetration levels while presenting an opportunity for TSOs to increase system security by providing system services such as frequency control when operated in V2G modes. EV charging introduces a new load uncertainty in the system therefore new forecasting tools are required for TSOs.

A summary on the conclusions that can be drawn from the automotive industry’s perspective and the EV owner’s point of view can be found in the appendix documents II and III

TABLE OF CONTENTS (UPDATE)

NEW ACTORS AND BUSINESS MODELS FOR THE INTEGRATION OF EV IN POWER SYSTEMS

1 INTRODUCTION

1.1 Current Setting

The integration of plug-in electric vehicles (EV) in electric power systems poses new technical, economic, policy and regulatory challenges. Due to energy efficiency and environmental advantages over conventional transportation, the future of EVs is promising. However there are still important technological and economic barriers mainly related with efficient and affordable storage technologies that will hopefully be resolved in the near future. Prospective studies indicate that in the next decade we will witness a significant deployment of EV technologies, plug-in hybrids and pure battery EVs[1].

The European Parliament recently adopted a resolution for the promotion and support of electric vehicles for personal transportation (EU, 2010). In this resolution different actions are proposed in order to achieve a single European EV market. Among those actions the call for international or at least European standardization of charging infrastructures and technologies, including smart grids, with open communication standards, can be highlighted.

In addition to technological developments and policy measures, regulatory issues related to investment and deployment of the required infrastructure need to be formulated and adequately solved. Coherently, there is a need for discussing how and which agents should be authorized to provide EV charging and pricing of those services, as well as how EV storage capability could be appropriately marketed to provide vehicle-to-grid (V2G) services (Kempton and Tomic, 2005). However, an accurate calculation of the benefits is a complex task in order not to misunderstand or overstate the potential (Dallinger et al., 2010).

The currently perceived purchase premiums compared to internal combustion engines are widely being discussed and a multitude of different policy schemes to foster EV adoption is evaluated. A comparative study shows that from a user perspective one time support at the initial investment is highly appreciated. However, recurring instruments like an annual tax benefit are more effective yet usually smaller in volume. (Kley et al., 2010a)

1.2 Motivation and Research Objective

Therefore, still many questions remain to be answered within a consistent regulatory framework considering rules and players in existing electricity markets. Setting the structure for a cost-effective development and deployment of the necessary charging infrastructures is a difficult task given the early stage of the industry. Predicting all possible occurrence of economically viable and socially desirable

[1] Numerous research and academic institutions together with governments recently have elaborated a significant number of studies on EV technology, see for instance (EPRI&NRDC, 2007),(Valentine-Urbschat and Bernhart, 2009), (Electrification Coalition, 2009), (IEA, 2009), (National Academy of Sciences USA, 2009), and (The Royal Academy of Engineering UK, 2010).

infrastructure development in accordance with smart grid requirements poses a great challenge for decision makers. It would involve determining the financing structure to be collective or private. Investment costs could be socialised among electricity consumers or more generally among all tax payers. Alternatively they could be recovered through EV user payments only. Furthermore it is yet unclear which agents should be responsible for developing them as well as whether the business would be bound to strong monopolistic regulation or characterized by competitive components. Depending on the intended outcome, the charging infrastructure could be considered a fully regulated monopoly, as transmission and distribution grids are, or a corporate entity allowed to own and deploy charging infrastructure.

All of the above raised issues can be extended to specific infrastructure capable of using EV storage for grid service provision V2G as peak power or ancillary services, frequency regulation and power reserves. However, V2G contains yet another challenge. The conditions to incentivize vehicle owners to adopt direct charging management mechanisms and control over the battery system are yet to be found. According to that, a regulatory framework needs to maintain the utility's obligation to provide reliable electric service balanced with a vehicle owner's desire to sustain control in case of personal need.

As electricity for charging EVs is used for transportation, there are various controversial arguments for a price differentiation from other electricity consumption, for instance including taxes for development of transportation infrastructure or by the contrary giving it subsidies because of carbon emissions reduction relative to traditional internal combustion propulsion systems for transportation.

The answers to the rising questions are different depending on the current regulatory framework for the electricity sector in each country or region. However there is a conceptual basis that remains common for all. In California, the Public Utilities Commission has opened a rulemaking process, in which a number of issues are proposed for consultation with stakeholders. It is yet to be determined i) how to implement obligatory variable tariffs, ii) legal status of electricity resellers, iii) incentive creation for users to adopt remote charge control of valuable batteries, and iv) allocation and recovery of investment in infrastructure in a fair non-discriminatory framework (CPUC, 2010a). Furthermore, there exists an intense discussion about critical metering policies in terms of metering arrangements (single, sub- and separate metering) and their implications on cost, installation time, and billing flexibility (CPUC, 2010b).

1.3 Structure of the Report

In this report, first a conceptual framework is developed in order to provide the basis for giving an answer to the main issues of regulating future large scale EV markets and defining the business models for involved agents. The regulatory framework for the organization of the European internal electricity market (EC, 2009) is taken as reference. However, many of the proposed concepts remain partially valid for other markets or regulatory structures. Further on, different charging modes for providing energy and V2G services are identified and presented in detail.

The structure of the report will be organized as follows: The introduction is followed by an overview of the regulatory framework for future EV scenarios in Section 2. This also recapitulates each role of the existing and involved agents in the electricity sector. Consecutively, the new agents related to the business of charging EVs are familiarized. Section 3 introduces definitions of grid and charging infrastructures while identifying required metering, communication and control equipment for charging EVs. In Section 4 different basic EV charging modes from charging at home to public and private charging stations are proposed. Section 5 sheds light on the automotive industry's perspective whereas Section 6 evaluates from the EV users point of view while special focus is given to the survey based results on EV user acceptance. In Section 7 the perspective of each agent is taken to revisit the opportunities and barriers for each agent's business model. Finally, conclusions and some policy recommendations are given in Section 8.

2 REGULATORY FRAMEWORK & AGENTS

In the following section, first, existing agents of the electricity sector are defined according to the functions assigned by EU legislation (The European Parliament 2003). Then, existing agents incarnating incumbent and future providers of mobility concepts are discussed. Then new types of agents who would play relevant roles in developing EV charging infrastructure and providing charging services are defined: the EV charging manager or EV energy service provider (CPM) and the EV electricity supplier – aggregator (EVS-A).

2.1 Existing Agents

2.1.1 Distributor or Distribution System Operator (DSO)

Distributor or Distribution System Operator (DSO): is the owner and operator of the distribution grid. It is assumed that distribution is legally unbundled from generation, transmission and particularly from supply and retail. Therefore distributors cannot trade energy. They only provide network services and are fully regulated monopolies.

2.1.2 Electricity supplier or electricity retailer/aggregator (SA)

Electricity supplier or electricity retailer is the agent who sells energy to final customers, the electricity end consumers. In this report the term retailer and supplier is used equally and it is assumed that there is no difference among the two. In countries where electricity distribution and supply have been unbundled, final customers remunerate the electricity supplier for the service who in return procures the energy and pays the distributors regulated charges for grid services and other system costs. In this report it is understood, that there exists the possibility of so called load aggregators, an agent who is offering demand side management by changes in load profile management and rescheduling. This function could be assumed by an electricity supplier or electricity retailer because they pay less for energy procurement for less deviations or it could be another agent that provides these types of services. In other countries without retail markets, distribution and supply activities are carried out by the same agent, the traditional vertically integrated utility.

2.1.3 Final customer

Final customer: is the agent that requires electricity for end-uses and purchases it from an electricity supplier. In general, by legislation, a final customer is not allowed to resell electricity to another final customer or to another agent. Final customers are residential, commercial or industrial customers. In some countries small residential customers used to purchase electricity at regulated rates, while large customers negotiate a supply contract with any electricity supplier. Nowadays, to promote efficiency, in some countries electricity suppliers are required to provide every final customer with at least one time variable or load variable tariff option as permitted by EU directive 2006/32/EG (Beyer, Heinemann, and Tusch 2009). Later on, it will be clarified that EV owners will not always be considered as final customers.

2.1.4 Independent System Operator (ISO) or Transmission System Operator (TSO)

Independent System Operator (ISO) or Transmission System Operator (TSO): is responsible for keeping a secure system operation at the regional or national transmission level. For meeting this obligation he procures system services, such as operational reserves and frequency regulation, from market participants.

2.1.5 The automotive industry

The automotive industry is the agent that designs, manufactures and sells EV to the EV owner/driver. The automotive industry will define specifications for batteries and battery control systems. These systems will be chosen to provide the EV owner with the most desirable solutions. The automotive industry business model will remain developing and selling the motive technology to the vehicle owner, but ownership of the battery may provide an opportunity for a new entrant to provide a solution to the high price of batteries by leasing to the vehicle owner.

2.2 New Entrants

2.2.1 Plug-in electric vehicle (EV) owner / driver

Plug-in electric vehicle (EV) owner: is the agent that owns an EV and requires electricity to charge its EV battery. In the future, he would be able to provide V2G services too. When charging, EVs would be physically connected to a charging point and in some scenarios the electricity could be provided by a specific EV electricity supplier (see definition below).

2.2.2 Battery Owners

As the primary and currently prohibitively high on-cost of an EV is the battery, different new business models may arise providing different ownership structures to lower the entry barrier for the new technology. Any of the above defined agents could take on the risk of owning, guaranteeing and controlling the operation of the battery to tackle battery life concerns, and reduce initial purchase premiums paid in comparison to conventional technologies by separating the cost of the storage capacity from the cost of the vehicle.

2.2.3 EV charging manager or Charging Point Manager

EV charging manager, EV energy service provider or Charging Point Manager (CPM): Acting as a final customer CPMs will buy the required electricity to charge its own EV or to resell it to other EV owners connected to the charging station under a commercial agreement. It is assumed that the installation of charging infrastructure on private property could be made by the area owner. Different situations could be possible:

- A residential customer who installs an EV charging point at his/her home garage for private use
- An office building owner who installs several EV charging points in the office parking area for private use of its employees

- A commercial building owner who installs several EV charging points in its parking area for use of its clients[2]
- An EV charging station owner who installs several charging points with different charging options, specifically fast charging modes, for delivering this service to the public.[3]

By legislation, CPM who resell electricity to a third party (EV owner) in a competitive activity would be defined as electricity suppliers or retailers. In this case, the access to the charging services would be made available on the terms and conditions set by the CPM. For obtaining a license to exercise this type of activity, they should demonstrate technical capability and financial liability according to legislation. For instance, this type of agent has recently been defined by the Spanish legislation (Spanish Royal Decree-Law 6, 2010)4.

2.2.4 EV charging infrastructure owner

The EV charging infrastructure owner is similar to the EV charging manager with the only difference that he is not providing the charging service and the management of all control functions himself. It is assumed that the installation of charging infrastructure on private property will be made by the area owner. This area owner could subcontract a CPM for the management and for providing all services. For example, facility managers of commercial buildings where the parking business is not the primary function of the construction might not want to worry about all the legal implications of becoming a CPM themselves and therefore opt for buying infrastructure however not operating it. On public property on the other hand, however, the installation of charging infrastructure would be part of the distribution business, and therefore the owner of this infrastructure would be the DSO.

2.2.5 EV electricity supplier-aggregator (EVS-A)

In the following we consider two main alternatives regarding the development of charging infrastructure: i) privately owned charging areas with private or public access for EV owners, and ii) public charging areas with public access for EV owners.

EV electricity supplier-aggregator (EVS-A): EV electricity supplier is the agent selling electricity to the EV owner. For example, EV owners could have a supply contract with an EV electricity supplier valid in different charging points. The novelty about this agent is that its contracts are not location based or bound to a single final outlet. The customers, the EV users will demand mobility and freedom to choose multiple charging points while remaining with the same EVS-A. EV electricity suppliers are retailers and therefore their business should be declared competitive activity unbundled from other vertical functions in the electric power system. EV electricity

[2] In case of parking areas at office or commercial buildings, the building owner already has a metered electricity supply. Then he can independently meter the EVs connection points if he wants to bill each charging point, or by the contrary there is no need for metering if the service is not directly related to consumption.

[3] For the purposes of this report fast charging is defined as a process with load higher than 32 A at 230V AC power connection, although other solutions are possible.

[4] The Spanish legislation defines this agent as the charging manager (“gestor de cargas”, in Spanish).

suppliers in general are expected to aggregate multiple EV contracts to conduct an integrated management. In this case the EV electricity supplier acting as aggregator could also play a key role in the future providing V2G services to the ISO[5]. In the following the EV electricity supplier-aggregator is considered a competitive business as other trading activities in the market.

2.2.6 EV IT service provider

Any one of the above named new entrants might fully take up the entire value chain of its business. However, the agents are always free to revert to other more specialized business to outsource certain services. Some of the charging modes require a significant amount of communications sustaining the relationships between the different players. It is easily imaginable that companies highly specialized in information and communication technologies seize the opportunity and jump in to provide certain, intermediate services.

In that sense IT-service providers could act as the link between the different agents such as EV owner and EV supplier, EV supplier and EV aggregator, or EV supplier/aggregator and DSO, while connecting all the different players to electricity market, by providing real time and accurate information. IT-service providers could be commercial players that invest in communication infrastructure and teleconnections, maintain the communication network and profitably IT services to all the previous players.

[5] In (Guille and Gross, 2009) aggregators are proposed as the key agent for V2G implementation.

3 GRID CONNECTIONS & CHARGING INSTALLATIONS

In this section the definitions for network and charging infrastructures are introduced. The existing distribution system infrastructures are complemented by additional charging equipment for EV, metering, control, and communication gear are detailed.

3.1 Grid Connection & Charging Installations

3.1.1 Distribution grid

The distribution grid consists of high voltage (HV), medium voltage (MV), and low voltage (LV) network installations, power lines and transformers, at which final customers are connected. Small residential customers are connected to the low voltage network while large customers, hundreds of kW, are connected to the medium voltage network. As it has been stated distributors are responsible for investment and operation of distribution grids.

3.1.2 EV charging infrastructure

The EV charging infrastructure is composed of one or several EV charging points and their connections to the distribution grid, i.e. Electric Vehicle Supply Equipment (EVSE). In some cases additional equipment such as transformers, generators, or storage devices can be part of the EV infrastructure in order to provide an efficient and reliable service. In this proposal, investment, operation and maintenance of EV charging infrastructure is responsibility of CPMs in privately owned parking areas and of distributors in public parking areas. In case of residential customers with a charging point for particular use, located at a private property, it would be the owner of the property the one in charge of installing and maintaining the charging point with notification to the distributor. In cases of commercial or office buildings and charging stations, the parking owner or its electricity supplier should also notify the corresponding distributor of the number and installed capacity of the charging points asking for the required connection capacity[6].

3.1.3 EV charging point or charging post (CP)

EV charging point or charging post (CP): is the connection point between the EV and the charging infrastructure, where the EV is plugged-in to be charged[7]. A single

[6] Final users with EV charging points, i.e. CPMs, may have to modify its utility meter to include time of use (ToU) electricity rates differentiation at least between peak and off-peak hours.
[7] In the USA, the EV connection standard SAE-J1772 was approved in January 2010. This standard provides two different levels of charging interface: Level 1 operates up to 120V/16A and Level 2 operates up to 240V/80A. In the future a DC high power connector (150-250 A) will be also defined by this standard.

or multiple charging posts, together with other equipment, would make up a charging station.

CP

3.1.4 Final customer meter (FCM)

Final customer meter (FCM): it is located at the final customer connection point. It is known as the “utility meter”. It meters the energy consumption (kWh) and peak consumption (kW) in a period of time. Measurements can be collected by time-of-use, in peak and off-peak hours for instance. Smart meters can collect hourly measurements and include bidirectional communication with the distributor and with the electricity supplier to include different features regarding pricing and control. In many systems, distributors are in charge of the installation of final customer meters. Electricity suppliers should also have access to the information provided by the meter. It is assumed that a reliable bi-directional communication system would be established between the meter and the distributor, and the electricity supplier. The final customer has direct access to the information provided by the meter. Smart meters with the possibility of ToU prices could be required as compulsory for those final customers with EV charging points, i.e. for CPMs.

FCM

3.1.5 EV meter (EVM)

The EV meter (EVM) would meter the energy consumption, the peak consumption and the period of time during which an EV has been connected to a charging point for billing purposes. EV meters can also be embedded in the car. EV meters would be communicated with the EV electricity supplier for billing and potential remote charging control.

EVM

3.1.6 Charging station

Figure 1 shows a simplified scheme of a charging station with associated infrastructure. It can be observed that a FCM is located at interface with distribution, and EVMs are located at each charging point.

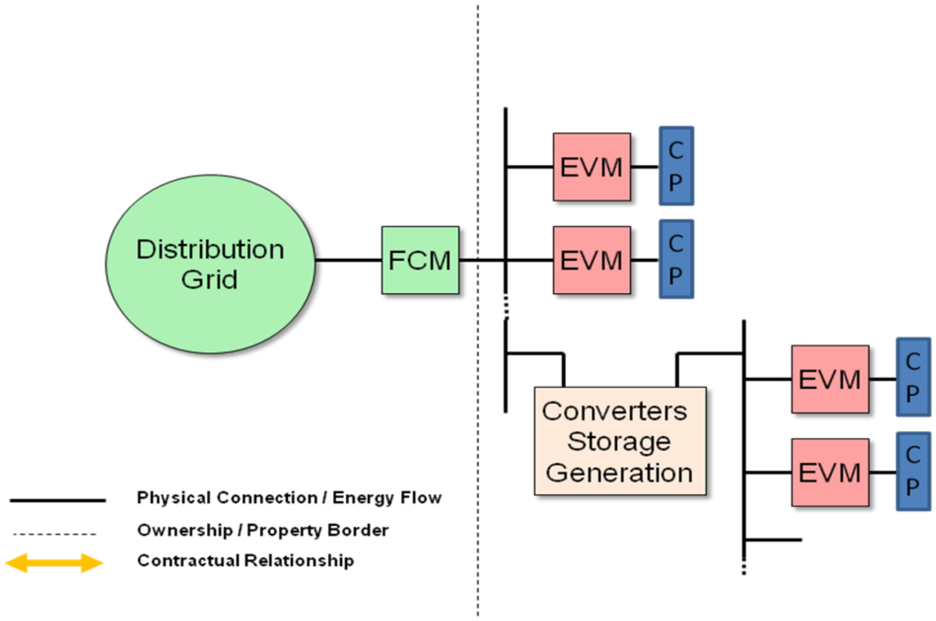
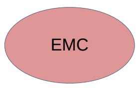


Figure 1. Charging station infrastructure

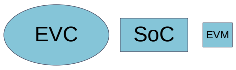
3.1.7 EV manager controller (EMC)

The EV manager controller (EMC) is a controller, similar to an energy management system or energy box, operated by the corresponding CPM or EVS-A (Livengood and Larson 2009). It schedules a charging program for each of the connected EV. The coordination between the EV manager controller and the on-board EV charge controllers should always be ensured for a correct operation of the charging process. A reliable bi-directional communication system should be implemented between both controllers.



3.1.8 On-board equipment (EVC, SoC and EVM)

In addition to the grid side elements of infrastructure, inside each EV the following measurement and control devices should be included. On-board EV state of charge indicator (SoC) measures the state of charge of the EV battery as a percentage of the full charge or in kWh. It is located inside the EV. An On-board EV charge controller (EVC) is a programmable controller that provides a menu of alternatives to the EV owner for charging the EV battery during its connection period. It is located inside the EV. The EV charge controller manages the electronic interface, i.e. the inverter, between the grid and the battery. Depending of the sophistication of the charging mode, this interface could be capable to respond in a bidirectional way, locally adapting the charge or discharge level according to the frequency or voltage variations. It is also imaginable that it responds to a set point received from the EMC. On-board EV meters (EVM) provide information about energy consumption, peak consumption, and times of connection on request.



3.1.9 Standardization

Characteristics and functions of EV charging points including EV meters, EV connectors and charge controllers should be standardized. On-board charge controller and meter functions should be also standardized. Open communication architectures for exchanging information between controllers and meters should be also defined. The aim is to ensure open access to markets for charging infrastructures and EV manufacturers.

3.2 Coordination between EVCs and EMCs

The requirements for charging infrastructure and communication modes between on-board EV charge controllers (EVC) and the EV manager controller (EMC) basically depend on the type of access, private or public, of the charging point (CP) as well as location of the intelligence either inside the vehicle or as part of the charging station. [8]

There is an ongoing debate about the best way of allocating communication intelligence and metering devices among the electric vehicles and charging infrastructure. There is a considerable argument for and against both possibilities, having implications for example on the details of the billing systems' processes, its components and operability consistent with current legislation (Link et al., 2010). However, this analysis does not enter in this type of discussion; it rather focuses on the main charging mode and according relationship of existing and upcoming agents.

[8] CF. Merge Deliverable D1.1 pp I-38 to 53

4 EV CHARGING MODES & COORDINATION

In this section, different charging modes for EVs are presented. Scenarios from less to more sophisticated charging alternatives are elaborated, differentiating the more realistic controlled charging in the short to medium term from rather sophisticated modes with V2G applications in the long term. It is expected that in the short-term charging EVs at home during nights will be the most practical and therefore common alternative as it is sufficient to most people's driving behaviour. However, public charging on public property as well as dedicated charging stations could provide complementary charging modes to cover the needs of EV owners. Under these three types of charging modes the role for developing the required charging infrastructure is assigned to different agents.

Charging modes are envisioned to co-exist alongside each other. Therefore their design should not mutually exclude each other even though there may be competition among them. Any charging mode should be designed to foster competition to the direct benefit of the final users and provide incentives for efficient, as well as cost effective operation. This document argues in accordance with the widely believed principle that markets and competition among agents help finding efficient outcomes and therefore regulation of these interaction should only be applied where necessary and socially desirable. Furthermore, this report supports the regulation of public goods. If the roll-out of highly efficient, comfortable, dynamic and noise-free driving electric vehicles is proclaimed to be a general goal of society, then the deployment of charging infrastructure providing sufficient electric mobility could be argued to be a public duty. Coherently, access to this infrastructure should be a public good as well.

Public charging infrastructure will be costly and will involve overcoming many hurdles, however this document and the presented charging modes do not contain any quantitative assessment on the cost implications of each alternative. It is reasonable to argue that in most cases the primary beneficiaries of the infrastructure, i.e. the users of electric vehicles, should pay for the cost of the charging service rather than society or tax payers as a whole. This recovery could be similar to the existing network charge billing systems in place.

Even though this paper is outlining a variety of different charging modes, with varying degrees of sophistication concerning the implementation of the system, it is important to note that any regulatory framework should focus on the more realistic solutions first, in order to foster adoption of the new technologies as quickly as possible. To give an example: the first charging mode, the individual domestic charge with an on board meter and a simple communication to the energy supplier is the most probable solution for most of the potential electric vehicle users. Any other charging mode would probably only be used as a supplementary service in irregular cases. Furthermore all efforts to foster quick deployment of charging options need to bear in mind the principle of non over-complication, i.e. all legislative requirements for charging point managers should be as simple as possible to lower the access barriers for all agents. The regulator should therefore only set extensive and legally binding rules and standards where absolutely necessary.

In public parking areas, streets and areas with public access, the installation of EV charging points will be more expensive. To have a large roll out will involve substantial expenditure and risk. When involving the use of a public good such as the public location, the business should be regulated and charging stations developed by the corresponding **distributor** in the area. In this case, the infrastructure would be considered as other grid expenditures and the access to the charging points should be made universal to EV owners contracted with different EV electricity suppliers. In the case of CPM acting on privately owned property, however, infrastructure could be installed and investment risk assumed by private agents.

An overview of all different charging modes by the location of each charging point is provided. Furthermore they are hierarchically separated by the degree of sophistication, that is, whether they include V2G capabilities or not. Each charging mode is named according to its classification, including the characteristics charging point location, intermediate agent for organising energy procurement or system services, and the degree of sophistication and control over the charging process. The charging point location can assume the occurrence HO for home charging, PR for private area with public access and PU for public area with public access. The intermediate agent can be the regular energy supplier aggregator for demand side management, denominated SA, the charging point manager, CPM, or the Electric Vehicle Supplier Aggregator EVSA. The distinctions concerning the control and level of complexity of the charging process are called UCO for uncontrolled charging and CC for controlled charging.[9] Vehicle to home (V2H) as well as vehicle to building (V2B) is the name for local optimization of energy bills, and vehicle to grid (V2G) for ancillary network and system services procured by the grid operators.[10]

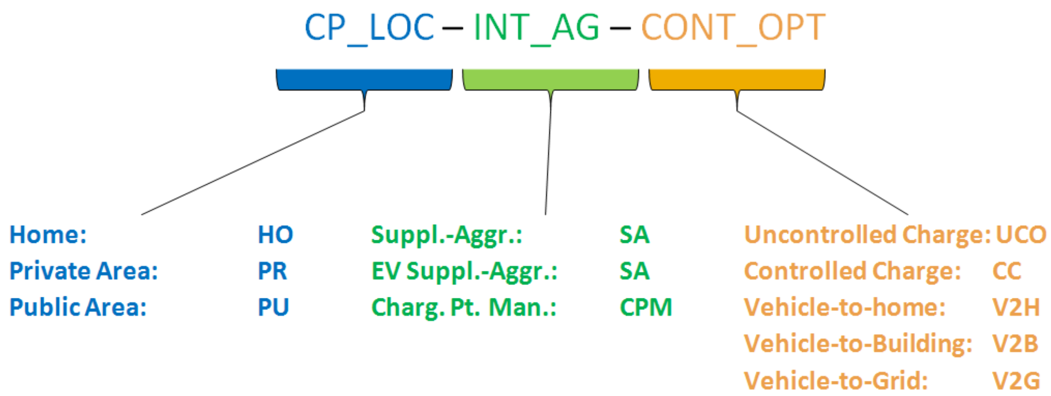


Figure 2. Classification logic for charging modes

[9] In uncontrolled charging (UCO) modes there is no management system directly signalling the load set points depending on the electric power system needs while in controlled charging (CC) there is an energy management controller (EMC) involved that optimally dispatches the loads. Note that in both cases the possibility to react to economic signals such as ToU tariffs exists.

[10] The definition of the V2G concept followed in this report, D5.1, is in accordance with what was specified in the MERGE reports D1.1 and D1.2.

Clarification of Terms

To enhance the current discussion this paper offers a set of definitions of terms, such that there is a clear and common understanding of the arguments. It might make sense to agree on a single and unique terminology to facilitate the debate about alternative regulatory approaches. This section contributes to this discussion very briefly:

Regulatory Option

For the purposes of this paper a Regulatory Option is an alternative set of rules that describes the responsibilities of agents of the electric power industry in rolling out public electric vehicle charging infrastructure. In particular, it is determined by certain agents' charging station ownership and or operation according to predefined regulatory principles. It also defines the rules of investment recovery and remuneration of the provided service.

Charging Mode or Charging Scenario

A charging mode or charging scenario defines a situation in which EV can be charged. It is determined by factors such as charging point location, interacting agents and their relations for delivering the final product or providing the final service, as well as the level of control over the charge and degree of sophistication for the charge.

Business Model

A business model describes how a product or service is provided, including perceived value creation of a certain product for a final customer. It is internal to one single agent and usually easy to assess by spending strategic thoughts on opportunities and threats.

Market Model

A market is an arrangement or a place where supply and demand meet for exchanging or trading a certain product or service. For instance, there are markets for ancillary services, energy (day ahead, intra-day) and so forth. A market model therefore describes the rules by which this trading platform functions. In the electric power system markets should not be confused by regulatory options – as done by (EURELECTRIC 2010).

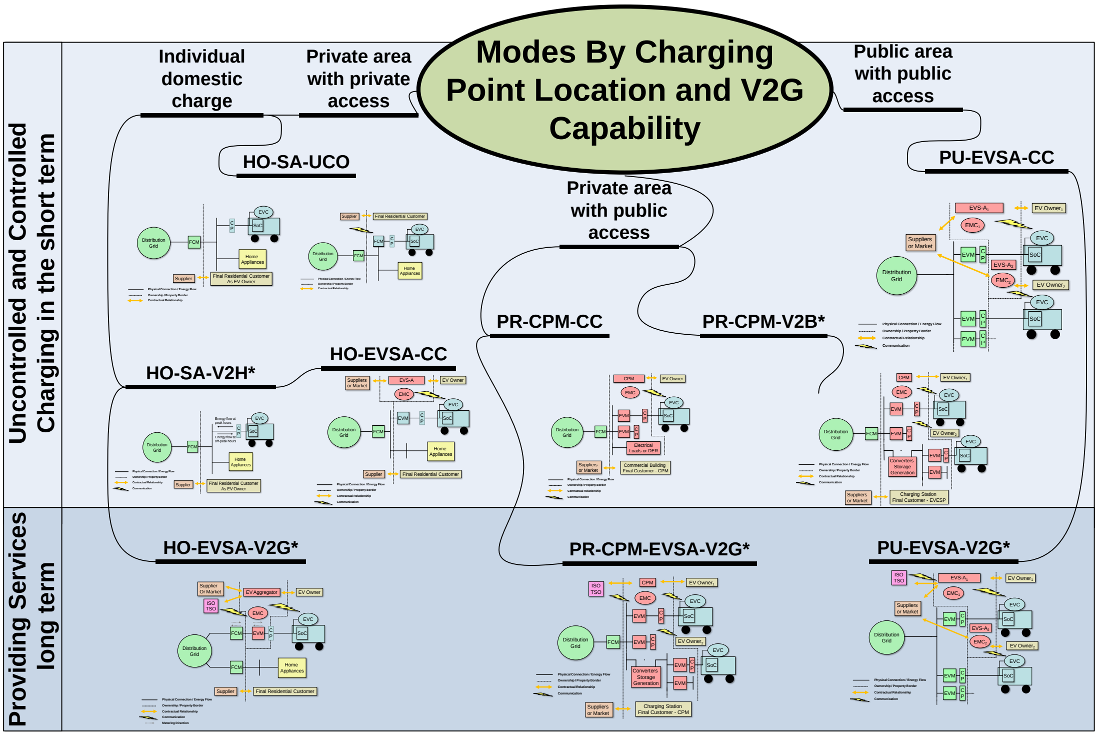


Figure 3. Tree overview of different charging modes *

The upcoming subsections of chapter 4 follow the same logic as this overview graphic. In 4.1, first all uncontrolled charging modes followed by the controlled charging modes that are presented together with the V2H and V2B modes. Then, in section 4.2 the future long term scenarios involving V2G services are outlined.

4.1 Uncontrolled Charging

4.1.1 EV home charging mode: HO-SA-UCO

In the simplest and most probable charging mode, the electricity used for charging the car is priced under a unique supply contract for a residential home (final customer). It is assumed that the home owner will install the EVSE with the EV charging connector while the distributor can play a role as advisor and supervisor of the EV required connector.

Agents involved: the home owner, the electricity supplier, and the distributor.

The home owner will notify the electricity supplier about the maximum required charging power whereas the electricity supplier will notify the distributor if additional power demand is required under the supply contract.

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* The charging modes marked with an asterisk can manifest a sophisticated CC, in which the level of power for charging the battery could be adapted in reaction to short term control set points or price signals.

From a regulatory point of view concerning the implications on business models of the interacting agents, the key requisite of the charging modes denominated with the prefix V2G is the communication with the system operator to provide the services required by the grid.

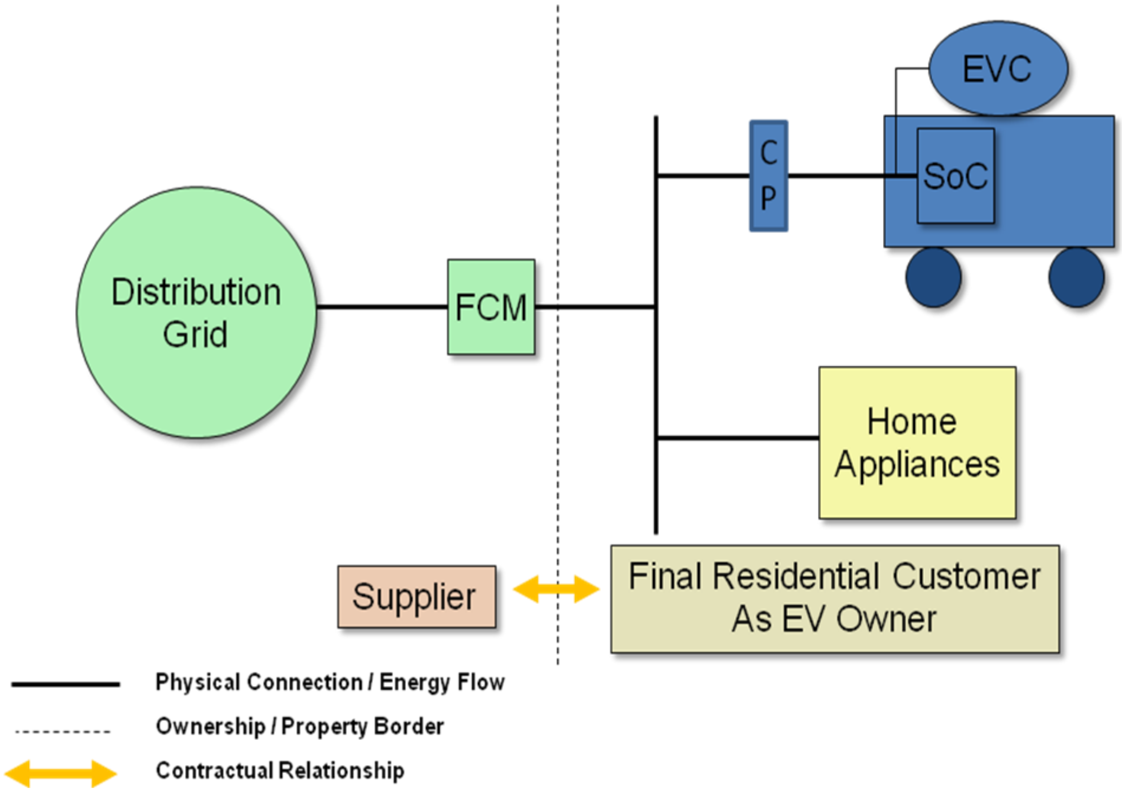

Figure 4. EV charged at home as electrical appliance

Contracts: The supply contract between the electricity supplier and the residential final customer would be a contract with at least time of use (ToU) prices, i.e. peak and off-peak prices to promote charging at off-peak hours, or it could be a more sophisticated contract with hourly time prices that promotes an integrated management of the EV with the rest of the loads. In this case the FCM should be upgraded to a smart meter in order to measure hourly consumptions. The electricity supplier will pay the distributor for the corresponding regulated network charges.

Communication and charge control: The EV owner would programme his EVC in accordance to his/her driver requirements and simultaneously minimizing electricity payments to the electricity supplier or load aggregator. The electricity supplier can offer the home owner an integrated management of his loads as well. In optimization mode there needs to be a communication of price signals between the electricity supplier and the EVC.

Settlement: The settlement of the contract would be based on the total home electricity consumption according to the prices set in the contract. These prices in general would be: i) a demand charge ($/kW-month), and ii) an energy charge ($/kWh) with different ToU rates or hourly prices.

4.1.2 Home Charging Variant with discriminative metering: HO-SA-UCO

Under this scheme it is not possible to bill the electricity used for transportation differently from domestic energy consumption. If this was the intention, as for instance necessary when including special rates or taxes on transportation, the connection of the EV charging point should be metered too. In figure 3 two parallel independent meters are installed for this purpose.[12] A series connection with subtractive calculation for billing would also be possible (PG&E, 2010). In these cases, the home owner could have two different supply contracts or rates, the former for billing the home electricity consumption and the new one for EV charging with an EVS-A for instance.

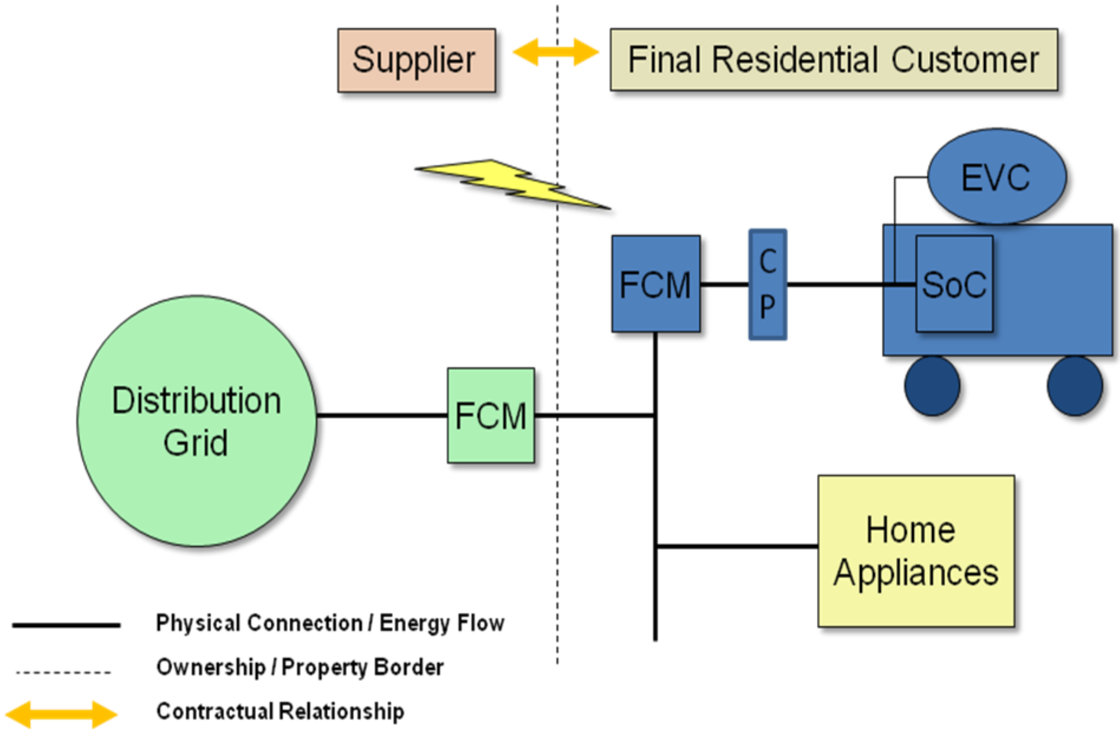

Figure 5. EV charged at home with separate meter

4.2 Controlled Charging

4.2.1 Controlled Public Street Charging: PU-EVSA-CC

Charging infrastructure in public areas with public access imply a different regulatory approach, as there are potentially multiple agents with complex inter-relations involved. The charging business modes for public use on public property pose certain specific contests for policy makers. The deployment of the infrastructure as a public good requires the allocation of the charging posts to follow transparent, objective and easily understandable criteria. Public authorities such as regulatory commissions, local governments and municipalities therefore need to derive suitable roll out plans for society as whole. Infrastructure costs are not negligible and therefore significant public funds are at stake.

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[12] This setup is not the only imaginable. A single meter can be used with two metering sets. This would similar to the type of meters that measure consumed electricity and produced electricity from microgeneration. In WP1 a reference to the specification for these meters has already been developed.

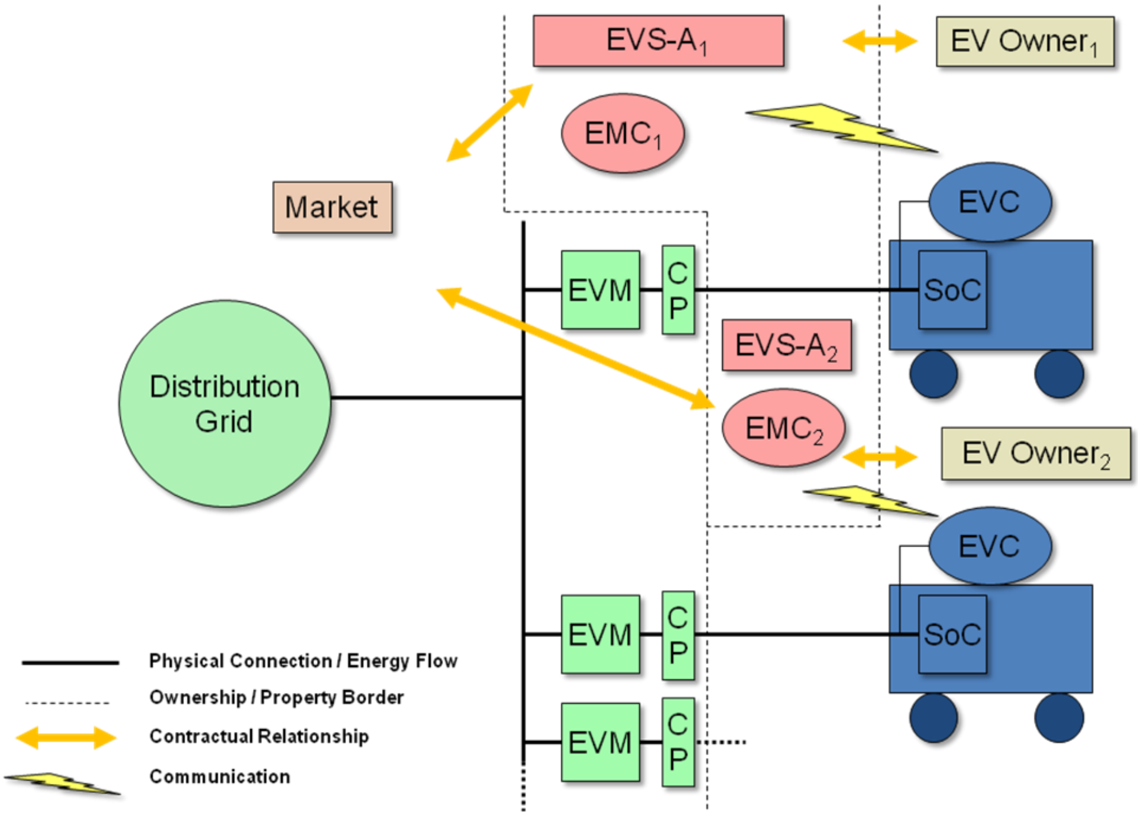

Figure 6. Public street parking area with multiple EV electricity suppliers

Agents involved: EVS-As, EV owners, and distributor

Contracts: EV charging posts are installed by the local distributor as part of distribution network in order to have low cost, and fast installation of standard chargers. Billing will follow the same system that distributors have in place for other transactions. Charging points should made accessible to any EVS-A with no discrimination or monopoly practices. EVS-As will sign contracts with EV owners for EV charging. EV owners will pay the electricity bills to the contracted EV electricity suppliers (EVS-A), the same or different from the one that supplies his home, giving the right to charge at any of EV public charging points. The EVS-A would pay regulated network charges to the distributor for paying back grid and charging infrastructure costs.

Settlement: Each EVS-A aggregates multiple contracts with different EV owners with the preference to charge in public parking areas and homes, in order to benefit from load aggregation and other economies of scale. EVS-As, taking the role of the traditional electricity supplier would be obliged to pay regulated network fees to the distributor for the use of the charging point as a function of the energy consumption measured by the EVM, the time of connection, and the required power.[13] In a competitive environment, the EVS-As contract the EV owners and pass on the regulated charges by designing end user tariffs according to the market conditions.

[13] The implementation of this settlement arrangements would require new ways of relationship between EV suppliers and distributors as well as methods for allocating the infrastructure cost that need further investigation.

Communication and charge control: Under this scheme when an EV is connected at the parking site the on-board EVC communicates the time of connection and the energy demand to the EMC. Then, the EMC would provide the EVC with a charging schedule that satisfies those requirements. The EVS-A could optimize energy volumes and periods for charging EVs in order to maximize profits. The design of the contracts between EV owners and EVS-As is a key issue in order to achieve the desired profitability.

4.2.2 Charging stations on private property with public access: PR-CPM-CC

On privately owned property, where vehicle parking access is nevertheless open to the public, such as corporately operated car parks, shopping facilities, dedicated roadside charging stations and commercial office buildings of various use, the regulatory framework needs to bear unique considerations. If the deployment of the charging station is undertaken by private entities that simultaneously procure and resell energy, the incumbent view of unbundling retail from distribution does not strictly apply any more. In this logic, the characteristics of the charging mode PU-EVSA-CC are shortly proposed in the following.

A charging station owner acting as CPM installs the required infrastructure. He would buy electricity from an electricity supplier and will provide EV charging services to EV owners.[14] Charging infrastructure may include additional equipment to convert, store, or even produce electricity in order to optimize and diversify the types of charging modes offered to their customers. In case of dedicated charging stations AC/DC converters and associated connection equipment may be required to provide fast and ultra-fast DC charging modes. Furthermore, local stationary storage capacity could, theoretically be useful for energy price arbitrage. For instance, the station could store significant amounts of energy during periods of low demand and inexpensive electricity in order to offer competitive charging prices during peak hours. Finally the combination of this storage capability with local generation sources based for instance on renewable energy can provide this business with additional profits. Something similar could happen under the same model of battery replacement where EVs park in dedicated stations for switching the battery within a matter of minutes. Figure 6 represents this charging mode schematically.

[14] In the description of this model it is assumed that a dedicated charging station is selling charging services to EV owners. However in case of other private parking areas, as commercial or office buildings, the relationship with EV owners can be much simpler and energy metering and billing services could not be needed.

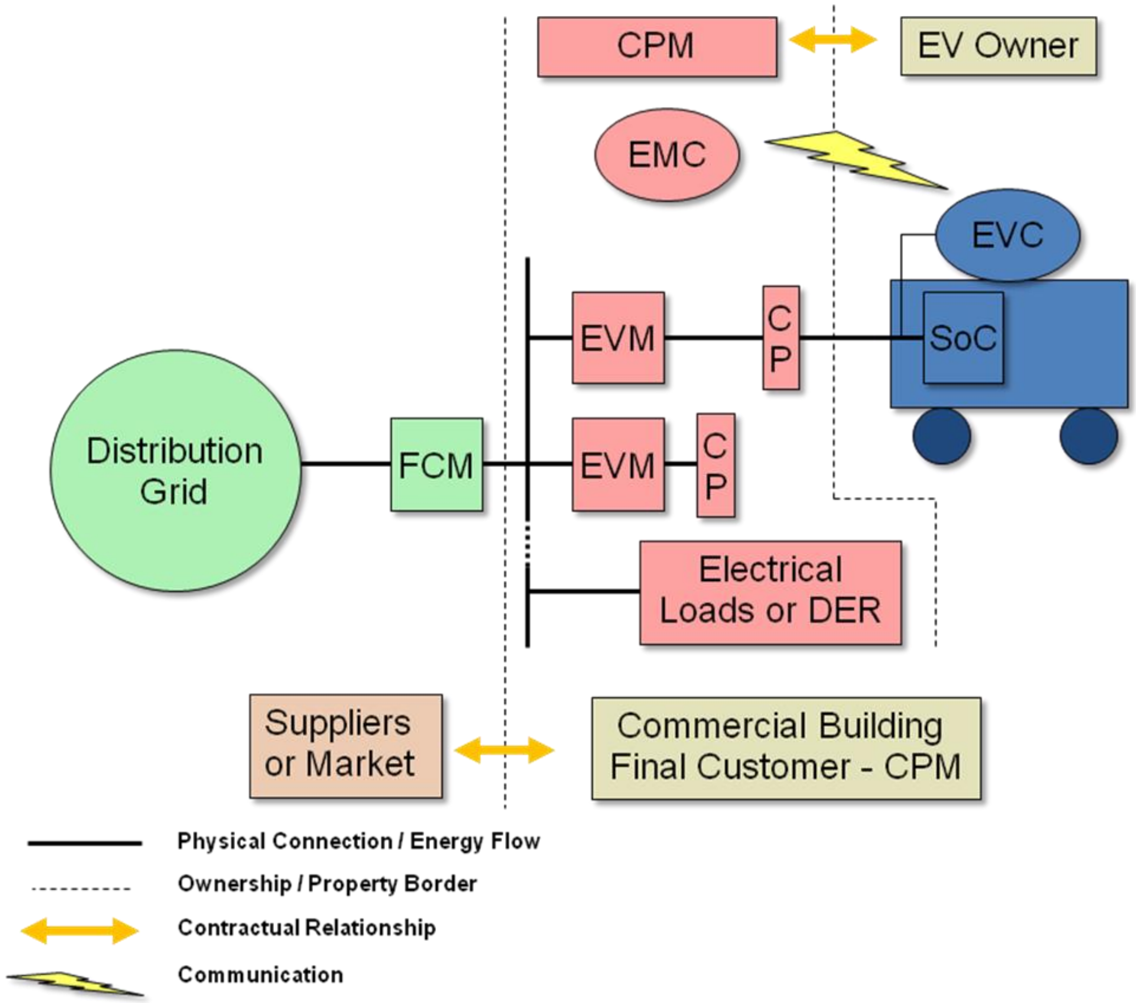

Fig 7. Privately owned charging station offering special services

Agents involved: Charging station owner (CPM), EV owners, electricity supplier and distributor.

Communication and charge control: Each EV will communicate its charging requirements through the on-board EVC to the EMC, and the EMC, if there is enough time, might optimize its charge subject to the imposed charging constraints.

Contracts and settlement: There would be a supply contract between an electricity supplier and the charging station owner (CPM) as a final customer, or the charging station could participate directly in the energy market. In the first case, the station owner would negotiate ToU energy rates or hourly prices and demand response services. The supply contract would be settled according to the energy and peak demand measured by the FCM, which should be upgraded to be a smart meter.

The charging station owner would notify the electricity supplier about the required connection capacity and the electricity supplier would forward this information to the distributor. The electricity supplier would pay to the distributor the regulated network charges based on the volumes measured by the FCM.

Each EV owner will be charged according to the energy amount transferred to the battery and measured by the EVM, the type of charge (regular, fast or ultra-fast) and the time when the charge was made. Charging at peak hours would be more expensive than at off-peak hours.

The profitability of this business will be determined by the capability of offering differentiated charging services that could not be obtained at home or in public parking areas and would be needed and appreciated by EV owners.

4.2.3 EV charge at home under EVS-A management HO-EVSA-CC

In this mode the EVS-A acts as an intermediate agent participating in the energy wholesale market while reselling this energy to EV owners who are managed under a charging contract. The EVS-A could conduct an integrated energy optimization by aggregating several charging points at the residential level (HO-SA-UCO) additional to the EV contracts associated with public charging points (PR-CPM-CC). As described before, this scheme allows separate pricing of energy consumed at home for transportation purposes, and therefore it makes it possible to include specific taxes or special rates.

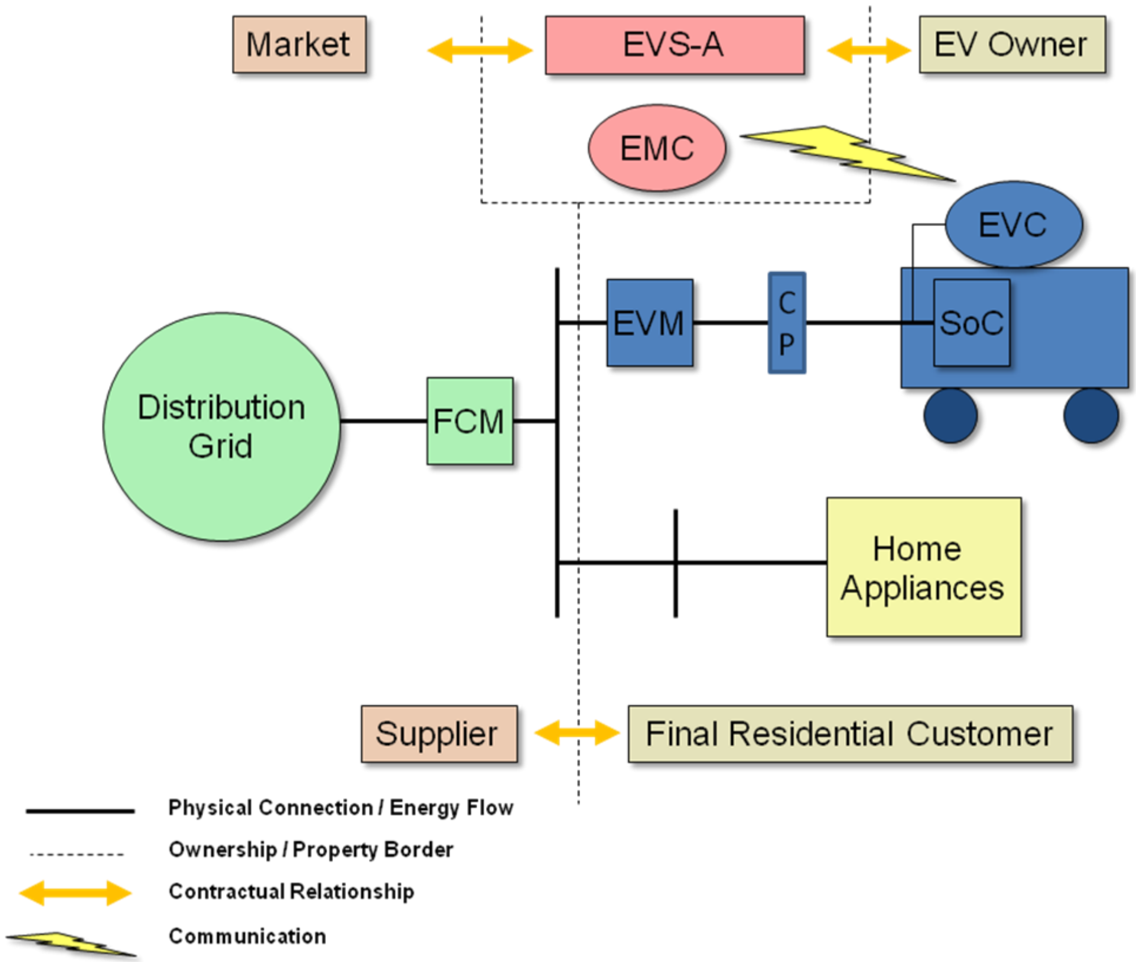

Figure 8. EV home charge under EVS-A management

Agents involved: the EV owner, the EV aggregator, and the distributor.

Communication and charge control: The home owner installs the EVSE and notifies the EV aggregator the maximum required charging power. The EV aggregator will install the EVM and communicate his EMC with the on-board EVC. Under this scheme, the EVC will communicate the time of connection and the energy demand to the EMC when the EV is connected at home. Then the EMC will provide the EVC with a charging schedule that satisfies those requirements. The EV aggregator will optimize energy volumes and periods for charging EVs in order to maximize its profits. There is a need for validation of the scheduling profiles with the DSO, which requires an interaction between the Aggregator and the local DSO.

Contracts: A charging contract between the EV aggregator and the EV owner. On the other hand, the aggregator would sign contracts with other electricity suppliers or would buy energy in the market, while paying network charges for each connection point to distributors.

Settlement: The charging contract between EV aggregator and EV owner will be settled according to the energy volumes and peak power measured by EVM, considering the prices and other conditions agreed upon. The supply contract between other electricity suppliers and the EV aggregator will be settled according to the energy volumes measured by FCM and the agreed prices and condition. The EV aggregator would negotiate one single supply contract for providing energy to many charging points. The EV aggregator would pay network charges to distributors for each connection point according regulated rates and volumes measured by FCM.

Observe that under this scheme it would also be possible to introduce vehicle-to-grid services through the EV aggregator, for instance providing power for the grid at peak hours or offering frequency regulation to the ISO.

4.2.4 Commercial or office building with EV parking and integrated management of energy PR-CPM-V2B

In this mode, it is assumed that the building acts as a CPM. It purchases energy to resell it to EV owners[15]. EV owners can be employees in an office building or customers in a commercial building. The CPM strategy is to maximize its profit as the difference between energy payments to the electricity supplier and revenues from EV charges or simply minimize energy payments to the electricity supplier. (Momber et al. 2010)

The building owner acting as CPM would install the required charging infrastructure. The cost of this infrastructure would depend on the type of parking access, the requirement for billing or not, the available charging power, etc. For instance, in Figure 8 the case in which the CPM will measure individual consumptions in each charging point (EVM) for billing purposes and will manage the charging periods through the EMC is represented. The infrastructure cost associated with this scenario is clearly much higher than the case where there would not be billing of energy, neither need for EVMs, nor management of the charging periods, and no need for EMC and communications.

[15] In this case it is assumed that the office or commercial building has a specific type of relationship with parked car owners, therefore it could provide the charging electricity service as part of this labour or commercial relationship, there would not be necessarily a payment from the EV owner to the building owner.

This charging mode is denominated V2B because the fleet of EVs connected to the building and mainly serves the needs of the building. The integrated management assures that the storage capacity is acting in response to the requirements of the building. It is important to understand the difference of this arrangement in comparison to the V2G concept, in which the vehicles are responding to communication signals from the system operator.

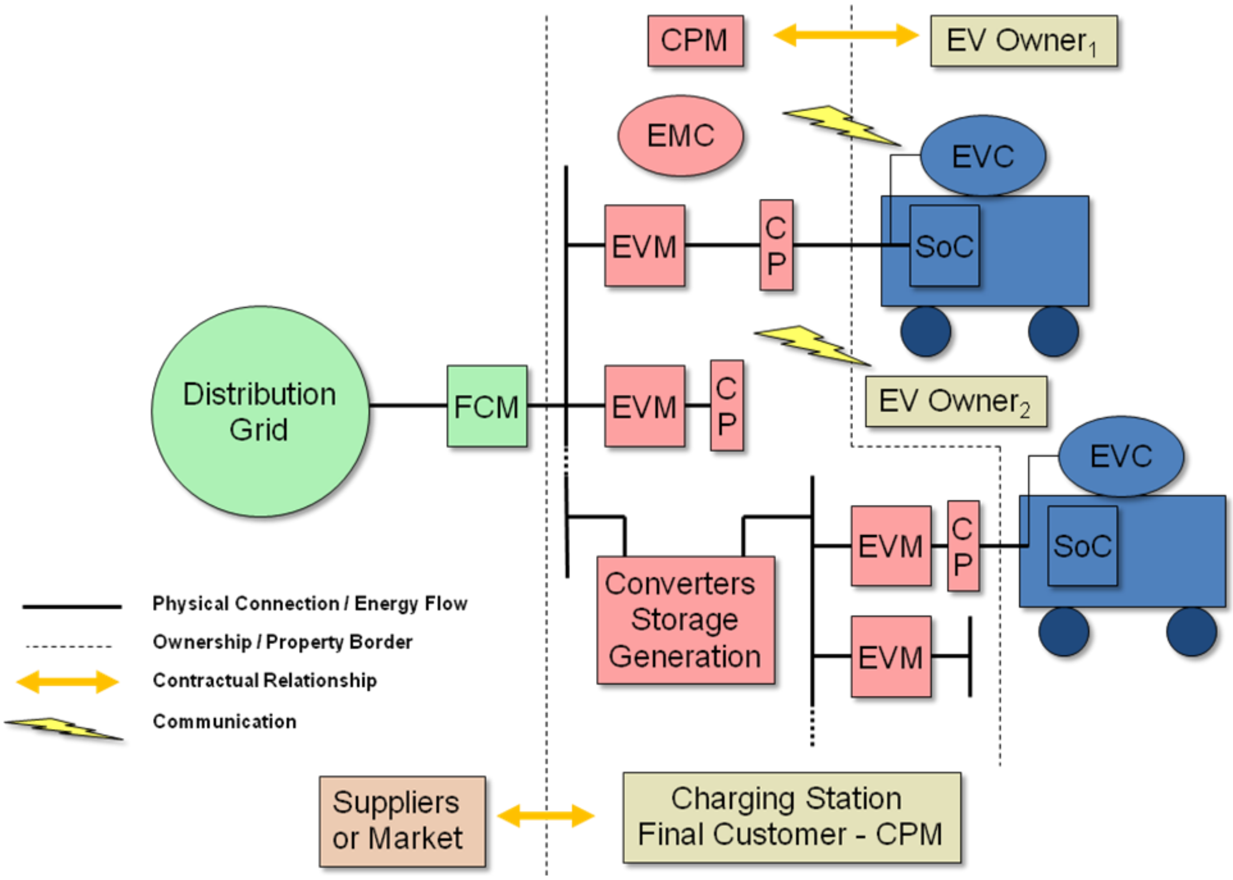

Figure 9: CPM as commercial or office building with integrated energy management

Agents involved: the office building owner acting as CPM, the EV owners, the electricity supplier, and the distributor.

Contracts and settlement: The supply contract between electricity supplier and building owner as a final customer is settled according to the energy measured by the FCM. This can be a traditional regulated contract with a demand charge and differentiated ToU energy rates, or a more advanced contract including a smart meter with hourly prices or critical peak pricing.

The building CPM can agree on the conditions for EV charging with the vehicle owners. The charge for services from building to EV owner will be paid according to the energy measured by EVM and the agreed price. [16] The building owner would

[16] Energy costs associated with charging parked vehicles on a daily basis are estimated to be very low. For instance, daily charges of 15 kWh, 5 hours connection at 3 kW, will allow

disclose the electricity supplier the additional required connection capacity while the electricity supplier would forward this information to the distributor. The electricity supplier would pay the distributor the regulated network charges based on the volumes measured by the FCM.

In the most sophisticated management mode, the CPM will conduct an integrated energy dispatch taking into account its energy needs as well as the volumes and periods of charging required by connected EV owners. This would result in an optimization problem where the decision variables would be the power to be injected into the EV batteries in each period of time, for instance every 15 minutes. Therefore each EVC will communicate to the EMC its requirements and the EMC will optimize the charging schedule for each EV connected sending back this information.

In this charging mode another possibility for the building owner is to delegate all the control and management of EV charging to an EV aggregator as it was proposed previously for residential EV charging.

4.3 EV charging modes for provision of V2G services by EV aggregators

In the previous modes we have assumed that the main goal was to supply electricity to charge EV batteries according to EV owners' driving requirements. The vehicle to grid (V2G) concept presents more sophisticated EV charging modes that require further technology deployment and contractual arrangements. EVs connected to the grid can be a valuable resource by adjusting their rate of charge or injecting power into the grid that would help to optimize power operation and minimize system costs EVs would obtain some revenues in exchange.

To make this charging mode possible, EVs would be equipped with an inverter and a control system that would inject power from the battery to the grid or vice versa, and the EV meter would count energy flows in both directions.

The EV aggregator will optimize the EV resources as storage that can be charged in some periods and discharged in others, always subject to driving constraints imposed by EV owners. In addition, he/she could subscribe specific contracts with an Independent System Operator (ISO) to provide regulation reserves or to sell or buy energy in real-time or day-ahead markets. In those cases specific metering and communication equipment should be deployed to meet the requirements to participate in those markets.

It is clear that despite the fact that one single CPM could provide V2G services this type of business would make only sense if an EV aggregator pools at least hundreds of EV units to acquire an equivalent size of MWs while benefiting from economies of scale in order to participate in the ISO markets.

Therefore, all the presented previous modes can be revisited assuming that EVs have V2G capability.

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driving a distance of 75 km at a cost of 2.25 €, assuming an electricity rate of 0.15 €/kWh. This cost can be integrated in the parking ticket or given by free to employees.

4.3.1 EV is managed at home as a storage resource to minimize electricity payments HO-SA-V2H

This is a variant of the charging mode presented for EV charging at home. In the proposed variant there is no need for special EV aggregators because the EV does not provide services to the ISO and therefore SAs can perform the task.

If the supply contract subscribed by the residential customer has different electricity prices for peak and off-peak hours then the EV can be managed to store energy at off-peak prices and to produce that energy at peak prices minimizing the home electricity payments in terms of capacity and energy. The dispatch of the EV as a generator needs to me managed by an energy management system, most probably requiring additional investment. The profitability of this strategy will be determined by EV parking times at home, EV battery efficiency and degradation, as well as hourly electricity price spreads (Momber et al, 2010).

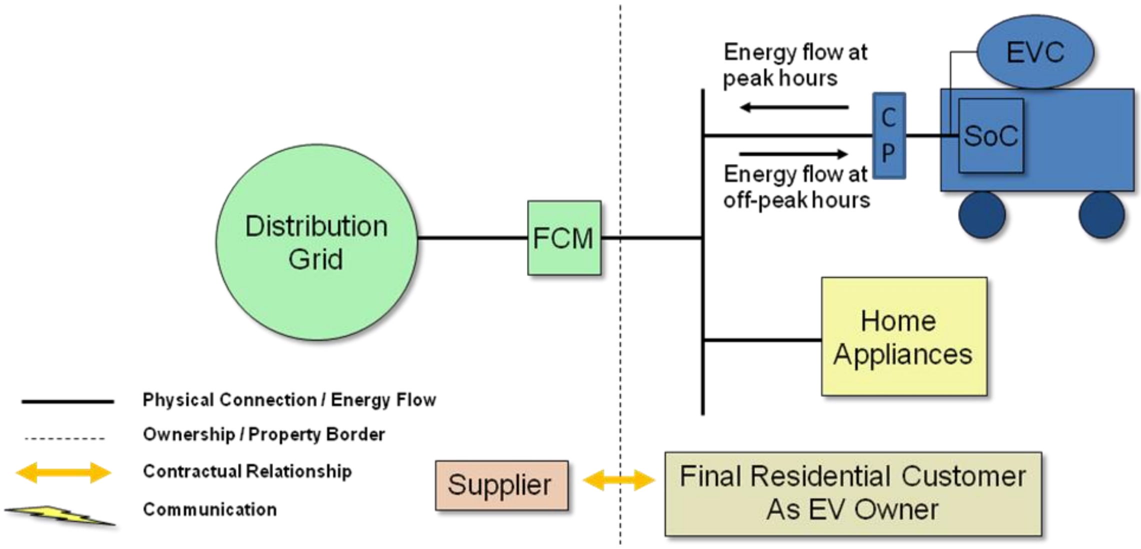

Figure 10. EV providing V2G to minimize home electricity payments

This type of business can be of interest for electricity suppliers and load aggregators that offer those services to residential customers making an integrated management of their energy consumptions including EVs.

This charging mode is denominated V2H because the EV is connected to the residential building and mainly serves the needs of the building. The integrated management assures that the storage capacity is acting in response to the requirements of the building. Even though there could be energy injections from the EV battery, it is important to understand the difference of this arrangement in comparison to the V2G concept, in which the vehicles are responding to communication signals from the system operator.

4.3.2 EV connected at home providing V2G managed by an EV aggregator HO-EVSA-V2G

This EV charging mode is a variant of previously presented HO-EVSA-CC. In this case the EV aggregator would manage EVs with V2G capability to buy and sell energy at the day-ahead and real-time markets to provide regulation reserves under supervision and control of the ISO. The EV management controller (EMC) should have a communication system with the ISO/TSO in order to put energy bids and to follow AGC control instructions to provide regulation reserves. In a first step, it could be sufficient to adapt the charging of the EV in reaction to the communicated signals of the ISO, while in the longer term, the capability to inject power into the grid can be also implemented.

The measurement equipment should be bi-directional such that the EV can deliver both primary and secondary frequency regulation services, while not all the EV owners would have to adhere to these concepts.

For islanded systems, participation in primary frequency control is of utmost importance and should be envisaged through a local autonomous control while for secondary frequency control this should be defined by the TSO from the AGC.

For participation in primary frequency control it is necessary to identify a new remuneration scheme, which as of today this usually a non remunerated service for normal generation.

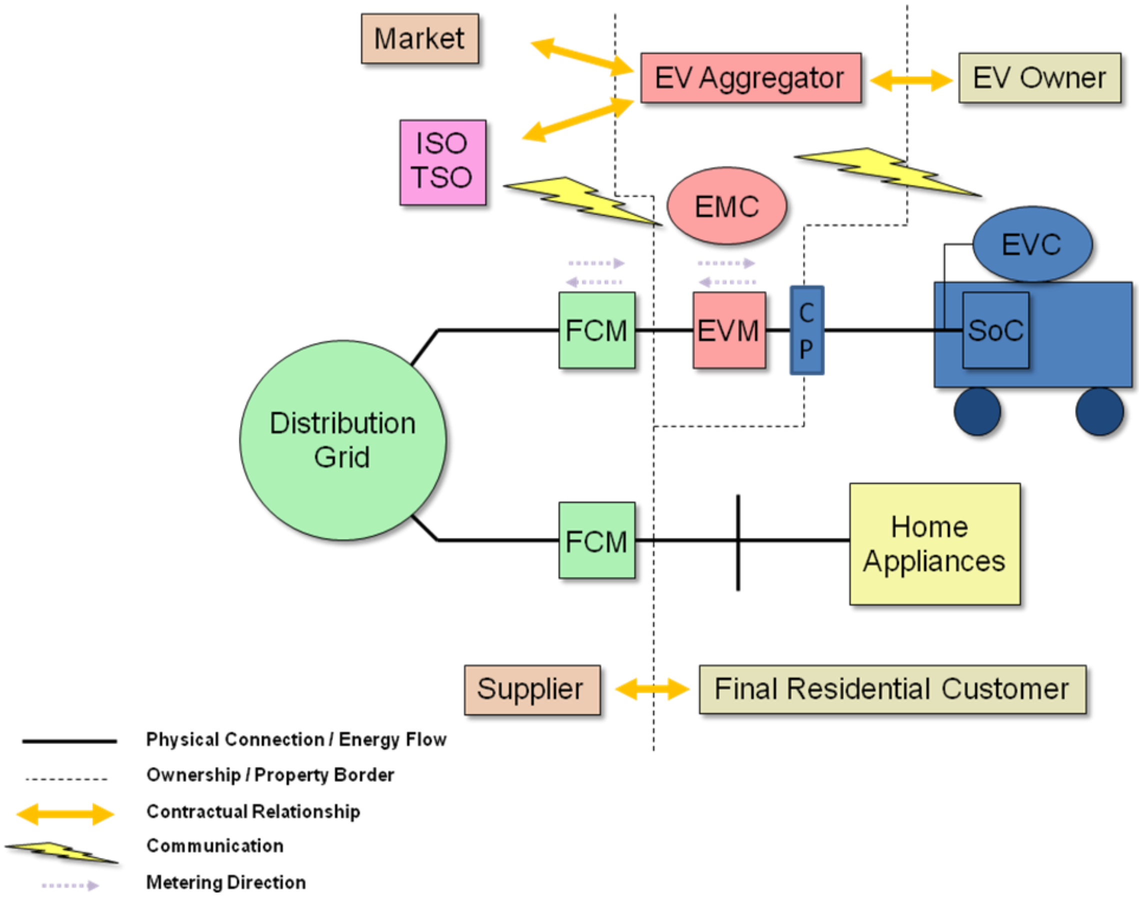

Figure 11. EV aggregator providing V2G services with home connected EVs

The EV aggregator will be compensated by the ISO or TSO for the services provided and he will compensate the EV owners too. The optimization of management strategies and the sharing of profits among the EV manager and EV owners is a complex mathematical programming problem (Beer et al, 2010).

4.3.3 EVs connected at public parking sites PU-EVSA-V2G, office or commercial buildings PR-CPM-EVSA-V2G providing V2G managed by an EV aggregator.

The EV charging mode with V2G for areas with public access would be similar to home charging presented in the previous section. It would be possible to pool V2G capabilities of connected cars with a contract with an EV aggregator for providing V2G services. The control and management of EV connected batteries would be assumed by the EMC of the aggregator. In these cases, similar metering, communication and contract arrangements with the ISO or TSO, as described for mode PU-EVSA-V2G, would be required too.

5 AUTOMOTIVE INDUSTRY

This chapter summarises the background and role of the automotive industry in the emerging EV market and gathers the main results of assessing how it will support the new market and potential new business models that may emerge as the market develops.

A series of roadmaps were developed, which detail how the automotive industry will introduce increasing levels of electrification in their fleets, for a range of types of vehicle from passenger cars to medium duty trucks. Roadmaps for the development of EV-related technologies such as batteries and electrical machines were also developed, showing how different technologies will enter the market and how some may decline or be superseded. Challenges, both technical and economic, were discussed.

Broad trends in the automotive industry were identified to provide a picture of how the industry has developed over the last twenty years and what consumers expect of their vehicles. This included trends in car ownership rates, new car registrations, diesel market share, engine power and displacement and fleet average CO2 emissions. The progression of technologies from conventional vehicles to full battery-electric vehicles, and eventually extended-range electric vehicles, in a series of phases was described.

Legislative emissions regulations, which represent the primary driver of the move to EV, were examined, showing how EV will help to achieve legislative targets for the automotive industry and quantifying how much progress needs to be made to achieve the 2015 target of European new car fleet average CO2 emissions of 120 g/km. Government incentives encouraging the uptake of low- or zero-emission vehicles were also discussed.

The roadmaps, trends and current and proposed emissions regulations and incentives programmes were combined to generate a series of penetration scenarios showing how many vehicles of each type will be sold in each region in the period 2010 to 2030. This became the primary deliverable of Task 3.2.

Strategies regarding charging and energy storage were discussed. Broad trends and assumptions were discussed, although the primary reports on these topics, with considerably more detail than is relevant to this report, are the reports on Task 1.1 and Task 2.1, respectively. Potential new business models – battery charging stations, battery swapping stations, battery leasing and grid balancing or ancillary services – were discussed in terms of their benefit to the end user and their interaction with the automotive industry, where appropriate.

For further in-depth reading please see the adjunct stand alone report on the automotive industry in appendix II.

6 EV USER'S PERSPECTIVE – SURVEYS ON BEHAVIOUR

This chapter provides an executive summary on the analyses of the willingness of potential EV users to make an effort in changing their current habits for refuelling internal combustion engine based vehicles to future recharging EV.

The appendix III contains two consumer surveys. The first survey investigated the consumers' general attitude toward EVs and their motivation to decide in favour of an EV when buying their next vehicle. After this rather general overview of the situation, there will be a more specific investigation on the potential customers' perception of the future charging process and its enabling or hampering impact on the mass introduction of EVs.

Therefore, in a first step, the current situation will be analysed. This includes a description of the traffic infrastructure in three selected markets. Moreover, the currently accepted ICE-vehicles shall be examined with respect to their fuel consumption and ranges and the driving habits of the customer segments they serve. On this basis, the requirements for a competitive charging interface for EVs will be defined.

In a first step, the current situation will be analysed. This includes a description of the traffic infrastructure in three selected markets. Moreover, the currently accepted ICE-vehicles shall be examined with respect to their fuel consumption and ranges and the driving habits of the customer segments they serve. On this basis, the requirements for a competitive charging interface for EVs will be defined.

In the subsequent chapter, a trend analysis of charging alternatives will be executed via literature references and expert consultation. The prerequisites for market success defined earlier will be taken into account. Furthermore, a typical refuelling process will be defined by means of observation and opposed to the future recharging practice.

The empirical part will then investigate the refuelling habits of conventional car drivers and compare these to three alternative recharging concepts for EVs. This will be survey driven. In the end, there shall be a recommendation on how designing the EV charging process in order to allow for maximum usability and customer acceptance.

For further in-depth reading please see the adjunct stand alone report on the consumer acceptance in appendix III.

7 OPPORTUNITIES AND THREATS FOR THE AGENTS' BUSINESS MODELS

In the perspective of the power system, the presence of EVs will lead both to opportunities and threats for the agents involved in the Electricity Sector. EVs could bring an added value to the electricity sector and each agent may play an important role contributing to maximize the net social benefit for the system as a whole.

With the support of the general framework and the charging modes described previously, this section identifies and qualitatively analyses the impact, opportunities and threats that the appearance of EV could bring up for the main players involved: Retailers, Aggregators and Charging Point Managers as well as Distribution and Transmission System Operators. Furthermore this section aims to make out each agent's internal business model regarding its role in dealing with EV by evaluating questions as to how agents contribute to enhance the added value related to the appearance of EVs in the electric power system. Even though the specific value creation will be decided freely by each agent, there are common properties concerning its operational decision process, inputs required, internal functionalities, outputs provided, risks faced as well the interaction with other actors and markets.

7.1 Retailers, Aggregators & Charging Point Managers

This section introduces the roles of retailers in their function as aggregators as well as the charging point managers. With electric vehicles penetrating the electric power system massively, both of the agents may face new and special internal business models regarding opportunities and threats and prospective profits and losses of their activities. The following paragraphs are building upon the definitions of the agent's functions in chapter 2 and the basic charging modes derived in chapter 4.

In the first three subsections, the key agents are presented in the less complex short term charging modes, while further on, the future, long term V2G charging modes are shown. Concretely, section 7.1.1 talks about the simplest and most probable, uncontrolled or V2H charging modes, in which regular, traditional supplier aggregators would present the main agent in facilitating the unidirectional charges or vehicle support for home appliances to optimize the grid interface of the final domestic customer with an electric vehicle attached. Further on, section 7.1.2 focuses on the role of charging point managers as the intermediate agents in uncontrolled charging modes and V2B scenarios. Section 7.1.3 highlights the functions of electric vehicle supplier aggregators facilitating controlled charging scenarios at home and on public property. The section 7.1.4 accentuates the interaction of both charging point managers and supplier aggregators in the future or long term V2G scenarios. Finally, the transversal functions of battery swapping stations and IT service providers are approached.

7.1.1 Supplier Aggregators in Uncontrolled and V2H Charging Modes

Electricity supplier or electricity retailer is the agent who sells energy to final customers, the electricity end consumers. As defined in chapter 2, in this report the term retailer and supplier is used equally and it is assumed that there is no difference among the two. The supplier therefore aggregates contracts with final customers and procures the energy in the wholesale markets, and possibly agrees on demand side reductions measures of the final customers to be offering other services to the market. Hence it is denominated supplier aggregator (SA)

In countries where electricity distribution and supply have been unbundled to favour competition among agents, all final customers have access to competing generators through their choice of SAs and regulated tariffs, if they exist, are intended to only present a back-up option. In these cases, final customers remunerate the electricity supplier for the service who in return procures the energy and pays the distributors regulated charges for grid services and other system costs.

From a regulatory point of view, the system is designed such that the suppliers are serving the unbundled electric power industry in many ways. The competition among them is supposed to reduce the costs of customer services, while they are adapting the final price options to the specific preferences of the final customer by promoting new products and services.

The activities of a retailer or supplier comprise so called technical and economic tasks. The technical tasks that a retailer has to carry out include the billing of the energy consumed by the final customer according to energy and capacity prices set in the agreed contract. Therefore of course a retailer has to store and use the information on the consumption of each final customer. The data needs to be metered, but this could be done by certified independent third party metering companies, if not the DSO is required to perform that by legislation. The economic tasks embrace the acquisition of energy, e.g. in a power exchange, which entails assuming certain levels of risk, which are much higher than in those businesses that are regulated ones such as for example distribution, and the commercial relationships with the existing and potential new customers. In order to complete these two sets of tasks, demand has to be forecasted for the different groups of contracted customers, access of the network managed in terms of new users switching, and financial guarantees for the trading have to be met (Batlle 2010). The responsibility of assuring that the customer enjoys an adequate level of technical quality of service does not lie with the retailing company. It is subject to the regulation of distribution networks.

The SAs are market players that bridge the trading gap between generation and demand by lot size transformation from the wholesale to the retail market. The profits result from the difference in prices at wholesale and final customer level. In order to assure a viable business model, the aggregated demand for the final customers has to be as accurately forecasted as possible, and then accordingly procured. If positions do not close as expected, that is, if the forecasting errors are causing a need for balancing of supply and the aggregated SA's demand, more costly products have to be procured. Due to the uncertainty, stand-alone retailing is regarded a high-risk and low-return business. In theory it is of high interest to the SA to obtain a very flexible demand which is able to respond to varying market prices in order to reflect the actual opportunity cost of the customers more appropriately and pass on part of the risk exposure to the final customers.

In the uncontrolled and V2H charging modes, most of the functions and objectives of the SA stay the same. In the described scenarios HO-SA-UCO and HO-SA-V2H where EVs are charged at home the EVs will merely present and additional net load to the SAs of domestic electricity customers. In short, this load is more volatile because it is a flexibly schedulable charge and hence presents the opportunity for more business, but also the threat of adding uncertainty to the forecasting. As there is no control over the charging process from the SA, the main means of influencing the charge of the electric vehicles will be the offer of EV user customized electricity prices with at least ToU differentiation. The main objective remains, to get the demand side involved in the market game by passing on the volatility of prices and thereby reducing its own risk. The proposition by electric vehicles could be theoretically a valuable one, as they present schedulable loads, which if reacting to the price signals may contribute to reduce uncertainty and risk exposure of the SAs, while increasing turnover significantly.

7.1.2 Charging Point Managers under Controlled Charging and/or V2B

Conform to the definition given in Chapter 2 Charging Point Managers or CPMs would be acting as final customers on private property with public access. They are understood to be buying the required electricity to resell it to other EV owners connected to the charging station under a commercial agreement with specific terms and conditions.

To the distribution system however, a CPM is regarded as a single final customer, which has to pay the regulated access tariff according to his contracted capacity and consumption measured on his interface to the network. CPMs should be free to define their objective function that is most beneficial to them. This could include an installation of EVSE that meters the connection points of each and every car and design according rates for the usage of this infrastructure. On the other hand, it could be favourable for the CPM to simply charge for parking time and space without measuring user specific consumptions by internalizing energy procurement and infrastructure investment costs on an aggregated level in the parking time rates. Hence, the CPM could be offering the charging of the electric vehicle as an additional service to customers with whom there already is some other type of commercial agreement. The second arrangement alludes to the main challenge of a regulatory framework forming the basis of legislation that fixes the rules for such operation of the charging service. Any set of requirements concerning metering layouts, financial liability and technical capability should be designed according to the principle of non-over-complication, applying restrictions only where absolutely necessary. In this regard, the regulatory framework could be an opportunity for CPMs to ease and foster business arrangements, or a threat that a highly complex business can only be taken over by specialized, possibly large players with high market shares.

It is important to note that the CPM, in both charging scenarios PR-CPM-CC and PR-CPM-V2B, is combining the ownership and operation of the charging infrastructure while managing its interconnection of the load according to the economic conditions determined by the perceived energy rates, access tariffs, investment expenditures on EVSE and the negotiated contractual conditions with the EV owners.

The major source of revenue to recover the initial outlay for the installation of charging investment is the margin between energy prices at procurement and revenues or business added value from EV owners. Therefore the greatest risk is posed by miscalculating future quantities and prices of energy sold at the time of investment decision. It could be estimated, that the activity of a CPM is rather local. Having one final connection point with the distribution system, being the intermediary agent between one supplier and a small size fleet of changing customers should be a business that is easier to oversee and therefore less risky

7.1.3 Electric Vehicle Supplier Aggregators in Controlled Charging Modes at Home and on Public Property

The Electric Vehicle Supplier Aggregator (EVS-A) is a specialized agent in providing charging services to the final customer, the EV user or driver. As introduced in the preceding chapters, the EVS-A is understood to appear basically in two possible settings, privately owned charging areas with private or public access for EV owners, and public charging areas with public access for EV owners.

In both cases, the charging infrastructure and the EVSE are owned by other agents and therefore the EVS-A is, disregarding V2G scenarios, really similar to the SA, an agent without physical assets carrying out the same technical and economic tasks.

On private property in domestic dwellings, the home owner is supposed to equip himself with the necessary charging installations while in areas involving public goods on public property, it is assumed, that the DSO or a similar specialized, fully regulated company would adopt the functions of infrastructure deployment and ownership. This entity would be unbundled from any retail activity, completely agnostic towards the EVS-As commercial relationships, only granting non-discriminatory access to the charging stations, for EVS-A as well as for the final EV owner. The business of the EVS-A is therefore essentially the same in both charging scenarios HO-EVSA-CC and PU-EVSA-CC.

The EVS-A predominantly being a pure EV electricity supplier, is the agent selling electricity to the EV owner. For example, EV owners could have a supply contract with an EV electricity supplier valid in different charging points. The novelty about this agent is that its contracts are not location based or bound to a single final outlet. The customers, the EV users might demand mobility and freedom to choose multiple charging points while remaining with the same EVS-A. EV electricity suppliers are retailers and therefore their business should be declared competitive activity unbundled from other vertical functions in the electric power system.

The unbundling of the EVS-A from charging infrastructure ownership is an important regulatory point to foster competition among different EVS-A. The same arguments hold, as they count for the unbundling of “regular” retailing activity from other steps in the electricity value chain. It is not sufficient to let one monopolistic retailer be offering one regulated tariff because this is suppressing cost efficient reductions of final prices of the services for final customers. As EVs are schedulable loads (this argument is reinforced with V2G provision), they could capture lots of value (or reduce the cost) during times of being connected. The margin that is given there is dependent on each of the EV user’s mobility pattern and therefore customized tariff packages (possibly with battery ownership and leasing) could be offered and reduce the prices or costs of the service to the final customers.

The EVS-A’s business contains significant differences to the activity of a CPM, as in general EVS-As are expected to aggregate multiple, hundreds or thousands of EV contracts to conduct an integrated management. Their exposure to market price volatility depends on the type of contract with the EV owners and essentially on the amount of variability passed on to them via charging rates. But this risk exposure, and the predominant threat of poor load forecasting, unavailability for balancing services and unprofitable energy procurements, will certainly surpass the one of CPMs and therefore will demand higher financial liability.

7.1.4 EVS-A Facilitating V2G in the Long Term

In the long term, the EVS-A is regarded to play the key role in facilitating the provision of V2G services. This could emerge either at home HO-EVSA-V2G or on private property with public access managed by CPMs PR-CPM-EVSA-V2G or on public property through DSO owned infrastructure PU-EVSA-V2G. In these rather futuristic scenarios, the contracted fleet of vehicles is creating value by facilitating bidirectional power exchange between vehicles and thus selling ancillary services to the ISO/TSO to manage grid security and stability. In all of these cases, the EVSA remains the intermediate agent bridging the gap between final EV users and the electric power system procuring the required energy demand and offering remunerated ancillary services based on load reductions, power injections, and regulation energy for power/frequency control.. In no instance the EVSA is an infrastructure owner or operator, but is rather only granted non-discriminatory access, while being in competition with other EVSA.

In addition to the activities carried out as a specialized SA for EV, the EVS-A then would have to predict the availability of the contracted car fleet to be connected to provide these services in order to estimate the timing and sizing of the bids for regulation energy. The strategy of these bids highly depend on the types of market, their rules and requirements for participation and is by far no trivial task. Furthermore, the EVS-A would need to find market situations, in which the provision of ancillary services is valuable enough to incentivize the final EV user (or whoever is owning the battery and caring about the economics of its operation) to compensate for battery degradation due to its use. Hence, the activity of EVS-As would include the estimation of these costs and require profound knowledge of the storage medium’s chemistry. Under- or overestimations would present a significant threat for the EVS-A.

The V2G charging modes pose an interesting challenge to the regulation of network usage and compensation similar to the one presented by high penetration of distributed generation on the grid. Regulation should acknowledge through an adequate design of regulated network charges paid by EVS-A, the costs incurred by DSOs due to variation of power flows, decrease in total energy delivered, increase in losses as well as the benefits incurred due to for instance deferral of investments related to network reinforcement.

	Electricity Supplier Aggregator (SA)	Charging Point Manager (CPM)	EV Supplier Aggregator (EVS-A)
Opportunities	Additional Load	Extension of other business to the offer of charging services	Management of a high energy demand per customer
	Turnover Increase	Turnover increase by electricity trading	Highly flexible and schedulable load
	Increase in Demand Flexibility	Simple regulatory framework easing the offer of charging services	Valuation of network investment deferral
	Demand Response to Price Signals	Offering charging services attracts clients for other business	V2G prospects for participation in ancillary service markets
Threats	Lack of Control	Strict financial liability requirements	High uncertainty: Availability forecast deviations
	Increased Demand Volatility	False long-term load forecasts to recover equipment costs	High risk exposure to market price volatility
	Added Uncertainty: Forecasting becomes more difficult	Over-complicated regulation as reselling entities	Under-/Overestimation of battery degradation costs

Table 1: Opportunities and Threats for SAs, CPMs and EVS-As

7.1.5 Battery Leasing and Battery Swapping Stations

With the advancing of EV deployment for massive use, specialized activities around battery ownership and operation will emerge, allowing for the appearance of new agents engaging in the business of battery leasing and battery swapping stations. For such agents, a capital intensive investment in batteries and or battery swapping stations would be indispensable. Revenue streams would emerge from final EV customers demanding either the lease of the storage technology, or a type of a mobility contract guaranteeing charges and swaps within a certain territory. A main hurdle for such business models to arise is the currently projected lack of standardization of the batteries (or their interfaces with the vehicles). In any case, similar to the EVS-A in V2G scenarios, a profound knowledge of the storage technology is required to make accurate estimation of the costs incurred by the usage of the battery to find adequate leasing or mobility rates.

A swapping station with a certain amount of batteries in stock and consequently a generally high net energy demand will engage in optimizing the charge of these batteries similar to the activity of a CPM with cars connected. Being a final customer it would have the opportunity to optimize the interface to the grid by scheduling the charges at the economically most favorable times. In future scenarios, the provision of V2G of such a battery stock is imaginable. Compared to an EVS-A with similar storage quantities contracted, the battery swapping station has a flexibility advantage and might need less communication technology because of the locational concentration of stationary battery stocks.

7.1.6 IT service provider

IT-service providers would assume auxiliary functions that are indispensible for the functioning of the entire system, which is highly dependent on communication and real time information exchange of the various agents in different charging scenarios. Hence, the IT service provider can be perceived as the necessary link that is not directly involved in the key business but rather provides highly specialized communication services that are essential to the business models of the other agents.

7.2 Distribution System Operators

This section provides an overview of the role of DSOs as managers of the distribution network and how this may have to evolve in order to ease the integration of EVs. Firstly, the conventional structure of a distribution network and the functions of DSOs and their regulation will be briefly described. Secondly, the possible stages of the introduction of EVs into distribution networks are enumerated. Finally, a review of the new threats and opportunities faced by DSOs in an environment where EVs play a significant role will be performed. The integration stages previously identified will be taken into account for this analysis.

7.2.1 Distribution networks and the role of DSOs:

DSOs are the agents in charge of building and operating the distribution grid. In some countries, DSOs are also in charge of metering electricity consumption or setting distribution tariffs (within the limits set by the regulator). Consequently, the effects of EVs on these issues will also be analysed below.

The typical structure of a distribution grid is shown in Figure 11. Firstly, the HV sub-transmission grid is located downstream of the transmission grid up to the distribution HV/MV substations. The sub-transmission grids are generally built and operated in meshed configuration, similarly to transmission networks. In fact, in some systems the sub-transmission network belongs to the TSO. Distribution substations connect the HV and the MV networks. MV networks are operated in radial configuration, albeit they are partially meshed in order to allow for reconfiguration so as to minimise the number and duration of interruptions. Finally, the MV/LV transformers supply the LV grids which are totally radial. EVs will be presumably connected to LV level or to MV when several vehicles are charging at the same place, e.g. a dedicated charging station, or a fast battery charging is required.

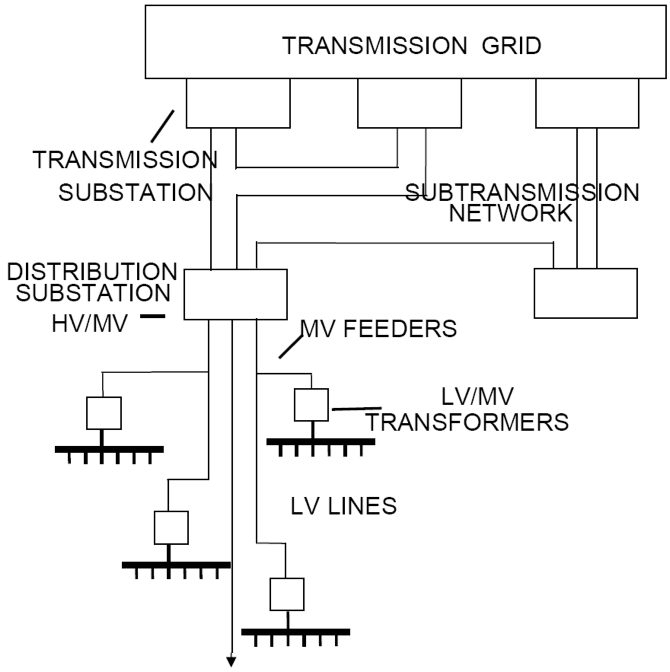

Figure 12: Typical structure of a distribution network

Traditionally, distribution grids were built so as to meet the expected growth in demand and operated passively assuming unidirectional power flows. However, there are several factors that are rapidly modifying this paradigm. On the one hand, new types of agents connected to the distribution network are starting to arise. These are active consumers, distributed generation and EVs. On the other hand, technological developments and the increased dependence on secure and reliable electricity supply of modern societies have led to the enhancement of the functionalities of electricity networks. As a result, distribution networks are rapidly evolving towards what is known as smart distribution grids. Smart grids will require innovative operating and planning approaches as well as the deployment of new communications and electronic devices throughout the electricity grid.

Electricity distribution is a regulated activity since it is deemed to posses the characteristics of natural monopoly. Therefore, it is the task of regulators to determine the revenues or tariffs that DSOs are allowed to collect from distribution network users. Originally, DSOs were regulated according to a cost of service approach, i.e. DSOs were remunerated their actual costs plus a "fair" return on their investments. This regulatory method is also known as rate of return or cost plus regulation. Cost of service regulation was widely criticised for not providing efficient incentives to DSOs. Hence, some form of incentive regulation has been implemented in most European countries. There are several different approaches to incentive regulation. Notwithstanding, they all share the characteristic that prices/revenues are decoupled from the actual distribution costs. Therefore, DSOs are incentivised to reduce their costs and earn the price differential. In order to avoid reducing costs at the expense of quality, additional regulatory mechanisms are usually implemented.

Given that DSOs are regulated entities, the transition towards smart distribution grids heavily relies on the design of an appropriate regulatory framework. Thus, regulatory frameworks should be adapted so as to align the signals perceived by

DSOs with the needs of consumers. Otherwise, the outputs desired may not be attained. In line with this argument, the threats and opportunities faced by DSOs as a consequence of the integration of EVs greatly depend on the specific regulatory arrangements, i.e. how allowed revenues are computed, what kind of regulatory incentives are in place, etc.

7.2.2 The progressive integration of EVs:

The adoption of the EV and its integration into electric power systems will not occur overnight. More likely, the penetration rates of EVs will grow gradually over the coming years. The pace of adoption of EVs in each region will depend on a myriad of factors such as possible economic incentives to purchase an EV, future technological developments, cultural factors, enforcement of environmental commitments, average commuting distances, etc. For illustrative purposes, this process has been divided into three subsequent stages. Note that this classification is made from the viewpoint of the distribution network and it may not fit for other purposes. These stages, ordered from the short to the long term, are:

i. **Uncoordinated charging**: Initially, EVs will likely behave as any other conventional load, i.e. EV users will plug them in for charging whenever they want. At this stage, there is no automatic control over the charge despite the fact that EV owners may pay time of use electricity tariffs. Consequently, DSOs will have to forecast the load growth in each distribution area and dimension the network accordingly. In order to do this, the DSO would have to estimate the charging profile of EVs which depends on the driving needs of EV users and the tariff schemes with time of use discrimination.

   Since the monitoring and control over EV charging at this stage is negligible, the DSO may not use them for operational purposes e.g. reduction of losses, voltage control, etc.

   Battery charging will mostly take place at home and to a lesser extent in charging points located in public areas such as streets, i.e. at consumer premises. These correspond to the EV charging modes located at the top of Figure 2. Thus, the evening peak in some residential areas could increase substantially if the adoption of EVs is high. During this initial stage, the number of EVs may not be large enough to foster the creation of independent EVS-A and large charging stations. Hence, battery charging in private areas with public access will not be very relevant at this stage.

   The uncoordinated charging of EVs may create several problems to DSOs, particularly in those areas where large penetration rates have occurred. These problems comprise operational issues, such as **increased energy losses** or **excessive voltage drops** (Clement-Nyns et al., 2009), and planning aspects, mainly **reinforcements needed to cope with EV charging** (Pieltain et al., 2009). From the regulatory and normative point of view, distribution network planning procedures and the computation of allowed revenues including the incremental costs driven by EVs will presumably be the central issues.

   Furthermore, the roll out of public charging infrastructure and how users pay for its use (free charging, pre-paid cards, coin slots on charging posts, etc.) will have to be addressed as well. This aspect is relevant to DSOs since they might be required to develop the infrastructures needed for this charging mode, at least in the initial stages.

ii. **Coordinated charging**: Coordinating and controlling the charging of batteries would minimise the negative effects caused by EVs and enhance their integration into power systems. Charging coordination will become much more relevant once overall EV penetration reaches significant levels. This control will be most likely done through economic incentives for EV users, which may have a local control system responding to the economic signals. Depending on the actual implementation, these incentives could be provided by DSOs, retailers, and/or EVS-A. In any case, it is not envisioned that DSOs direct control over battery charging. Therefore, should DSOs require certain services that can be provided by EVs, they would have to contract them from EVS-A and/or CPM. The coordination of the battery charging will allow DSOs to minimise the reinforcements needed in the network and mitigate operational problems caused by EVs.

As previously stated, coordinating battery charge is particularly relevant when EVs have been widely developed. Furthermore, a large volume of EVs will facilitate the charging mode in private areas with public access such as dedicated charging stations and car parks with charging infrastructure. Thus, the upper half of Figure 2 would be completed by this point. It is worth remarking that metering and billing may become much more complicated and new schemes may appear. These new schemes may involve dedicated meters, either on board the vehicle or on the charging posts.

The most relevant regulatory developments at this stage concern the **design of efficient economic incentives for EV users** and the definition of the **roles and responsibilities of the different agents** involved. These are mainly DSOs, retailers and EVS-A/CPM.

iii. **V2G implementation**: This is the final stage of the integration of EVs. In addition to being a controllable load from the point of view of the grid, EVs also provide certain system services by injecting energy back to the grid in certain periods. EVS-A/CPM will play a central role should the implementation of the V2G paradigm be successful. It is still to be determined what agent adopts this role, i.e. either new companies may arise or existing agents, such as retailers or car park owners, may adopt this role as a complement of their current functions. Since DSOs are regulated entities, they must be legally and functionally unbundled from other activities in the power sector (EU, 2009). Therefore, DSOs could not adopt the role of EVS-A but they could indeed contract certain services from them.

This stage implies that all the charging modes depicted in Figure 2 have been implemented. The developments in the distribution networks that are required for the V2G to become a reality do not differ much from the ones needed for the coordinated charging stage. The major differences will probably correspond to the meter (allowing for two-way power flows) and EVM functionalities (most likely outside the responsibilities of DSOs) and the contractual relationships between all the agents involved.

Regulation at this stage should focus on the definition of **technical and contractual requirements** to grant new agents the access to provide system and ancillary services. These could include DSOs in case EVs can provide some services at local level, similarly to DG or demand response. In any case, if the DSO performs the metering activity, it is the central agent in order to validate and bill the provision of those services whose settlement depends on the meter readings.

7.2.3 Threats and opportunities for DSOs as a result of the adoption of EVs:

The large-scale connection of EVs poses several challenges to DSOs. At the same time, EVs could become an added source of controllability and an extra driver to the implementation of enhanced communications and grid monitoring. Hereafter, the threats and opportunities for DSOs that have been identified will be described. This description intends to follow a chronological order consistent with the three stages previously described. The main threats and opportunities are summarised in Table and Table respectively.

– Threats:

From the DSO perspective, the main threats resulting from the adoption of EVs can be broadly classified under four topics: **network planning**, **operational aspects**, **metering issues** and **tariff setting**.

- Network planning:

  The uncoordinated charging of EV batteries may require **reinforcing the grid** in some areas due to the load increase caused by an uncoordinated charging. This may originate two kinds of problems for the DSOs. On the one hand, if the load growth in a particular region occurs very fast because of a very favourable environment for the adoption of EVs, the DSO affected may not be able to make the necessary reinforcements in time. On the other hand, reinforcing the grid comes at a cost. In case the allowed revenues of the DSOs computed by the regulator do not include these extra costs, they will be penalised.

  DSOs usually carry out **load forecasts** for the different areas in which they operate in order to develop their planning activities. These prognoses are based on historical load growths, connection requests and the DSO expertise. Nonetheless, the progressive introduction of EVs may hamper the task of network planners as traditional approaches to load forecasting do not consider this factor. Whenever the future load forecast is not accurate enough, the distribution grid will not be appropriately dimensioned. If load is greater than expected, the DSO may face congestions or voltage problems. On the contrary, if load is overestimated, investment costs will be higher than necessary and the consumers will pay higher distribution charges. In case the allowed revenues of DSOs do not include these investments, DSOs will bear these costs. Note that this risk already exists for conventional loads. Notwithstanding, adapting to the presence of EVs may involve a learning period for DSOs. This problem may become relevant when EV penetration rates have reached a significant level but DSOs still lack experience with the operation of distribution networks with EVs.

  DSOs could be given the responsibility of **being the charging infrastructure owners**, for example in charging modes for public areas with public access; see Figure 2. Being this the case, they would have to carry out **potentially high-risk investments**. The risks would be related with the possibility that EVs are not developed as expected and the possible lag between the development of the charging infrastructure and the adoption of EVs by consumers, as it seems unlikely that small car buyers opt for the electric option if the needed infrastructure is not in place. Therefore, it seems rather unlikely that DSOs develop the charging infrastructure unless cost recovery is enforced by regulation, at least in the initial stages.

However, if the charging infrastructure owner is different from the DSO, the **development of parallel networks** should be avoided following the principles of non-discriminatory network access. This is particularly relevant for the charging modes involving the use of public areas. Dedicated charging stations and car parks providing charging services would be treated as an individual consumer from the DSO point of view, despite the fact that their own electrical installations may be used to provide electricity to the final EV users.

- Grid operation:

Energy losses in distribution grids **will increase** as a result of EV battery charging, regardless this is coordinated or not. In the former scenario, peak demand in some areas will rise thus reducing the loss factor[17]. On the contrary, in the latter case it is consumption during valley hours that will increase the most thus increasing the loss factor. Incremental losses will be larger in case of uncoordinated charging since *copper* losses are proportional to the square of the current.

The impact of EVs on energy losses is intimately related with the incentives to reduce energy losses that regulators typically set to DSOs. This is basically done through a bonus-malus mechanism that penalises DSOs if losses exceed a certain threshold or reference value and are given an economic incentive if actual losses fall below the former threshold. The reference values are set according to historical values as a percentage over the total energy distributed. Therefore, depending on when the load growth caused by EVs take place, energy losses as a percentage of energy distributed can be affected differently. Consequently, if the reference values do not incorporate the effect of EV charging, DSOs can be unfairly penalised (unless some extra investments are included in the allowed revenue computation).

As previously mentioned, uncoordinated charging can result in significant load increases. This can create **excessive voltage drops**, thus creating voltage problems such as malfunctioning of certain loads. This issue can be especially relevant for weak radial networks.

Moreover, EVs may cause some power quality problems, e.g. high injection of harmonics, if on-board inverters do not fully comply with appropriate EMC standards.

Contrary to certain DG technologies, inverters do not provide short circuit current. Hence, it is not envisioned that EVs may cause the same protections problems as DG. Nonetheless, there have been some problems concerned with unintentional islanding in areas where several PV installations were located. These situations should be avoided due to security concerns. Unintentional islanding may occur in areas where several inverters (from PV plants) are connected in parallel and DG production is similar to the local load. Under the V2G paradigm, EVs could behave as inverter-based DG during certain periods. Notwithstanding, it is highly unlikely that the conditions required to have unintentional islanding problems could be caused by EVs. In any case, a

[17] The loss factor is the ratio of average energy losses over peak energy losses.

standardisation of the requirements for anti-islanding protections for inverters that takes into account the possibility of several of the connected in parallel ought to be in place.

Finally, in the long-term, DSOs may purchase certain services from EVS-A/CPM, for instance to manage congestions in the distribution grid. Nonetheless, EVS-A/CPM would have to control a large number of punctual loads whose state of charge and availability may not be fully ensured. Thus, EVS-A/CPM may apply some probabilistic method to provide system services. Nevertheless, these agents face some risk of not being able to deliver these system services in the conditions agreed. Being this the case, DSOs will have to face operational problems or even supply interruptions. These risks can be mitigated or shared if the DSO is allowed to set penalties for non-compliance or some other kind of enforcement is made.

Additionally, V2G services imply more battery cycling which prejudices the lifetime of the EV batteries. Therefore, consumers may not be willing to allow any agent to manage the energy stored in their cars if the cost of degrading the battery is not adequately compensated.

- Metering:

Different business models for EVs imply different metering arrangements. In the initial stages when battery charging may not be coordinated, current metering schemes may suffice. Being this the case, it must be ensured that the smart meters that are being deployed nowadays are able to cope with the future needs imposed by EVs. Otherwise, metering costs could increase substantially. Furthermore, as an enhanced coordination of the battery charging is made and EVS-A/CPM appear, dedicated meters and more complicated metering arrangements will be needed. DSOs will be responsible, in those systems where regulation states so, for those meters used for billing network charges and other system costs.

There are two broad approaches for metering at CPM premises. On the one hand, a CPM may become a single consumer from the viewpoint of the DSO thus requiring only one meter. In order to bill their customers, a CPM may install additional meters (outside the responsibility of the DSO) at each charging point or use simpler billing procedures. Being this the case, the DSO would just have to deploy one meter per CPM. On the contrary, every EV or charging point could be considered as a single consumer for billing purposes. This alternative would imply the deployment of a considerable amount of new meters, probably comparable to the ongoing roll-out of smart meters.

Appropriate regulation and standards would be needed in order to obtain a timely and cost efficient deployment of meters for EVs. Regulation should focus on the responsibilities of the different agents concerning metering and billing. On the other hand, standards ought to state clearly the technical requirements of the different types of meters. In several countries, DSOs carry out the metering activity. Therefore, they may be the pivotal player for metering purposes in those systems, unless regulation is changed.

- Tariff setting:

Distribution tariffs could be used to promote battery charging in those periods that are more convenient for the distribution network. As mentioned in the introduction, some DSOs are in charge of computing the distribution use of system charges paid by end consumers connected to distribution networks. Since distribution is a regulated activity, regulators typically set caps and other constraints to the tariff design in this case. However, in those countries where distribution tariffs are not computed by the DSO itself, this efficient design of distribution tariffs has to be done by the regulator. Nevertheless, regulators may not have all the information required or the willingness to compute the more efficient distribution tariffs.

Energy tariffs are generally much higher than distribution charges. Nonetheless, the design of energy tariffs falls under the responsibility of electricity suppliers, or regulators in the case of last resource tariffs. Hence, DSOs may see how, even if distribution use of system charges for EVs are optimally calculated, energy tariffs distort the incentive provided by distribution charges.

– Opportunities:

EVs are bound to increase the volume of electricity that is delivered through distribution networks. However, this is not a direct benefit for DSOs when distribution is unbundled from the remaining activities. This is the situation across the EU, as mandated by Directive 2009/72/EC. Therefore, this will not be considered as an opportunity for DSOs in this report. Nevertheless, this could represent an opportunity for DSOs depending on the specific regulatory framework of each country (how load growths are considered) and the costs actually incurred by DSOs in order to connect EVs. For example, under a price cap approach, DSO revenues directly depend on the volume of electricity distributed. However, many countries are moving towards regulatory frameworks closer to revenue caps instead of price caps in the European context, thus decoupling DSO revenues from energy delivered.

Inverters can easily control reactive and active power injection/retrieval. Therefore, EVs could provide some kind of voltage control. Nonetheless, inverters have to be over-dimensioned in order to provide this control. The R/X ratio in LV lines is high. Thus, voltage drop mainly depends on the active power flow. Consequently, reactive power control by EV inverters may not yield significant benefits. On the contrary, dedicated charging stations and car parks will probably be connected to higher voltage levels where the R/X ratio is lower. Therefore, reactive power control could be used by DSOs to improve the distribution network voltage profile.

The promotion of RES and CHP across Europe has resulted in higher shares of DG of electricity. In fact, some distribution areas may require significant upgrades in order to be able to cope with the production from DG units, i.e. load growth is no longer the main or the only factor considered in network planning. If battery charging takes place at the moments when DG production largely exceeds local consumption from conventional loads, DSOs could defer or avoid new network investments in the areas with a high concentration of DG units.

Several countries have mandated DSOs to perform a roll-out of smart meters at the premises of small domestic consumers. In order to take advantage of the possibilities offered by smart metering, an extensive use of ICT will be required. This roll-out will imply incurring considerable expenses. However, there is no consensus as to whether the benefits that can be obtained by smart metering outweigh the costs incurred. The major uncertainties derive from the lack of responsiveness from demand given that at the current energy prices, the savings that a single home can obtain are rather slim. An enhanced coordination of battery charging and the implementation of V2G concepts will also require extensive use of ICT. Therefore, EVs could benefit from the deployment of ICT for smart metering and provide extra benefits that can serve to finally outweigh the implementation costs.

Moreover, since EV could serve as an additional driver for demand side management. Hence, it could be considered that EVs will facilitate an increase in the volume of controllable load made available to DSOs.

The future creation of EVS-A/CPM and the implementation of V2G concepts will presumably allow DSOs to access new services related with power flow control at distribution level. The power flow control services could be applied, for example, for congestion management, minimise duration of interruptions and operational planning. This would constitute a trade-off for DSOs between the costs or performing conventional operational actions or reinforcing the distribution grid against the purchase of the services offered by EVS-A/CPM. Furthermore, some large EVS-A operating in wide distribution areas might provide DSOs load forecasting services and communicate with the distribution control centres similarly to what large DG units are doing nowadays in some countries, e.g. Spain.

DSO threats	
Network planning	Distribution network planning: more complicated to forecast the future load growth including EVs. Grid reinforcements which may not be included in the allowed revenues could be required If DSOs are responsible for developing charging infrastructure, these are high-risk investments unless regulation ensures cost recovery. Otherwise, the development of parallel networks could take place.
Grid operation	EV charging will increase energy losses in distribution grids. Since DSOs frequently have incentives to reduce energy losses, this could affect their revenues. The approaches to set target values for enregy losses should be reviewed. Uncoordinated EV charging may cause excessive voltage drops in heavily loaded lines, particularly in long radial networks. EV inverters may create power quality problems, e.g harmonics. Relying on EVs to provide system services poses certain risks of non-compliance which should be managed and shared by the DSO and EVS-A/CPM.
Metering	Smart meters currently deployed may need to be suitable to cope with EVs If dedicated meters are required to separate EV charging from other electricity consumption, a significant roll-out of new meters would be required. The extent will depend on the market models implemented. The role of DSOs and how to finance the costs of the deployment of new meters is not determined by regulation. This could create some uncertainty.
Tariff setting	Lack of freedom to design cost reflective distribution charges that could send efficient economic incentives. Energy tariffs could distort the incentives provided by distribution charges. This can create problems in some distribution areas.

Table 2: Summary of threats for DSOs

DSO opportunities
An increase in the amount of energy distributed could constitute an increase in the DSO revenues under some regulatory frameworks where revenues are not decouple from energy
Local voltage and reactive power control is possible by EV inverters. This is particularly relevant to car parks and dedicated charging stations connected MV networks.
EV charging can compensate for high DG production during valley hours (typically at night), thus allowing DSOs to alleviate congestions and reduce or defer grid reinforecements.
The equipment and ICT deployed for demand side management could be applied for the control and coordination of EVs, thus providing added value to these investments.
EVs will increase the volume of load that can be controlled, thus creating an added driver for the implementation of demand side management.
New services related with power flow control at distribution level could be offered by EVS-A which could serve as a substitute of conventional operational practices to minimise interruptions, manage congestions or plan maintenance actions.
Large EVS-A could be communicated with a DSO control centre and provide services such as load forecasting, thus facilitating grid operation.

Table 3: Summary of opportunities for DSOs

7.3 Transmission System Operators

As a complement to the previous Distribution System Operators' (DSO) perspective, this final section provides an overview of the opportunities and threats that a significant Electric Vehicle (EV) integration could bring to the Electricity Sector from the Transmission System Operators (TSO) point of view. TSOs are companies in fully regulated monopolies in charge of the operation and maintenance of transmission assets and, if necessary, the extension and reinforcements of lines for the transport of electricity from input to output nodes. There is an explicit obligation for the TSOs to assure the capability of the system to meet the demand in electricity transmission permanently and satisfactorily by installing the corresponding transmission capacities needed. Furthermore, they have to assure that the transmission system is secure and reliable as well as to guarantee the supply of energy. Together with the generation, the TSOs jointly provide secondary services of voltage control and system security. As Transmission Operators they also contribute to secondary services of voltage control and system security by operating network related devices, such as a banks of capacitors, and banks of reactors, transformers' tap etc.

In order to guarantee the electricity supply, the structure of transmission networks is in meshed configuration, differently to the low voltage distribution grids radial configuration. Traditionally, future transmission grids were planned, in a deterministic method, in order to meet the expected peak load from the "well-known" conventional generation by means of more or less easily predictable power flows. However, the introduction of several new electric system agents has changed that methodology. The significant development of distributed and renewable generation as well as the emerging of active demand (for example electric vehicles) introduces an important uncertainty in future scenarios. The generation is now dispersed and variable. EV load could increase demand uncertainty. Therefore, new stochastic methodologies have to be used. On the one hand, EV use patterns depend on technological vehicle options, social acceptance and charging infrastructure deployment, which makes the impact on system load unclear at the moment. On the other and, it is worth mentioning that electric vehicles are mobile units which in the future will create different geographical demand scenarios. Those factors of uncertainty together with the long time period required to build transmission assets poses the threat of situations of inadequacy of the transmission network to fulfil the demand supply. In opposition, with large EV integration levels, an appropriate coordination of Vehicle to Grid (V2G) services and transmission network needs could defer and even avoid new network investments.

Concerning transmission network operation and maintenance, the challenges, opportunities and risks would be similar to the ones incurred by DSOs but may occur only at higher levels of EV penetration: increase in energy losses, deterioration of power quality and requirements for active management of fluctuating flows.

With regard to system operation, TSOs have to guarantee the continuity and security of power supply and the proper coordination of production and transmission systems in normal and abnormal (with irregular incidents) conditions. Therefore, detailed long term planning and programming tasks are performed as well as an instantaneous adaptation of generation supply units to cover demand evolution. The system operator manages all available resources in real time operation to adapt generation programs, resulting from the daily and intraday power markets, to the instantaneous quality, reliability and safety requirements of the power system by means of the balancing markets and other mechanisms. Increasing the level of “non controllable” generation and of demand uncertainty (wind power, EVs which are mobile loads) leads to an increase of generation re-schedules, and even unit commitment, i.e. start-up and shut-down actions, and therefore to higher balancing needs and costs. Thus the system will require a higher participation in ancillary services provision and more flexible generation/demand. On the contrary, accurate generation/load forecasting tools and the participation of these new “not controllable” agents on intraday and balancing markets will reduce system uncertainty. More flexible balancing tools and models as well as adequate pricing mechanisms would also yield several advantages.

TSOs, as DSOs and EVS-A/CPM, would need to study EV load profiles and develop forecasting tools in order to manage real time system operation. For that purpose, it is desirable that EV parameters like load, state of charge, etc., are available to the EVS-A, the DSO and even the TSO, at aggregated level. This implies not only the need of special meters but also rules for protecting private data. However, without those parameters, forecasting models couldn’t be accurate and the system would need more balancing resources.

In electric power systems with increasing penetration of renewable intermittent generation (with characteristics of high variability and unpredictability), the installed capacity of conventional flexible generation is a key issue in order to cope with load, renewable supply variability and the provision of regulation reserve. In fact, due to renewable uncertainty, the amount of installed capacity of conventional generation technology needed in the system is almost as much as the forecasted peak-load levels. However, as renewable generation shares increase, conventional energy sales and marginal energy prices could decrease. Also the degradation associated with more frequent start-ups and shut-down may cause investment in conventional generation to become less attractive. If EV load mainly occurs on peak hours due to simultaneous uncoordinated charging, then difference between the daily peak and valley load would increase, aggravating the aforementioned problem of conventional generation cost-effectiveness. In that case, additional long term economic incentives, such as reliability options, to install new generation capacity should be adopted, to complement the generator's revenue from energy sales. If these investment payments were not implemented, systems might be prone to experience reserve margin shortages. This could increase price volatility and have serious effects on system adequacy (long term) as well as firmness and security (short term).

On the contrary, if EVs are dispatched appropriately they could add value to the operation of the adequate and secure system. In fact, in systems with significant wind penetration, as the Spanish one, there are increasing problems with valley hours' adequacy and security. During valley hours with high wind production, conventional thermal units must be disconnected or the wind farms curtailed in order to maintain a balance between generation and demand. However, this fact might reduce power plants life span and increase operation costs and wear. Besides, system security might be jeopardized, not only due to the mentioned conventional units wear and reduction in ancillary services availability, but also due to the fact that a punctually high dependency on renewable system might cause a sudden trip of a great amount of renewable units in the system because of lacking fault ride-through capabilities. Nowadays a great percentage of old-technology renewable units connected to the system are deficient in power electronics equipment and therefore are not able to withstand voltage dips caused by faults in the system. This might change in future scenarios, but currently in the foreseeable short to medium term there is a minimum amount of conventional generation that must be connected to the system and in some cases renewable resources spilling are unavoidable.

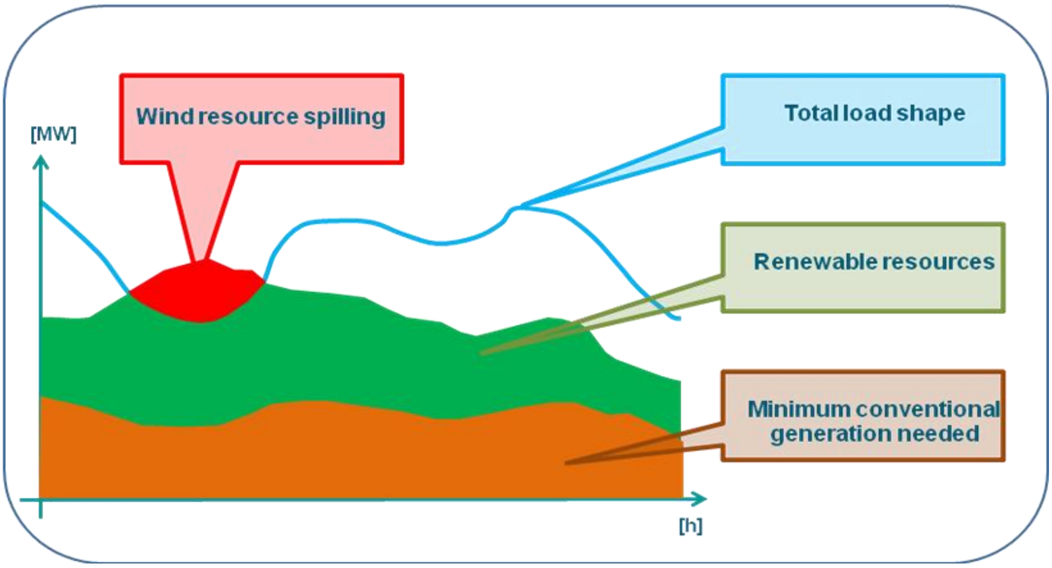

Figure 13: Wind resource spilling without additional load dispatch by EV

The allocation of EV load in these periods would reduce renewable resource spilling, allowing the system to better withstand high wind production during valley hours. It would also avoid the disconnection of conventional thermal units and, therefore, increase system security and adequacy since more reserve and balancing energy would be available.

In general, to cope with large intermittent renewable generation the challenge for future electric power systems is to increase the flexibility, both of existing generation units and of demand by means of demand management systems. The main advantage of promoting demand management and flexibility is that it may counteract higher price volatility caused by an increasing renewable supply level in the system, which brings benefits from the point of view of generation adequacy. There would be lower financial risks due to price volatility. It also can provide more secure system operation in the short term, and higher system adequacy in the long term. In that sense, electric vehicles, as electricity storage systems, have a significant capacity for demand response. Different mechanisms are under study to encourage a more active role of demand regarding ancillary services provision in several time horizons (annual, monthly, weekly and real time), throughout contracts between TSO´s and providers. Thus, in controlled charging scenarios (suffix –CC), EV via EVS-A could commit to reduce consumption when generation scarcity occurs in the system. Vice versa EV could commit to increase consumption when generation surplus occurs, in return of earning the payments established in the contract. When V2G would be implemented, the participation in ancillary service provision could be more active, leading to higher economic efficiency and security improvement. EVS-A would have to obtain mechanisms to guarantee services commitments: minimum aggregated size nowadays 10 MW in the Spanish system, controllability tests capability to keep a given schedule, specific tests for each type of ancillary services, i.e. regulation up or down etc.

For this purpose, EVS-A should receive continuous information about energy market prices as well as from individual EV in order to be able to adapt their consumption. As the time reaction gets very short, automatic control response devices become more effective than incentives based on market price signals. Thus, local control equipments could be installed in order to allow reaction to changes in frequency, which are less likely in interconnected systems, and voltage drops in the system. Beside, additional control schemes could be developed to allow TSOs to pass real-time customers load reduction/increase instructions, when required.

Primary reserve deserves special consideration. The objective of primary control is to maintain a balance between generation and demand within the synchronous area. Primary control aims at European synchronous area operational reliability and stabilises the system frequency at a stationary value after a disturbance or incident in a time-frame less than or equal 30 seconds, but without capability to completely restore system frequency and power exchange to their reference values. Considering primary control as one of the main services needed to guarantee the security of the electricity systems, the goal is that all generation units should provide it, if technologically possible. Currently, primary reserve contribution is mainly provided exclusively by conventional units. In order to encourage more renewable/disperse production in the system, TSOs should allow the possibility to transfer the reserve requirements between different generation units (renewable units vs. conventional ones) by means of bilateral agreements. In the future, this could be desirable between generation units and other providers, such as EVS-A. Thus, primary reserve service could represent a business opportunity for EV aggregators.

Opportunities	
Transmission Network Planning	**Controlled chargin/V2G** Avoidance or deferral of network reinforcements
Transmission Network Operation	**Controlled chargin/V2G** Possible participation in voltage and reactice power control Possible participation in congestion management
System Operation	**Increase of Valley Load** Increase of renewable integration Increase of system security
	EV is a potential key actor of demand management Reduction of price volatility Increase of system security
	Participation of EV in Ancillary Services Reduction of price volatility Increase of system security
Threats	
Transmission Network Planning	**Uncertainty of future scenarios:** Need to develop new forecasting tools Need to develop new planning tools Risk of inadequacy of future grids
Transmission Network Operation	**With high EV penetration:** Uncoordinated chargin and hourly tariffsignal could create significant voltage drop in the system Massive inverters connection could create local power quality problems
System Operation	**Increase of forecasting load uncertainty:** Need to develop new forecasting tools Need of observability (identification of real EV load) Increase in need for ancillary services and costs
	Increase of peak load/valley load ration Reserve margin shortages impact on price volatility Reduction on generation investments Impact on System adequacy and security Need for mid and long term generation capacity markets
	Participation of EV in ancillary services: Commitment guarantee Need for automatic control

Table 4: Summary of TSOs' Opportunities and Threats posed by EV

8 CONCLUSIONS

In this report the main business models of agents involved in the integration of plug-in electric vehicles in the electricity sector have been identified and several proposals regarding the definition of new agents, charging infrastructure ownership and development, and future EV charging modes with commercial relationships between involved agents have been made.

New agents called the Charging Point Managers (CPMs) have been introduced. CPMs are in charge of developing charging infrastructure in privately owned parking areas and charging EVs acting as a final customer in the market. In public areas it has been derived that the local distributor will develop the costly charging infrastructure providing public access to EV owners. EV supplier aggregators (EVS-A) will have contracts with EV owners for selling charging services in public parking areas. Furthermore, the function of aggregating vehicles for pooling multiple EV owners providing V2G services to the ISO or TSO has been described. EVS-A are considered qualified and authorized market agents who provide EV charging services and V2G services on a competitive basis.

This report derived a classification and according of nomenclature for the major charging modes that are currently imaginable. The names follow the logic of conveying the location of the charging station (public, private with public access, or private with private access), the intermediate agent facilitating the charging process as well as its level of sophistication. Before discussing each charging mode including the entailing interaction of the agents in detail, a comprehensive overview and tree-like classification was derived. Finally it turned out that the contractual relations and business models of the agents depend on the charging modes and therefore the regulatory issues to be addressed.

After having formed the conceptual basis, the individual business models of each agent were assessed to derive a common understanding of the internal functions, and value creation during the process of charging. Retailers, aggregators, charging point managers, distribution system operators as well as transmission system operators were therefore analyzed in detail to derive each agent's potential profit and loss structures and the specific opportunities and threats posed.

To complement this perspective the perspective of the automotive industry and of the final EV customer were taken to gain insights about market uptake and user acceptance.

Furthermore it is proposed, that DSOs are entities being the best option for developing public charging infrastructure because of the existing incentive regulation of natural infrastructure monopolies and the fostering of competition for retailing and aggregating services. In this case, as DSOs are regulated entities, the recovery of investments as well as the impact of charging infrastructures on the network is the critical issue to be taken into account by regulators.

In these arrangements, EV supplier-aggregators engaging in competitive activity based on supply contracts with EV owners that can be charged in different locations, mainly areas with public access. Charging point managers are electricity final customers that are allowed by legislation to supply charging services to EV owners on their premises, such as private parking areas. Battery leasing/swapping companies present other types of business models with different opportunities and threats associated to battery standardization among car manufacturers. IT-suppliers might play an important transversal role in linking different agents during the charging process. EVs charged during valley hours could benefit the integration of renewable energy, mainly wind, in systems with high penetration levels while presenting an opportunity for TSOs to increase system security by providing system services such as frequency control when operated in V2G modes. EV charging introduces a new load uncertainty in the system therefore new forecasting tools are required for TSOs.

Automotive industry trends have highlighted consumer's vehicle preferences and the industry's progress in performance and emissions. By means of constructing EV technology and product roadmaps to suggest the development of vehicle electrification and related technologies for the study period to 2030, it was found that legislative emissions regulation is the key driver for low-CO2 vehicle technologies.

Two comprehensive surveys among EV owners in different European countries conclude the main motivators for buying an EV. The combination of renewable energy at a competitive price (at least 40 % less than fuel) is essential. The results hint, that the current EV range has to be increased significantly (minimum range should be 110 km) and that current recharging durations have to be reduced. What is known today as “fast charging” is considered slow by consumers. In future, “slow charging” should take 15 minutes, while “fast charging” should not exceed 5 minutes. In addition there seems to be a need to provide a dense net of charging points which meet the service availability and expectations but still generate a reasonable return on investment. Finally, avoiding exposure to hazardous substances unexpectedly ranked highest among the advantages recharging instead of refuelling bring about.

Further deductions that can be drawn from the automotive industry’s perspective and the EV owner’s point of view can be found in the appendix documents II and III.

In conclusion, all the different involved key actors have been analysed by conducting a cost/benefit assessment, developing business models internal for each agent taking into account various charging scenarios. However, further work remains to be done, with the aim to recommend regulatory changes for all the regulated businesses and commercial practices for the de-regulated business in order to procure profitable scenarios for all the necessary parties.

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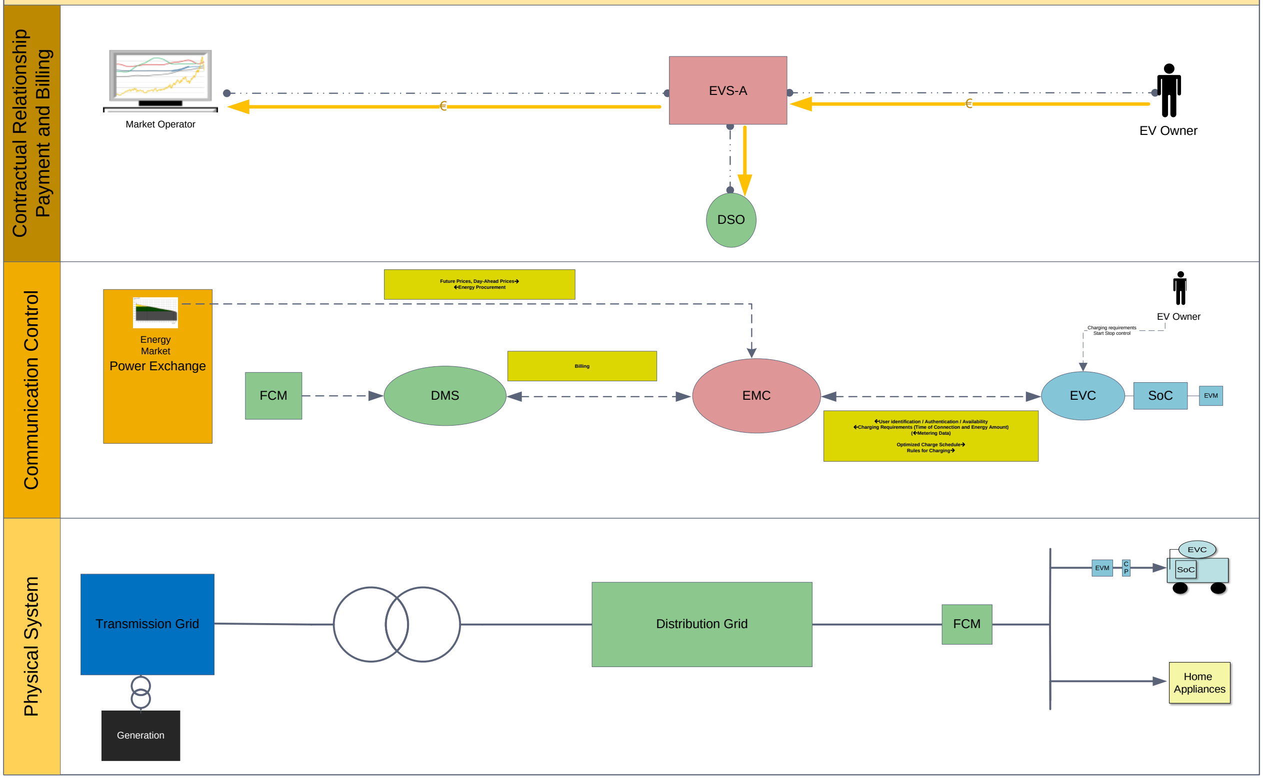
APPENDIX 1 – CHARGING MODES

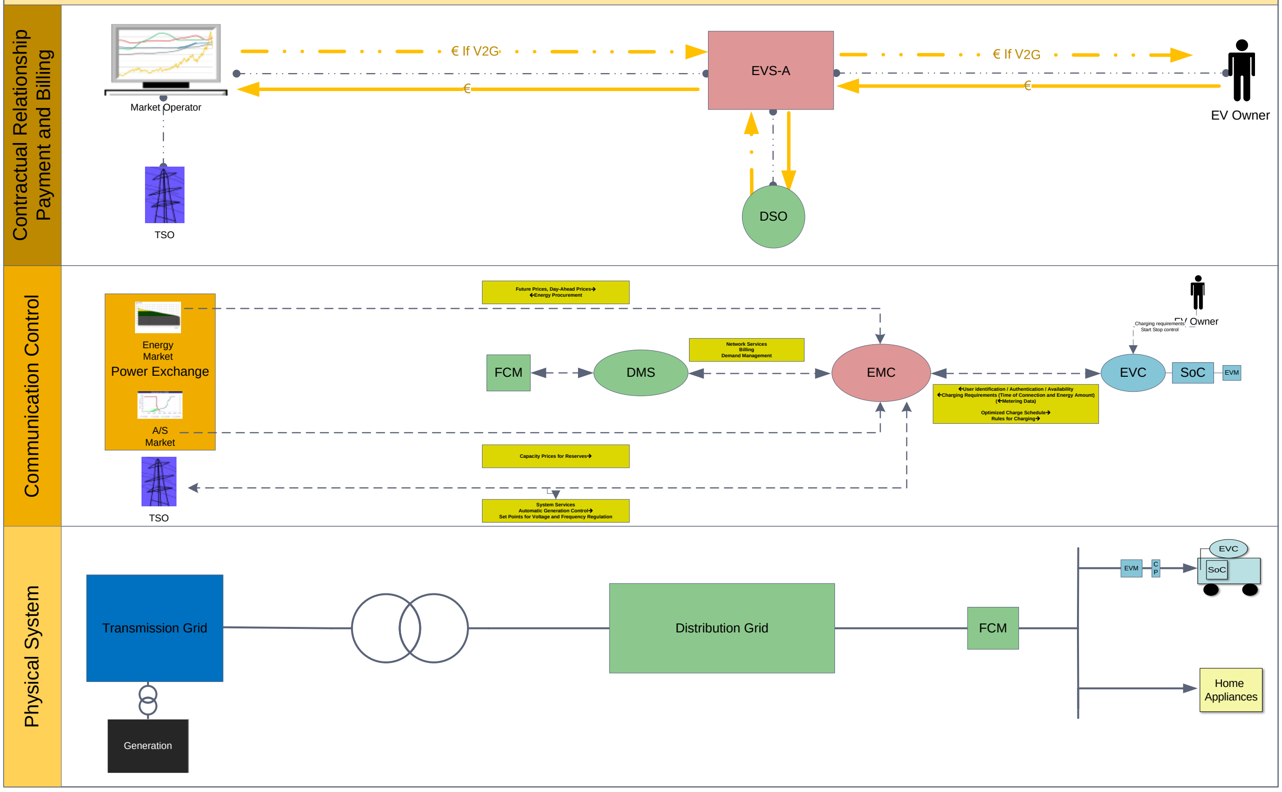
Physical Interactions, Contractual Relationship, Communication and Control

Domestic Charge – Controlled Charging



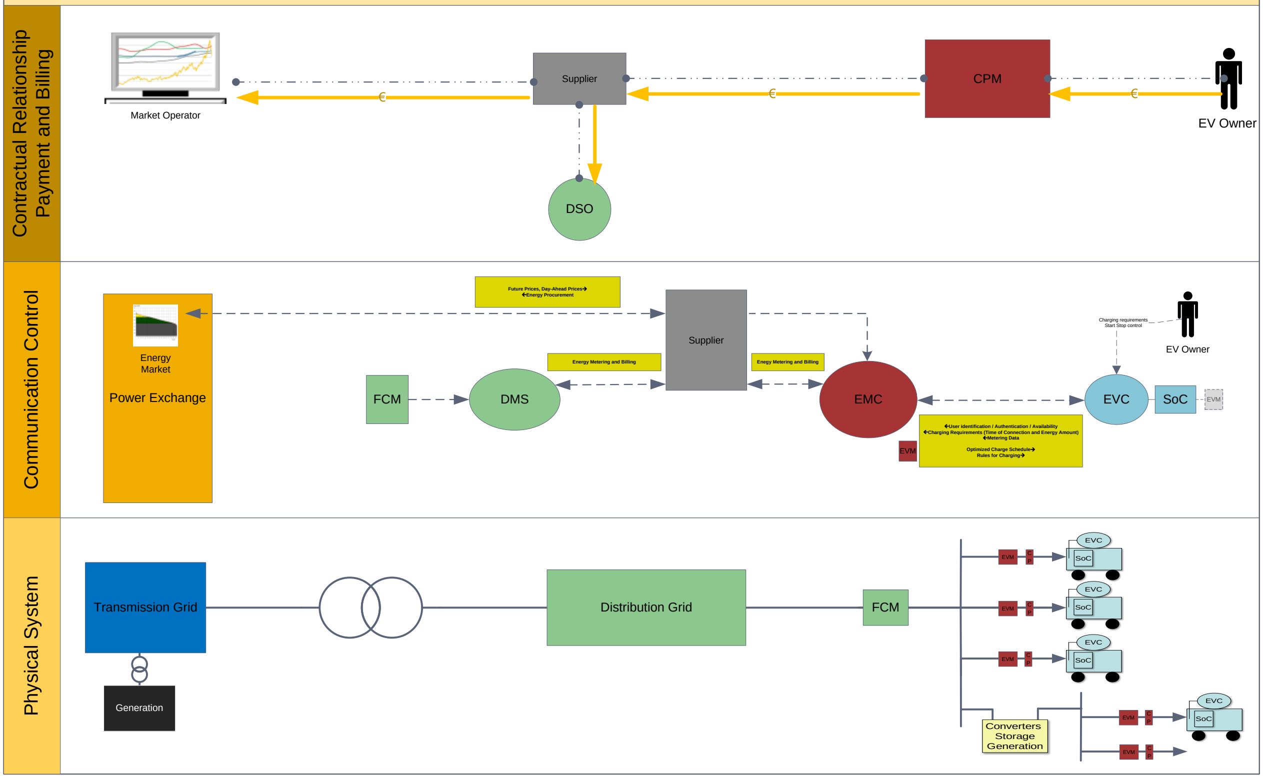
Physical Interactions, Contractual Relationship, Communication and Control

Domestic Charge – With V2G



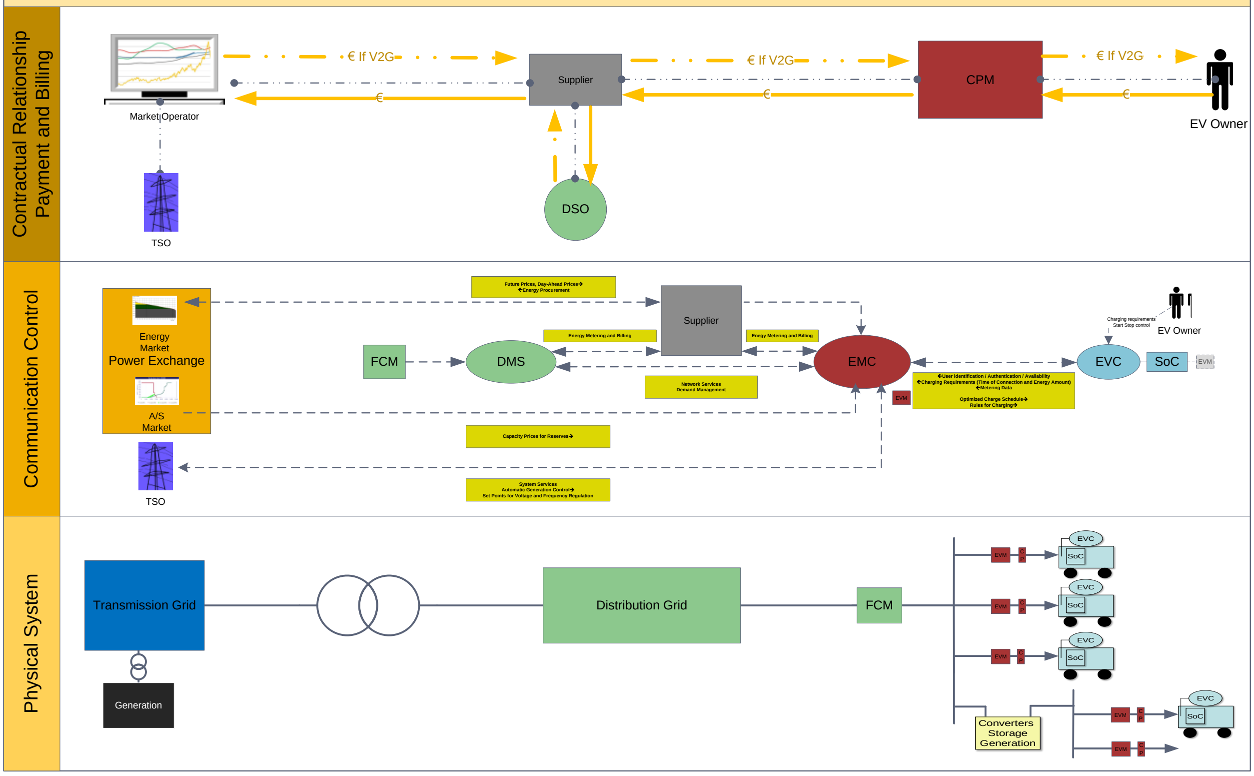
Physical Interactions, Contractual Relationship, Communication and Control

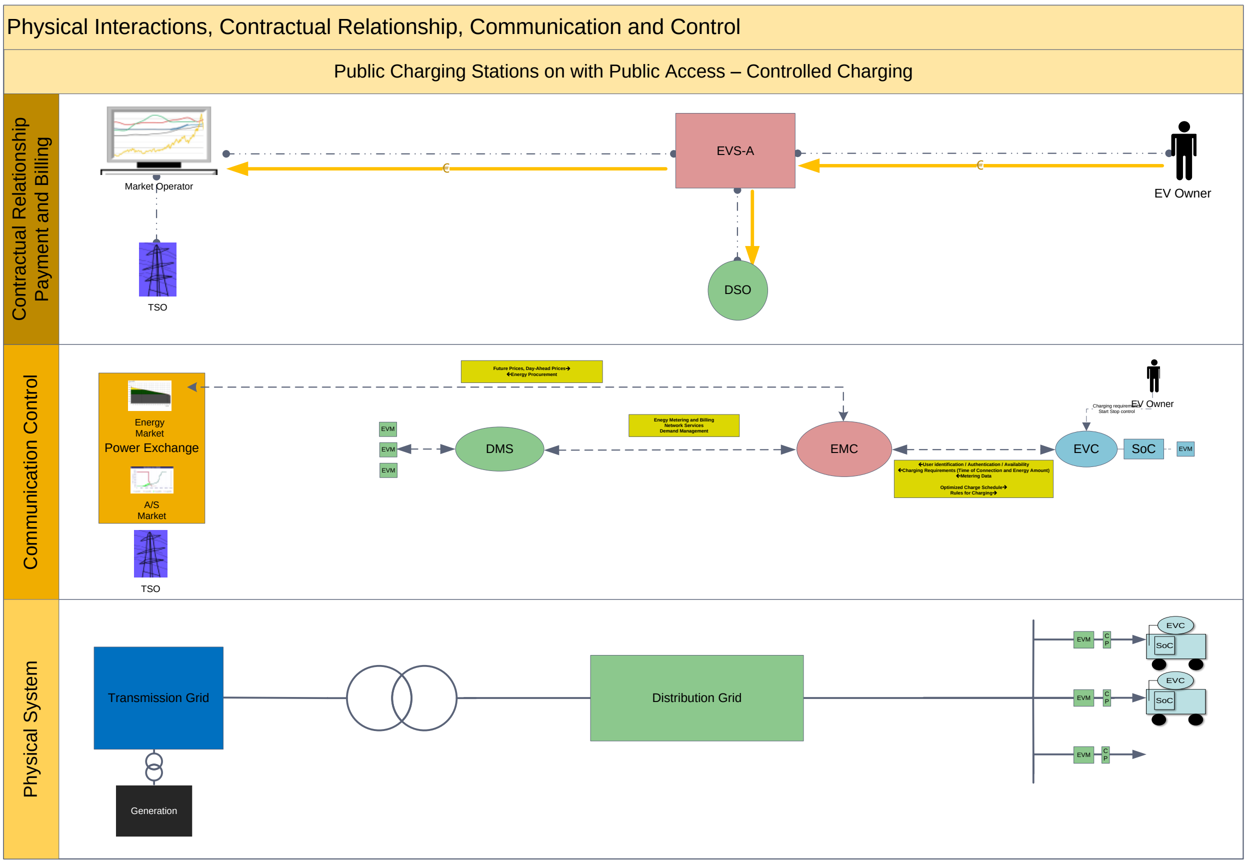
Privately Owned Charging Stations with Public Access – Controlled Charging



Physical Interactions, Contractual Relationship, Communication and Control

Privately Owned Charging Stations with Public Access – With V2G




Physical Interactions, Contractual Relationship, Communication and Control
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Contractual Relationship
Payment and Billing
Market Operator
TSO
EVS-A
€
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EV Owner
DSO
Communication Control
Energy Market
Power Exchange
A/S Market
TSO
Future Prices, Day-Ahead Prices→
←Energy Procurement
Enegy Metering and Billing
Network Services
Demand Management
EVM
EVM
EVM
DMS
EMC
←User identification / Authentication / Availability
←Charging Requirements (Time of Connection and Energy Amount)
←Metering Data
Optimized Charge Schedule→
Rules for Charging→
Charging requirements
Start Stop control
EV Owner
EVC
SoC
EVM
Physical System
Transmission Grid
Generation
Distribution Grid
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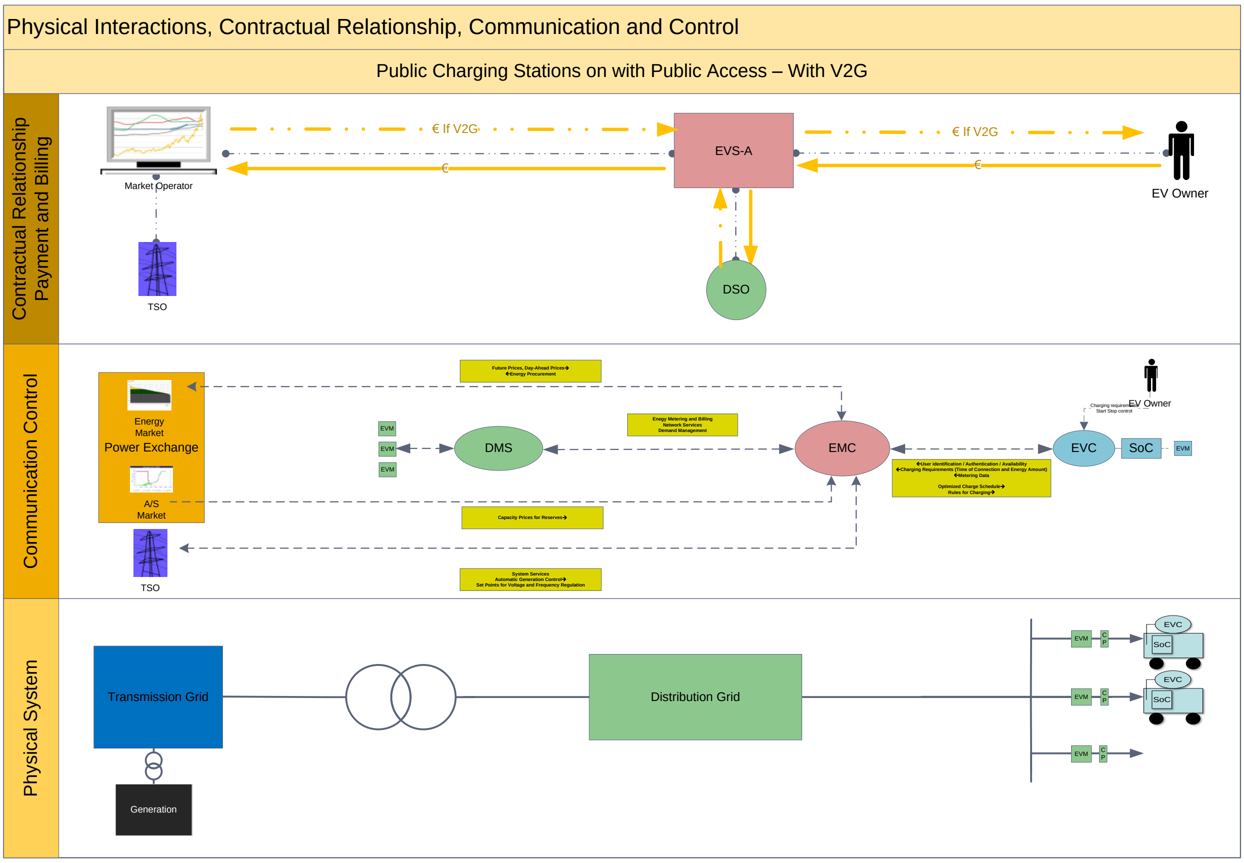
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EV Owner
DSO
Communication Control
Energy Market
Power Exchange
A/S Market
TSO
Future Prices, Day-Ahead Prices→
←Energy Procurement
EVM
EVM
EVM
DMS
Enegy Metering and Billing
Network Services
Demand Management
EMC
Capacity Prices for Reserves→
System Services
Automatic Generation Control→
Set Points for Voltage and Frequency Regulation
EV Owner
EVC
SoC
EVM
←User identification / Authentication / Availability
←Charging Requirements (Time of Connection and Energy Amount)
←Metering Data
Optimized Charge Schedule→
Rules for Charging→
Physical System
Transmission Grid
Generation
Distribution Grid
EVM
EVC
SoC
EVM
EVC
SoC
EVM

MOBILE ENERGY RESOURCES

IN GRIDS OF ELECTRICITY

ACRONYM: MERGE

GRANT AGREEMENT: 241399

WP 1
TASK 5.1
DELIVERABLE D5.1

APPENDIX II

DEFINITION OF KEY ACTORS AND THE ASSOCIATED BUSINESS MODELS – THE AUTOMOTIVE INDUSTRY

25 NOVEMBER 2010

REVISION HISTORY

VER.	DATE	NOTES (including revision author)
01	22/10/2010	Initial release
02	25/11/2010	Incorporating feedback from project team
03		
04		
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AUTHORS

Neil Downing Neil.Downing@ricardo.com

CONTRIBUTORS

Ed Bower Ed.Bower@ricardo.com
Peter Miller Peter.Miller@ricardo.com

APPROVAL			DATE
Project Coordinator	PPC	N. Hatziargyriou	04/02/2010
Technical Coordinator	INESC Porto	J. Pecas Lopez	04/02/2010
Work Package Leader	Comillas	T. Gómez/M. Rivier	10/12/2010

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SUMMARY

This report examines the background and role of the automotive industry in the emerging EV market and assesses how it will support the new market and potential new business models that may emerge as the market develops.

A series of roadmaps were developed, which detail how the automotive industry will introduce increasing levels of electrification in their fleets, for a range of types of vehicle from passenger cars to medium duty trucks. Roadmaps for the development of EV-related technologies such as batteries and electrical machines were also developed, showing how different technologies will enter the market and how some may decline or be superseded. Challenges, both technical and economic, were discussed.

Broad trends in the automotive industry were identified to provide a picture of how the industry has developed over the last twenty years and what consumers expect of their vehicles. This included trends in car ownership rates, new car registrations, diesel market share, engine power and displacement and fleet average CO_2 emissions. The progression of technologies from conventional vehicles to full battery-electric vehicles, and eventually extended-range electric vehicles, in a series of phases was described.

Legislative emissions regulations, which represent the primary driver of the move to EV, were examined, showing how EV will help to achieve legislative targets for the automotive industry and quantifying how much progress needs to be made to achieve the 2015 target of European new car fleet average CO_2 emissions of 120 g/km. Government incentives encouraging the uptake of low- or zero-emission vehicles were also discussed.

The roadmaps, trends and current and proposed emissions regulations and incentives programmes were combined to generate a series of penetration scenarios showing how many vehicles of each type will be sold in each region in the period 2010 to 2030. This became the primary deliverable of Task 3.2.

Strategies regarding charging and energy storage were discussed. Broad trends and assumptions were discussed, although the primary reports on these topics, with considerably more detail than is relevant to this report, are the reports on Task 1.1 and Task 2.1, respectively. Potential new business models – battery charging stations, battery swapping stations, battery leasing and grid balancing or ancillary services – were discussed in terms of their benefit to the end user and their interaction with the automotive industry, where appropriate.

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DEFINITION OF KEY ACTORS AND THE ASSOCIATED BUSINESS MODELS: THE AUTOMOTIVE INDUSTRY

1 INTRODUCTION

They key driver for the widespread uptake of EV is CO_2 emissions legislation being imposed on the automotive industry, which is leading it to develop low-emission vehicles to reduce its fleet average CO_2 emissions levels, particularly during the phase-in period of the legislation when low emission vehicles are counted as multiple vehicles in fleet average calculations.

Although the power industries would like to specify technologies that would allow easier integration of EV in Europe's electricity networks, the technology that ultimately will appear on vehicles will be chosen by the automotive industry and must be acceptable to the consumers that purchase the vehicles. While some smart grid technologies aim to reduce overall load on the grid, this may be seen by consumers as restricting their freedom to charge or use their vehicles at a time that suits them. This is a perception that the manufacturers must seek to avoid.

For EV to be successful in replacing conventional vehicles, significant development of battery, electrical machine and other related technologies will have to occur at an accelerated pace, and the initial limitations of EV from performance or cost standpoints must not become the lasting perception in consumers' minds of what EV technology represents.

The global credit crisis has severely affected the automotive industry, as most new passenger cars are bought on credit. This has reduced the cash reserves and profitability of most vehicle manufacturers, which may reduce the budgets available to develop new technologies. Developing viable EV technology that will help achieve the fleet average CO_2 targets must be achieved without having to subsidise much of the additional cost of the new vehicles at the expense of profits from conventional vehicles.

2 OBJECTIVES

The objectives of Task 5.1 are:

- To provide a vision with quality assessment of how power system participants will be affected by the deployment of EV
- To create different business models to analyze the threats and opportunities for each agent under this new situation, based on the outputs of WP3 and WP4 where the impacts of EV deployment on costs and benefits were assessed

The key actor discussed in this report is the automotive industry. The objectives of this subtask are:

- To combine EV technology and product roadmaps, together with automotive industry intelligence and trends, and legislative emissions regulations in order to provide a picture of how EV will penetrate in the different European regions
- To provide a picture of what kind of strategies related with charging, storage, and services provision are the most plausible

3 GLOSSARY

TERM	DEFINITION
BEV	Battery Electric Vehicle
BISG	Belt-Integrated Starter-Generator
CISG	Crank-Integrated Starter-Generator
CPM	Claw-Pole Machine, a type of E-machine
DC	Direct current
DSM	Demand-side management
DSO	Distribution System Operator
EREV	Extended Range Electric Vehicle
EV	BEV, HEV or EREV
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
IM	Induction Machine, a type of E-machine
IPM	Interior PM Machine, a type of E-machine
METI	Ministry of Economy, Trade and Industry (Japan)
NiMH	Nickel Metal Hydride, a battery chemistry
PHEV	Plug-in Hybrid Electric Vehicle
PM	Permanent Magnet
SPM	Surfaced PM Machine, a type of E-machine
SRM	Switched Reluctance Machine, a type of E-machine
TSO	Transmission System Operator
V2H	Vehicle-to-home
V2G	Vehicle-to-grid
ZEBRA	Zeolite Battery Research Africa, a battery technology

All units used in this study are part of the International System of Units (SI) and, as such, are not defined herein.

4 EV TECHNOLOGY AND PRODUCT ROADMAPS

4.1 Introduction to Ricardo technology roadmaps

Ricardo produces overviews of how technologies are forecast to enter the market, achieve maturity and sometimes leave the market, which it calls technology roadmaps. Figure 1 shows the structure of these technology roadmaps and the meanings of the symbols used in them.

The initial grey chevrons represent the first introduction of a technology to the market. The solid blue colour represents acceptance of the technology in the market. The transition to blue chevrons represents the technology achieving full maturity of development and its maximum market penetration. Blue tail chevrons represent the technology continuing at a constant market penetration, while grey tail chevrons represent the decline of the technology in the market.

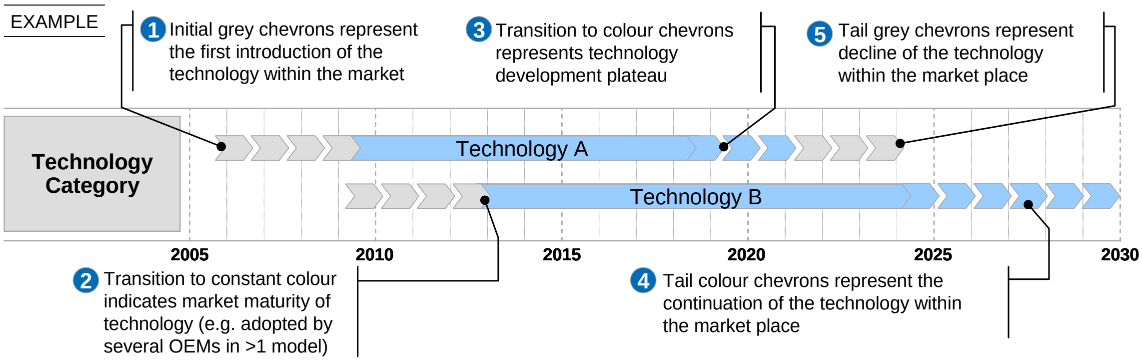

Figure 1: Ricardo technology roadmaps

4.2 Technology roadmap for passenger vehicles

Figure 2 shows the technology roadmap for passenger vehicles.

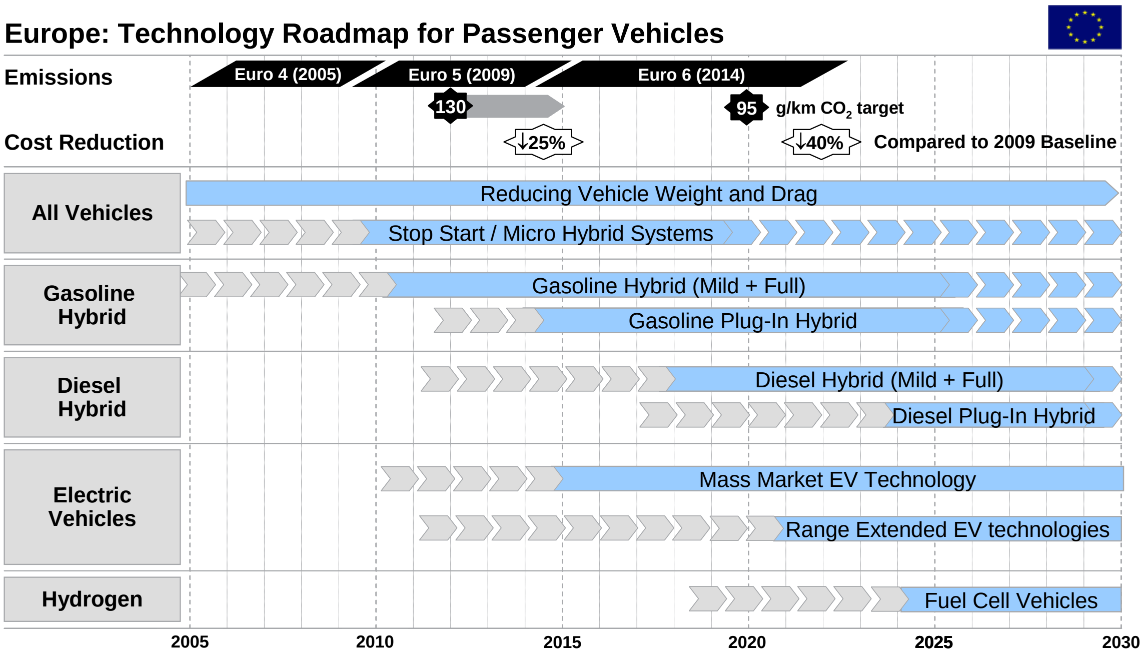

Figure 2: Technology roadmap for passenger vehicles

The top of the roadmap shows the legislative drivers for technology development in the marketplace, specifically emissions and CO_2 legislation.

Throughout the review period there is a continuing trend of reducing vehicle weight and drag. This trend has historically been tempered by legislation requiring increasingly stringent safety considerations and it should be noted that the trend of weight and drag reduction refers to improvements in the base platforms independent of safety systems.

Stop/start systems have been introduced on a small number of vehicle models over the past five years and will achieve a significant market share over the next ten years, by the end of which they will become standard hardware on almost all vehicles.

Gasoline hybrids will mature over the next 15 years, while plug-in versions will begin to appear on the market from 2014 and will mature by 2025. Diesel hybrid vehicles will begin to appear on the market towards the end of the decade, and plug-in versions of these will be introduced around 2020.

Battery electric vehicles will grow in market share over the next five years and will develop at a more rapid pace from 2015 forward. Range extended electric vehicles will not make a significant impact until after 2020 as this technology depends strongly on conventional BEV technology to mature.

Fuel cell vehicles may begin to appear towards 2020 but will not achieve any significant market share until about 2025.

4.3 Technology roadmap for light-duty commercial vehicles

Figure 3 shows the technology roadmap for light-duty commercial vehicles.

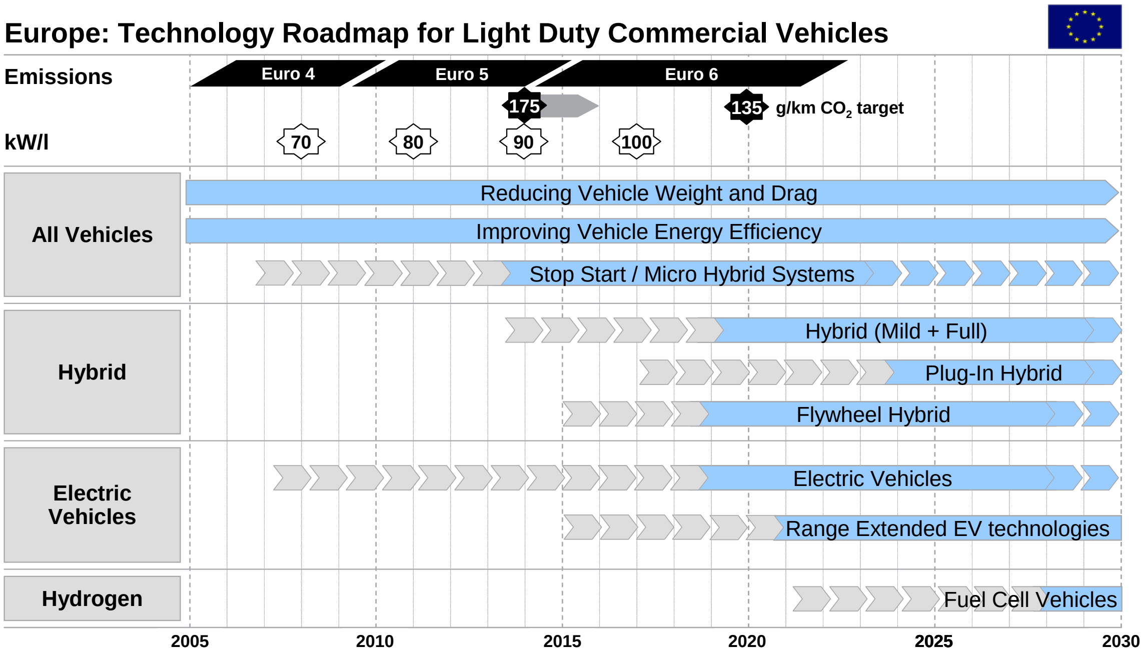

Figure 3: Technology roadmap for light duty commercial vehicles

Similarly to the passenger vehicle roadmap, the top of this roadmap shows the legislative drivers for technology development in the marketplace, specifically emissions and CO_2 legislation. It also shows a trend of increasing power per engine displacement (kW/l), which is expected to continue through this decade.

There is a continuing trend throughout the review period of reducing vehicle weight and drag, and of improving vehicle energy efficiency. It is anticipated that stop/start systems will begin to gain significant market share towards the middle of the decade.

There will be a range of demonstrator hybrid light-duty commercial vehicles from the middle of the decade but this technology will not gain significant market share until about 2020. Plug-in versions of these will appear on the market approaching 2025. Mechanical hybrids, which recover and store energy kinetically using a flywheel, will be introduced about the same time as diesel/electric hybrids and this technology may compete strongly with electric hybrids due to potentially lower on-cost and higher efficiency due to fewer energy conversions.

Full battery electric vehicles will continue to appear as demonstrators throughout the coming decade and will begin to take a market share approaching 2020. These will be followed relatively quickly by range extended electric vehicle models, which will build on developments in range extender technology for passenger vehicles.

There may be demonstrator fuel cell vehicles soon after 2020, but this technology will not gain any significant market share until well after 2025.

4.4 Technology roadmap for medium- and heavy-duty trucks

Figure 4 shows the technology roadmap for medium- and heavy-duty trucks.

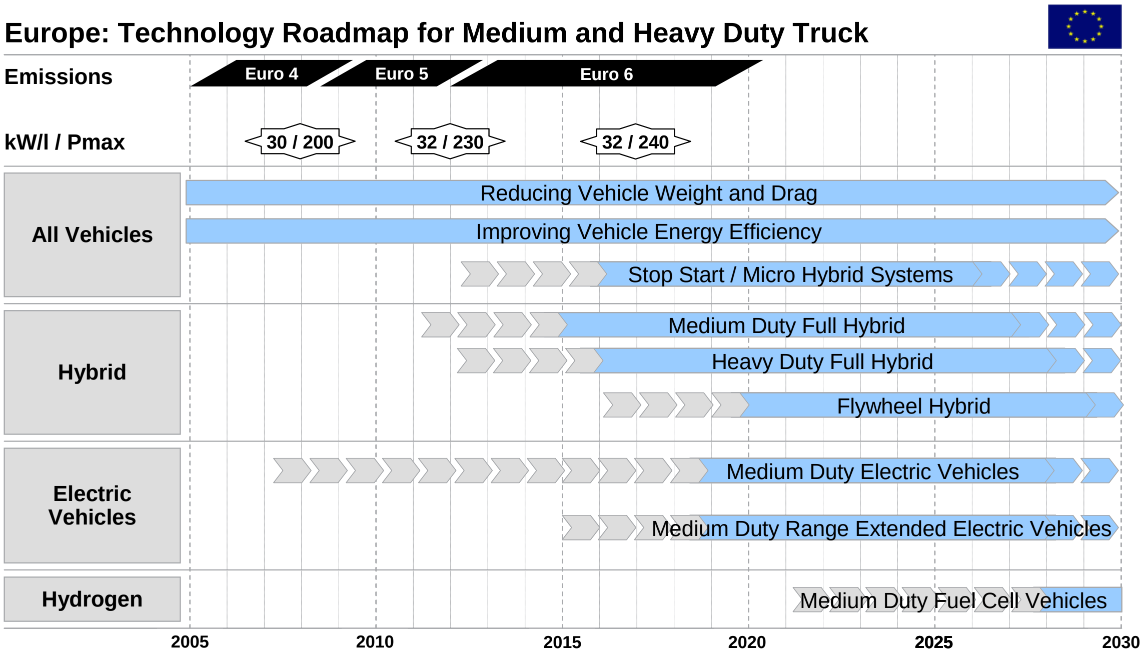

Figure 4: Technology roadmap for medium and heavy duty trucks

Similarly to the passenger vehicle and light duty commercial vehicle roadmaps, the top of this roadmap shows the legislative drivers for technology development in the marketplace, specifically emissions legislation, although there is no current or proposed CO_2 legislation. Historically the cost benefits of fuel economy have provided a sufficient incentive to truck purchasers such that there is no need to set legislative targets (fuel economy improvements and CO_2 reduction are coincident with each other so it is only necessary to legislate for one of them – if CO_2 targets exist, there is no need for fuel economy targets, and vice-versa). It also shows a trend of increasing power per engine displacement (kW/l) and in-cylinder pressure (P_{max}), which is expected to continue through this decade.

There is a continuing trend throughout the review period of reducing vehicle weight and drag and improving vehicle energy efficiency. It is anticipated that stop/start systems will begin to gain significant market share towards the middle of the decade.

Full hybrid systems will begin to be introduced in the next few years, and will achieve significant market shares in the latter part of this decade. The delay in introduction compared to passenger vehicles and light-duty commercial vehicles is due to the lower overall benefit of the technology in heavy duty applications due to these vehicles operating duty cycles with longer times spent at high speed, high load conditions and short stoppage times.

Full electric versions of medium-duty trucks will begin to gain market share approaching 2020, and range extended versions will appear around the same time, building upon developments in the passenger car market. Medium duty fuel cell vehicles may begin to gain a market share approaching 2030.

It is not anticipated that fully-electric heavy-duty trucks will gain any significant market share in the review period, as the cost of batteries, length of time required to recharge and very long duty cycles are not conducive to electric propulsion without a step change in technology.

4.5 Technology roadmap for batteries

Figure 5 shows the technology roadmap for batteries for automotive applications.

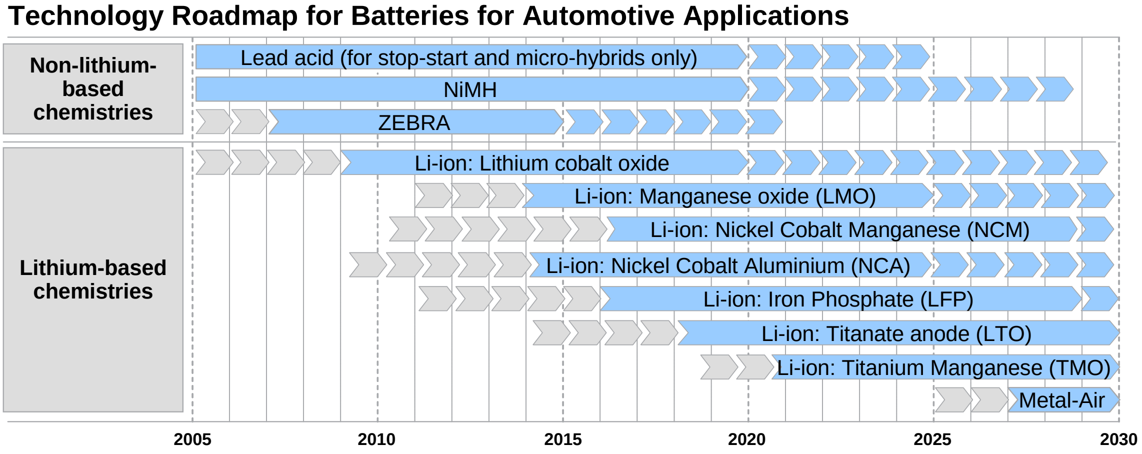

Figure 5: Technology roadmap for batteries for automotive applications

Currently lead acid and nickel metal hydride batteries are mature technologies for automotive applications but both of these will reduce in market share in the latter part of this decade and will eventually be completely replaced by alternative battery chemistries with higher energy densities and higher power densities.

ZEBRA batteries may find use in a number of vehicles over the next five years but this technology does not have a long-term future due to the high operating temperature of the technology.

There are many lithium-ion based chemistries being developed at present. Some, such as lithium iron phosphate and lithium titanate have been used in vehicles already and some are due to be incorporated in vehicles in the very near future, such as lithium nickel oxide and lithium manganese spinel. Lithium cobalt oxide has an issue with "thermal runaway”, whereby overcharged batteries can generate heat in an exothermic reaction which causes the battery to catch fire, but it is possible that this issue may be averted in second-generation lithium cobalt oxide batteries so they may return to the market. Lithium polymer and lithium sulphur batteries are currently under development for a range of applications and may find a space in the automotive battery market place during this decade.

Although there is a wide range of lithium-based battery chemistries on the market and in development, it is likely that one, or a small number, of chemistries will achieve dominance, either due to superior performance or due to a large number of manufacturers choosing that chemistry, leading to economies of scale. It is not possible at this stage of development to assess which chemistry or chemistries are most likely to achieve the highest market share but it is certain that battery technology will be the primary focus of development and investment over the next ten to fifteen years.

Battery costs are currently in the region of $1,000/kWh, but a number of groups have set targets to reduce this cost over the medium term. The UK's New Automotive Innovation and Growth Team (NAIGT) targets $800/kWh towards the end of this decade, $500/kWh by the middle of the next decade and $200/kWh by about 2025 [1]. The United States Advanced Battery Consortium notes that, for long-term commercialisation of BEV, the cost must come below $150/kWh and ideally must drop to $100/kWh [2] and for energy-optimised PHEV, should be below approximately $300/kWh [3]. Japan's Ministry of Economy, Trade and Industry (METI) targets a reduction to one-seventh of the 2005 cost (from $2,000/kWh to $285/kWh) by 2015 and a reduction to one-fortieth of the 2005 cost (from $2,000/kWh to $50/kWh) by 2030.

The actual prices paid will continue to vary depending on volume, raw commodity fluctuations and sourcing models. The industry structure is still immature so sourcing decisions for supply and integration of cells and modules into battery packs may cause these figures to vary significantly. It should be noted that all of these UK, US and Japanese targets are considered very ambitious and it is likely that a step change in technology, rather than incremental improvements, will be required to achieve them.

4.6 E-machine technology and integration

There are a number of e-machine technologies that have been considered for use in EV. In this report, four categories of technology have been considered:

1. Brushed DC & claw-pole machine (CPM) – currently used for starter motors & alternators. Can provide stop/start, limited launch assist, stall protection and regeneration (micro-hybrid)

2. Brushless permanent magnet – high power density and high peak efficiency. However, there are concerns over rare earth magnet materials cost and resource availability

    a. Surface PM machine (SPM) – are mature in industrial applications and were used by Honda for its first generation Insight and Civic HEV but they are unlikely to be used in lieu of the above technologies in future EV applications

   b. Interior PM machine (IPM) – have frequently been used for BEV and HEV applications by Toyota, Honda and Ford and is probably the most common choice currently for EV applications

3. Induction machine (IM) – lower power density than permanent magnet machines but may become more attractive, given concerns over PM. Appropriate for truck or bus applications where packaging space may not be as much of an issue as in passenger cars

4. Switched reluctance machine (SRM) – comparable power density to induction but commonly perceived as 'noisy' and 'complex control'. Simple construction means low BOM cost and an inherent level of fault tolerance

5. Other – There are many further variants of electric machine which may become suitable for EV applications given further development as the market matures

Figure 6 shows a comparison of these technologies in terms of suitability for EV and technology maturity from laboratory, to demonstration and fully-commercialised.

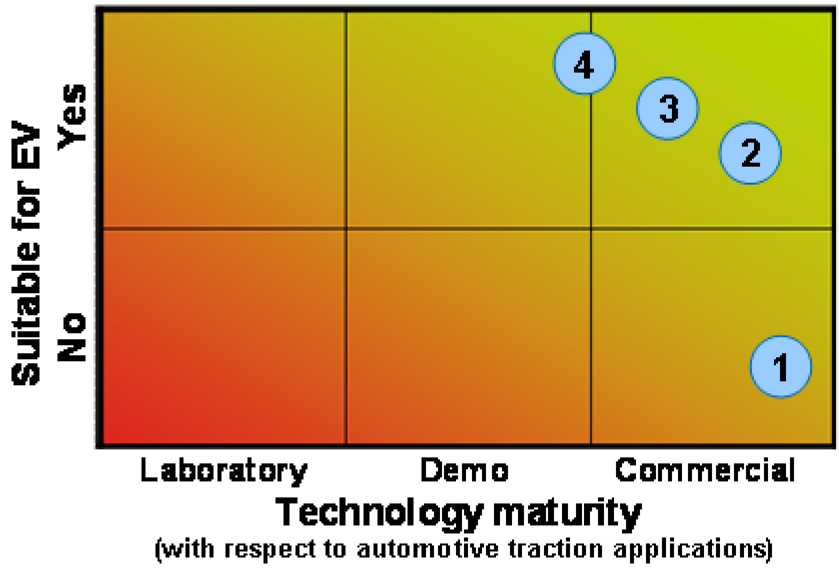

Figure 6: Comparison of e-machine technologies

E-machines can be mounted in a number of locations in the architecture of a hybrid vehicle. The e-machines used in first-generation mild hybrids were mounted on the belt of the engine (belt-integrated starter-generator, BISG) as this was a simple "bolt-on" solution that did not require a major redesign of the engine packaging. Later, full hybrids had e-machines mounted on the crank (crank-integrated motor-generator, CIMG) so that they could provide torque assist to the engine. Some hybrid vehicles have the e-machine mounted on the axle (electric rear axle drive, ERAD, or e-axle) so that the motor is not geared. In some implementations, the engine and gearbox are used to drive the front wheels and the e-machine is used to drive the rear wheels (sometimes referred to as a "through-the-road" hybrid). Some vehicles have used wheel hub motors so that there is no transmission required to transmit the torque of the motor to the wheels. However, this increases the unsprung mass of the vehicle, requires at least two e-machines and requires a sophisticated control system to balance the torque to each wheel, particularly to control cornering. Figure 7 shows these four locations.

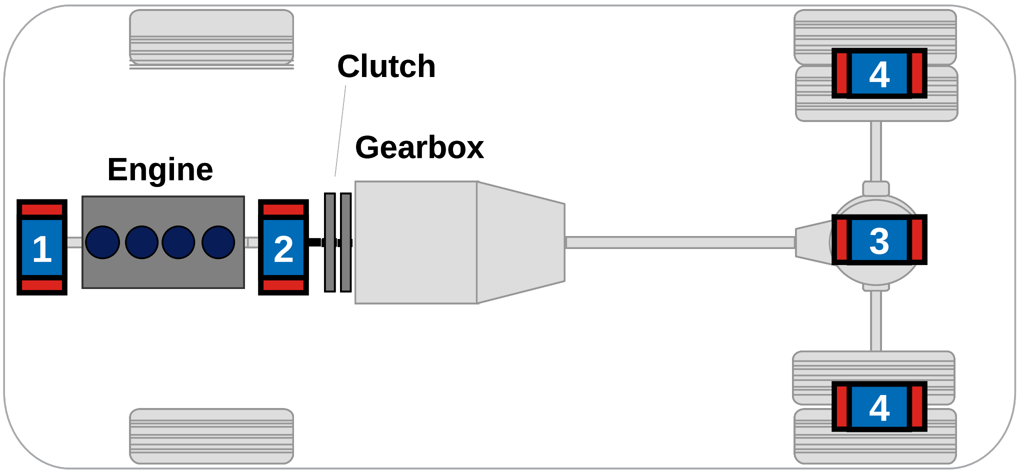

Figure 7: Four regions where the electric machine can be mounted on a hybrid-electric vehicle, moving progressively towards the point of energy usage: (1) BISG, (2) CIMG, (3) e-axle and (4) wheel hub motors

5 AUTOMOTIVE INDUSTRY INTELLIGENCE AND TRENDS

5.1 Car density in Europe

Figure 8 shows the car densities of Europe, Japan, USA, China and India. This shows that Europe has the highest rate of passenger car ownership in the world, at 470 cars per 1,000 inhabitants. Although the USA has a lower car density than Europe, the rate of vehicle ownership is higher as significant numbers of Americans drive light-duty trucks, such as pick-ups, as their primary personal vehicle, and these are not included in this data.

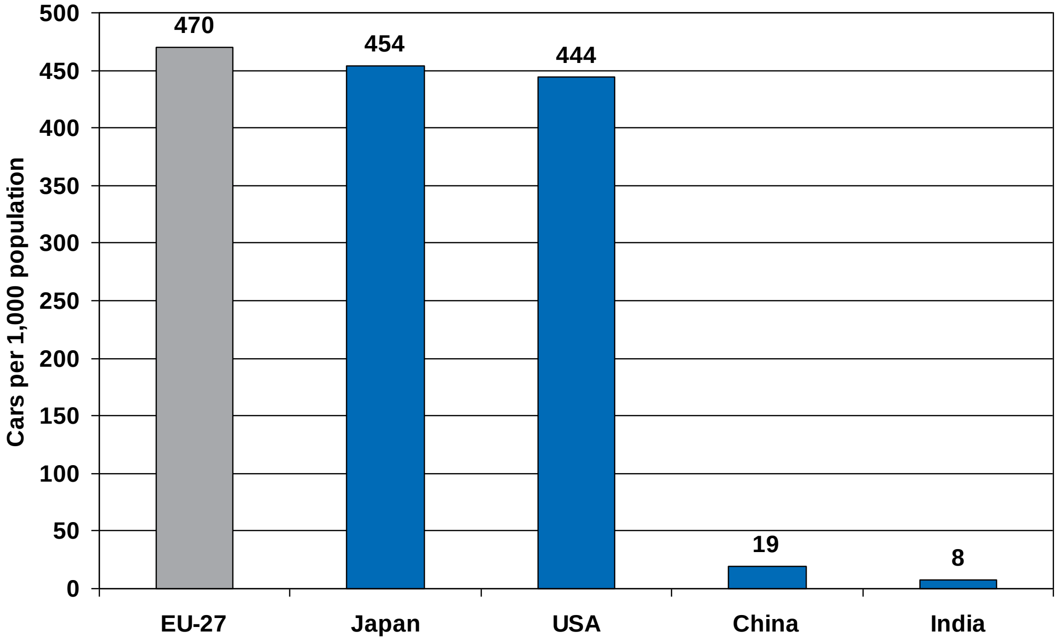

Figure 8: World car density [5]

China and India have significantly lower car densities than Europe, Japan and the USA, with China's rate of car ownership only 4% and India's rate less than 2% of Europe's rate. This disparity is likely to drive unprecedented growth in passenger car sales in these territories over the coming years and decades, as their economies grow and personal wealth approaches that of the Western world.

In 2009, China became the largest passenger car market in the world, partly due to a significant decline in passenger car sales in the US because of the global financial crisis, and partly due to Chinese government tax incentives used to stimulate the market, which lead to 45% year-on-year growth in sales. It remains to be seen if that year's sales can be built on in the next few years or if some consumers merely purchased a vehicle earlier than intended, to take advantage of the incentives, which may cause a drop in sales in the following year to two years.

In India, two-wheeled vehicles outsell passenger cars at a rate of five to one, but the rate of growth in sales is considerably higher for passenger cars than it is for twowheelers. New vehicles from Indian manufacturers, such as the Tata Nano, which is one of the cheapest passenger cars ever to go on sale, are likely to drive significant growth in India's passenger car market over the next two decades as passenger cars take market share from two-wheeled vehicles.

Figure 9 shows the car densities of the five countries of interest to MERGE, compared to the EU-27 average car density. Germany, UK and Spain have higher rates of car ownership than the EU average, while Greece and Portugal have lower rates. A simple average of these figures (not weighted by population or number of vehicles in the fleet) is 465 vehicles per 1,000 inhabitants, which is very close to the EU-27 average.

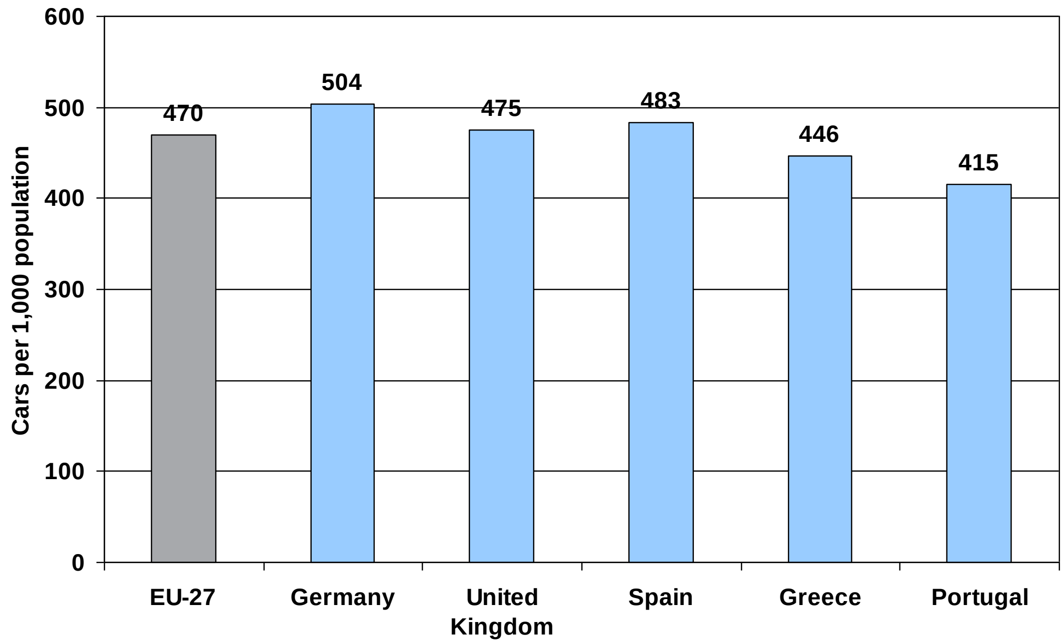

Figure 9: Car density in the EU-27 and the five countries under study [5]

5.2 Car sales in Europe

Figure 10 shows the sales trends for gasoline and diesel passenger vehicles in Europe from 1996 to 2009. There was strong growth at the end of the '90s, before the market settled at a level between 14 and 15 million vehicles per year for most of the decade. Following the global credit crisis, sales in 2008 and 2009 fell to about 13.5 million vehicles in each year. There was strong growth in diesel passenger car sales throughout most of the period, starting at about 3 million vehicles in 1996 and peaking at almost 8 million vehicles in 2007. It is anticipated that the total passenger car market will recover to about 15 million vehicles per year by the middle of this decade as European countries emerge from recession.

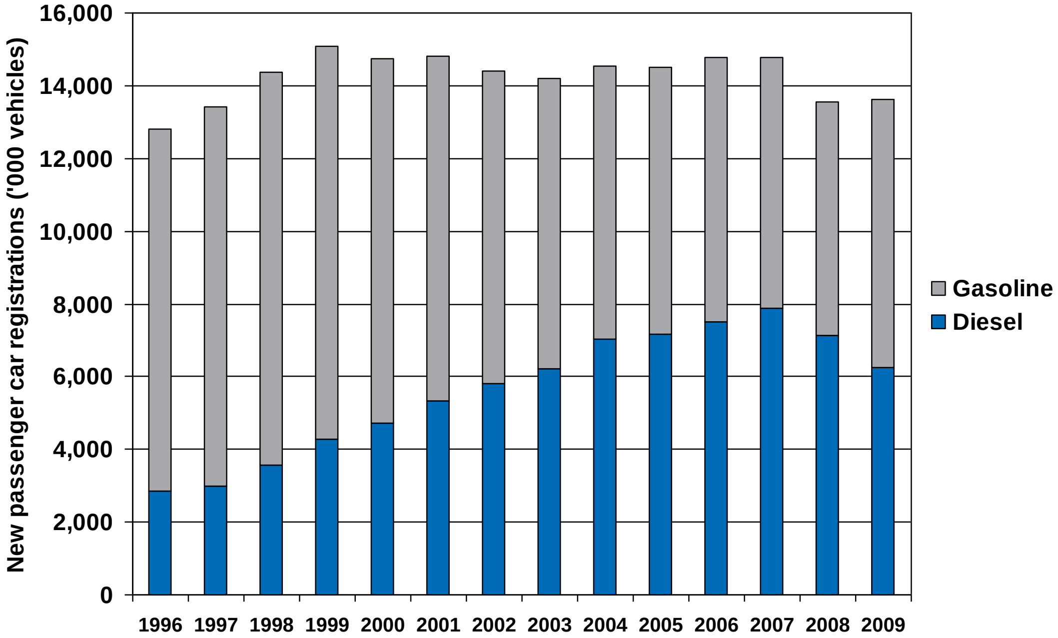

Figure 10: Passenger car sales trends, Western Europe, 1996-2009

5.3 Car market segmentation in Europe

Figure 11 shows the breakdown of segments within the new passenger car market in Europe. The three smallest segments, A, B and C, made up three-quarters of new car registrations in 2008, with more than one-third of sales being C segment vehicles such as the Ford Focus. 13% of vehicles sold were D segment vehicles, such as the Volkswagen Passat.

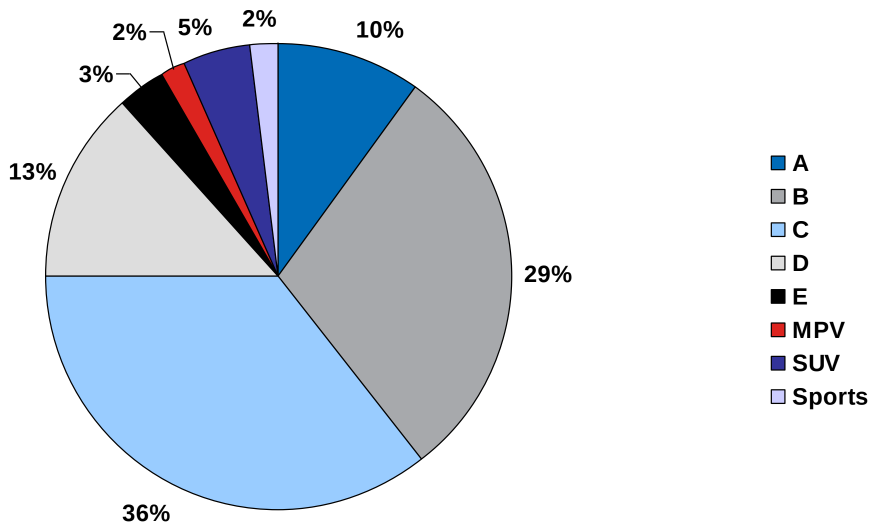

Figure 11: Europe passenger car market segmentation

Figure 12 shows the trends in segmentation of the new passenger car market from 1990 to the first quarter of 2010. It is clear from this figure that the market share of small and lower-medium segment vehicles has grown over the last twenty years, from just under 60% in 1990 to 75% in the first quarter of 2010.

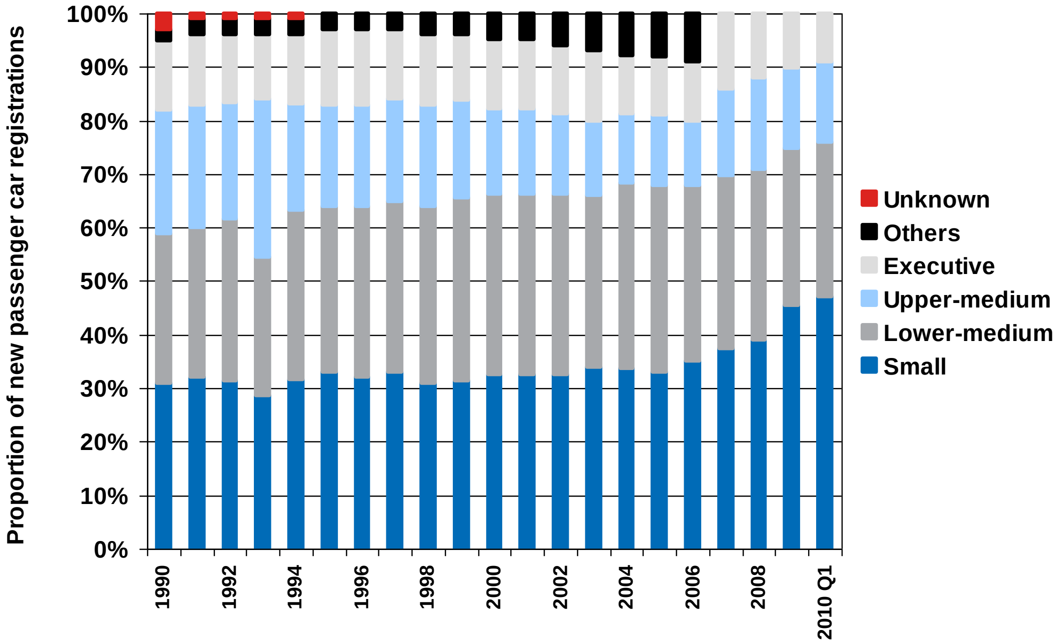

Figure 12: Trends in European passenger car market segmentation

5.4 Car technology trends in Europe

Figure 13 shows the trends in diesel market share in the new passenger car market from 1990 to the first quarter of 2010. In that period, the market share of diesel cars in new passenger car registrations grew significantly from approximately 10% in 1990 to about 50% by the first quarter of 2010. As diesel vehicles tend to have better fuel economy than gasoline vehicles, this trend of increasing dieselisation of the European vehicle fleet is a major contributor to decreasing carbon dioxide emissions from the transportation sector.

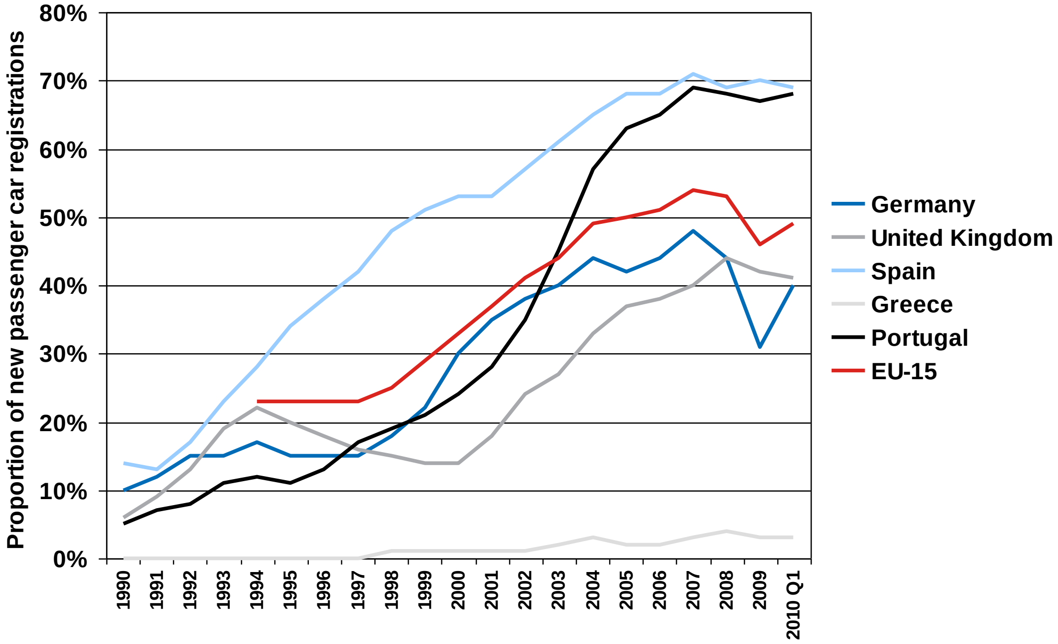

Figure 13: Diesel market penetration for new passenger car registrations

Figure 14 shows the trends in fleet average CO_2 emissions for new passenger cars in each of the five countries of interest to MERGE. There are clear trends of reducing CO_2 emissions for each of the countries, with each of the countries reducing the fleet average CO_2 of new passenger cars by about 10-20 g/km from 2000 to 2008. It is also clear that there are major differences in fleet average CO_2 values from country to country, with Germany's fleet average of 166 g/km significantly higher than Portugal's fleet average of less than 140 g/km.

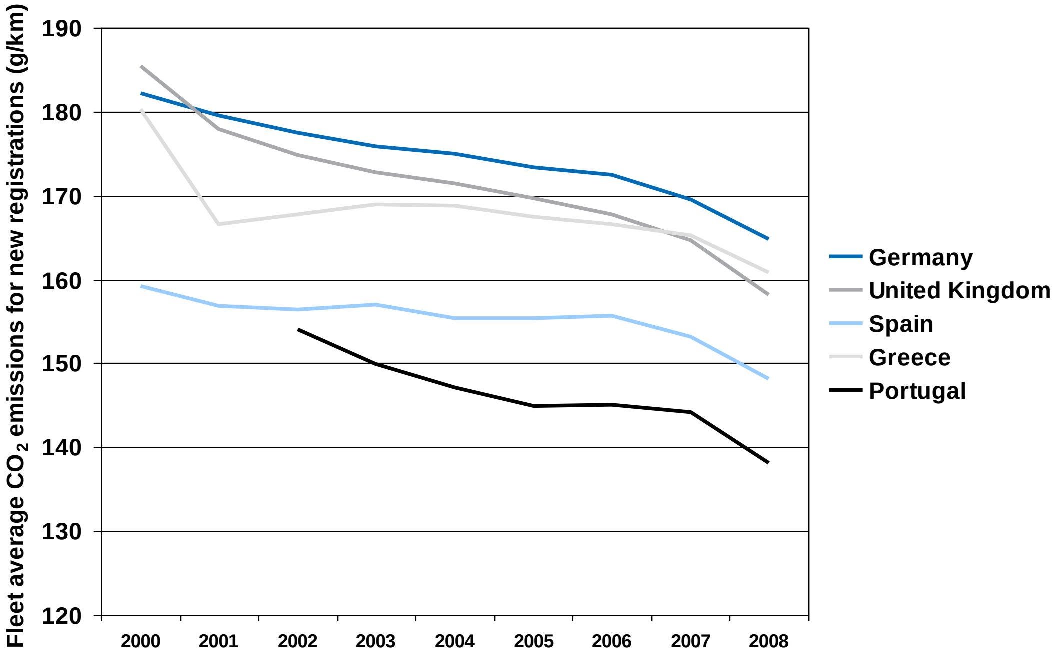

Figure 14: Fleet average CO_2 emissions of new passenger cars

Figure 15 shows the demand for new cars emitting less than 120 g/km CO_2 over the period 1996 to 2009. There has been significant growth over the last 15 years, primarily in two phases. The initial growth period from 1997 to 2004 is primarily driven by first generation hybrid vehicles, while the stronger growth in the latter part of the period was also driven by very efficient small conventional vehicles, such as the Smart ForTwo, in addition to later-generation hybrid vehicles.

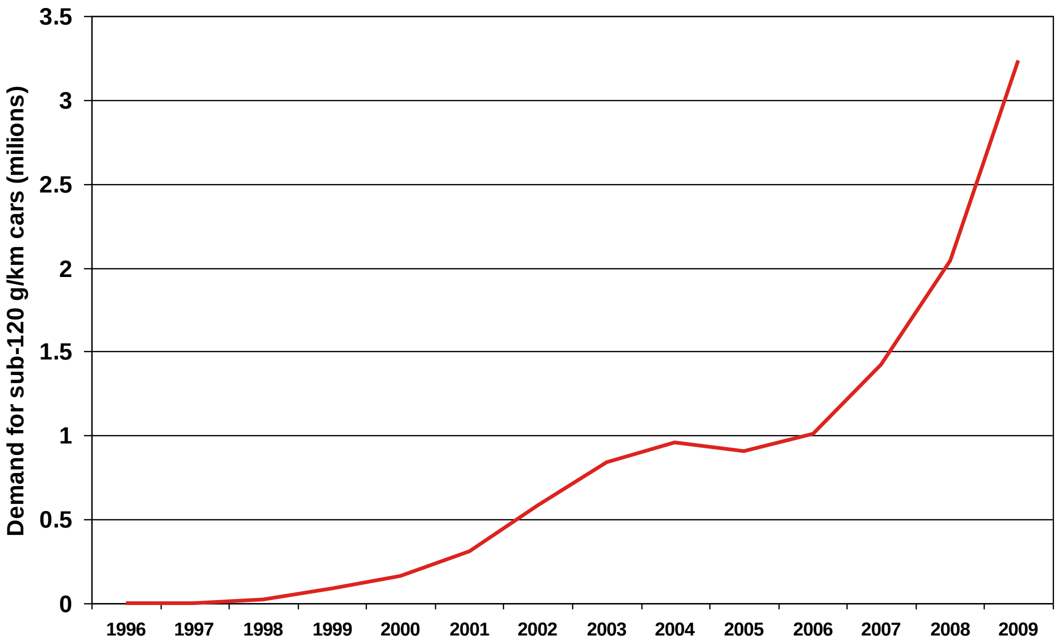

Figure 15: Demand for new cars emitting less than 120 g/km CO_2 in Europe

Figure 16 shows the trends in engine displacement for new passenger car registrations for the five countries of interest to MERGE and the EU-15 average, from 1990 to the first quarter of 2010. Although Portugal has show a significant increase in average engine displacement over the last twenty years, there has been no definite trend for the other four countries, or for the European average, which remained between 1600 and 1800 cc in that period.

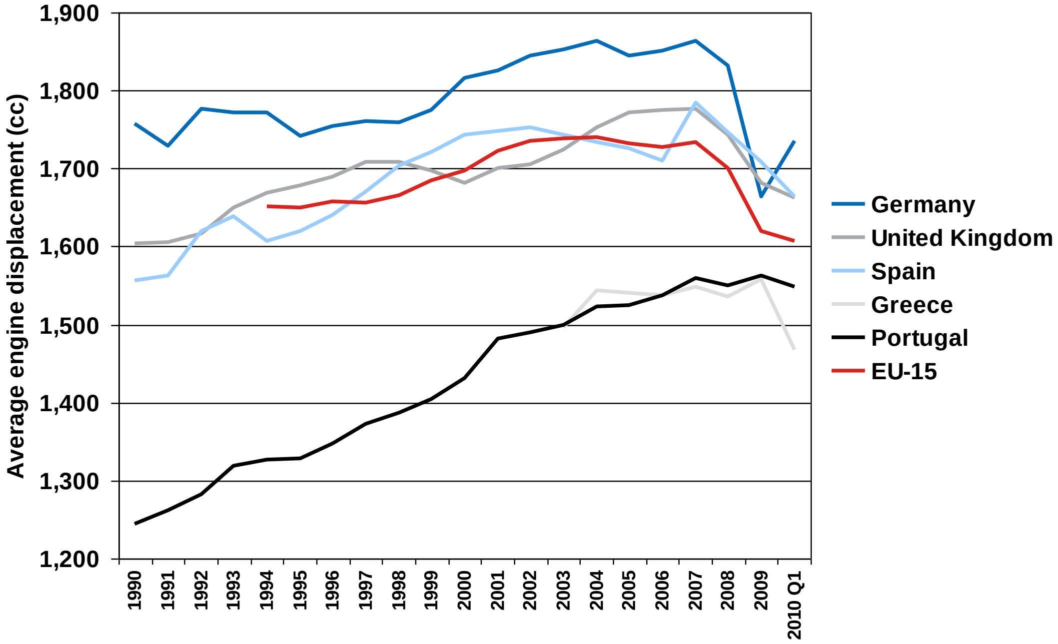

Figure 16: Trends in engine displacement, new passenger car registrations

Figure 17 shows the trends in average engine power for new passenger car registrations in the period 1990 to the first quarter of 2010 for the five countries of interest to MERGE and the European average. There is a strong trend of increasing average power for all countries shown, with the European average growing from 63 kW in 1994 to 81 kW in the first quarter of 2010. This trend, when seen in the context of no significant change in average engine displacement in the same period, represents increasing efficiency of passenger car engines, which is a major driver of the trend of reducing fleet average CO_2 emissions in the same period.

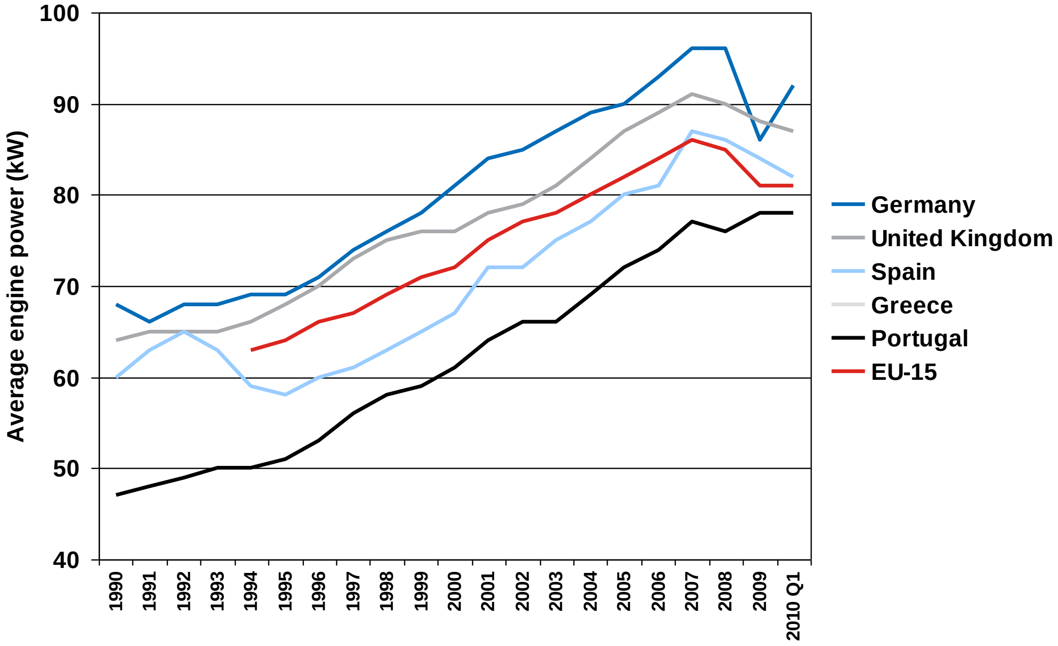

Figure 17: Trends in average engine power, new passenger car registrations

5.5 Car electrification technologies

Figure 18 shows the progression of vehicle electrification technologies from basic stop/start systems, through mild hybrids, full hybrids, plug-in hybrids, to full battery electric vehicles. This progression represents a trend of increasing contribution of electricity to driveline power and also a roadmap for how conventional vehicles can be developed in a logical series of phases, achieving ever-increasing CO_2 benefits. It also represents increasing driveline complexity, until the final step, as a BEV is a simpler driveline configuration than any of the hybrid architectures, which require integration of two sources of motive power.

Electrification	CO_2 reduction potential		Challenges	Outlook
Micro Hybrid – Stop/Start	**- 6%**	Best applications: Urban delivery vans, Gasoline city cars	Larger Diesels harder, less benefit	Will be widespread in regulated markets by 2015
Mild Hybrid – Torque Assistance	**- 15%**	Best applications: Family cars with downsized turbo engines	High cost versus ICE improvements	Possible mainstream solution 2015-20 in EU & US
Full Hybrid – Flexible power unit	**- 30%**	Best applications: Large/premium vehicles, delivery vans & trucks	Very high cost versus ICE improvements	Image & niche products to 2015; growth thru 2020
Plug-in Hybrid – Flexible fuel source	**- 40%**	Best applications: Family cars with mixed journey usage	Cost and life of enlarged battery pack	Affluent early adopter niche 2015-20
Electric Vehicle – Farewell ICE?	**- 65%**	Best applications: Vehicles with limited, predictable daily use	Battery cost / size versus range; fast charge limits	Limited to city cars and vans until battery breakthrough

- **Niche PHEV & EV need to synergise with more mainstream HEVs for economies of scale**

Figure 18: Comparison of progressive electrification technologies

Extended-range electric vehicles (EREV) are likely to appear later than BEV on a similar technology roadmap, as they require the BEV technology to be mature, because EREV requires a full independent electric driveline, before the additional complexity of a range extender engine can be incorporated.

Although range extender engines are functionally similar to generator sets, their use in EREV applications introduce new potential challenges, such as the possibility of fuel and lubricants remaining in the system for long periods without use, if the driver operates almost exclusively in full EV mode.

6 LEGISLATIVE EMISSIONS REGULATIONS

6.1 Timeline of emissions regulations in Europe

Emissions legislation has been introduced in phases in Europe with “Euro 5” being the current standard, having been introduced in 2009. The next phase, “Euro 6” is due to come into effect in 2014. These “Euro” stages represent regulation of CO, NO_X, unburnt hydrocarbons and particulate matter but not CO_2. The legislation governing fleet average CO_2 emissions is separate from the Euro emissions standards, and will be introduced in stages from 2012. This is discussed in section 6.2. There was a manufacturers’ voluntary fleet average target of 140 g/km by 2008, but this was not met. Figure 19 shows the progression of Euro emissions standards and voluntary and legislative CO_2 targets.

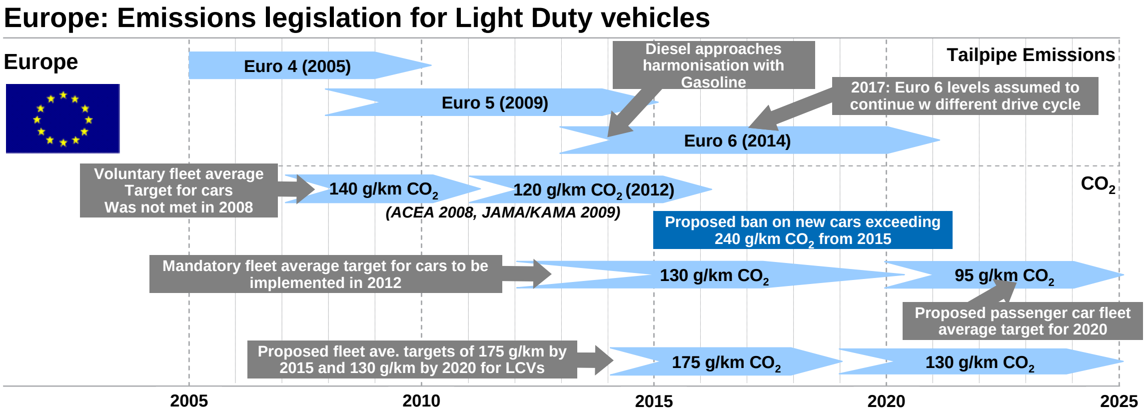

Figure 19: Timeline of emissions legislation introductory dates in Europe

6.2 European fleet average CO_2 legislation

The fleet average CO_2 emissions legislation will be introduced in phases from 2012, aiming to reduce the European new passenger car fleet average CO_2 emissions to 120 g/km. It has been decided that manufacturers should target 130 g/km CO_2 in homologated tests, and will assume that the remaining 10 g/km will be achieved through "complementary measures" such as low rolling resistance tyres and more economical driving styles.

To encourage development of low emission vehicles including hybrids, PHEV and BEV, during the introductory period, vehicles with CO_2 emissions less than 50 g/km will be counted as more than one vehicle in the calculation of fleet averages to assist manufacturers of these vehicles to meet their targets. This system has been referred to as “super credits”. Table 1 shows the proportion of the fleet that is required to achieve the target in each year of the phase-in and the value of the “super credits” for low emission vehicles.

Year	% Fleet	Car <50 g/km counts as:
2012	65%	3.5 cars
2013	75%	3.5 cars
2014	80%	2.5 cars
2015	100%	1.5 cars
2016	100%	1 cars

Table 1: Proportion of fleet required to meet CO_2 target by year and "super credits" for low emission vehicles

Each manufacturer has its own target fleet average, which is based on the mass of its vehicles. Figure 20 shows the current CO_2 emissions and weights of vehicles on the market and the CO_2 emissions targets by vehicle mass. This shows the there is a considerable gap between current emissions levels and the target. Note that vehicle masses are recorded in a set of weight classes, which is why the data appear mostly in vertical lines.

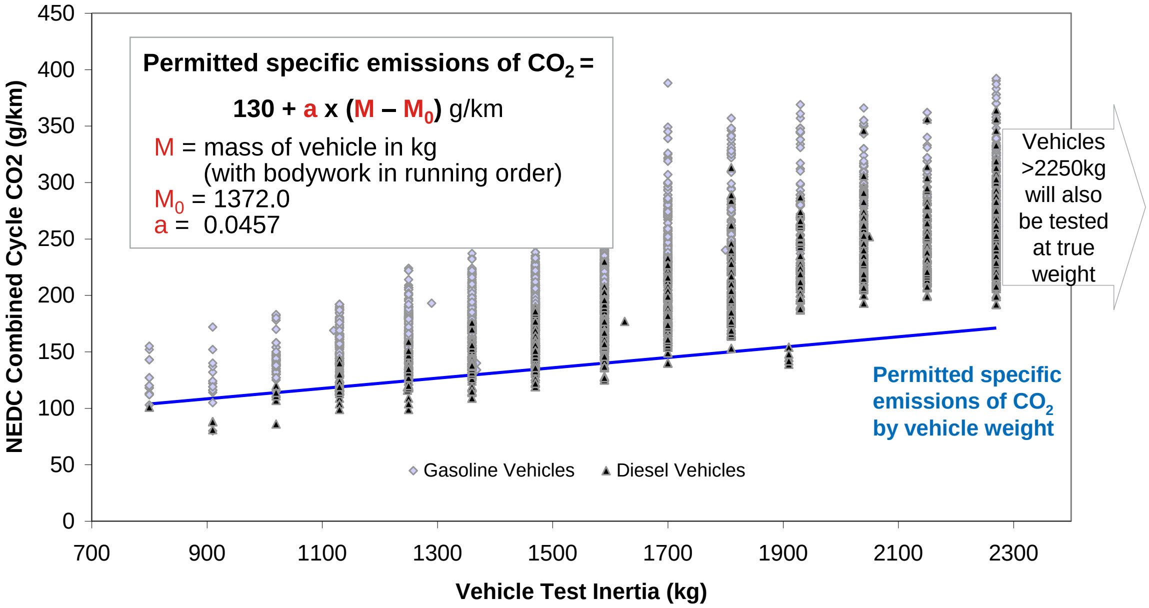

Figure 20: Position of current vehicles relative to the 2012 fleet average target

6.3 CO_2-based taxation and incentives in Europe

Many European countries have recently, or are planning to, reform their vehicle taxation so that it is based directly on the CO_2 emissions of each vehicle. To date, 17 of the EU-27 countries have introduced some form of CO_2-based vehicle taxation [6].

The European automobile manufacturers' association ACEA has lobbied European governments to encourage this taxation basis, as it assists them in selling low CO_2 vehicles by increasing the cost of running more CO_2 emitting vehicles. Table 2 shows the basis of taxation for the five countries of interest to MERGE, highlighting the CO_2-based taxation in Germany, United Kingdom, Spain and Portugal. Greece does not currently tax vehicles on the basis of CO_2 emissions.

Country	Tax on acquisition		Taxes on ownership based on
	VAT	Registration tax based on	
Germany	19%	(none)	CO_2 emissions
United Kingdom	17.5% (20% from 4 Jan 2010)	(none	CO_2 emissions
Spain	18% (since 1 Jul 2010)	CO_2 emissions	Engine power
Greece	23% (since 1 Jul 2010)	Engine displacement and Euro emissions level	Engine displacement, age
Portugal	20% (since 1 Jul 2010)	Engine displacement and CO_2 emissions	Engine displacement and CO_2 emissions

Table 2: Basis of vehicle taxation for the five countries of interest to MERGE, highlighting those based on CO_2 emissions [6] [7]

Many countries also offer incentives, such as reduced vehicle tax or rebates on a proportion of the purchase price of low CO_2 vehicles. These can sometimes be significant, such as the up-to-£5000 purchase incentive the United Kingdom government offers for purchase of BEV or PHEV, or the up-to-€6000 purchase incentive offered by many regional governments in Spain for BEV [8]. However it should be understood that these are likely to be temporary measures and are often designed with political intent and so can be introduced or withdrawn in short time periods depending on the political climate.

7 EV PENETRATION SCENARIOS

The analysis conducted in generating this report fed into the EV penetration scenario modelling for Task 3.2, which produced three scenarios (Scenario 1, Scenario 2 and Scenario 3) for the penetration of a range of vehicle types in each of the five countries of interest to MERGE, for the periods 2010-2020 and 2020-2030.

Figure 21 shows the market share of EV in new passenger car registrations over the next ten years, from 2010 to 2020. Each of the scenarios show EV following exponential rises in the period, with Scenario 1 achieving 4% of the new passenger car market in 2020, Scenario 2 achieving just over 8%, and Scenario 3 achieving 17%.

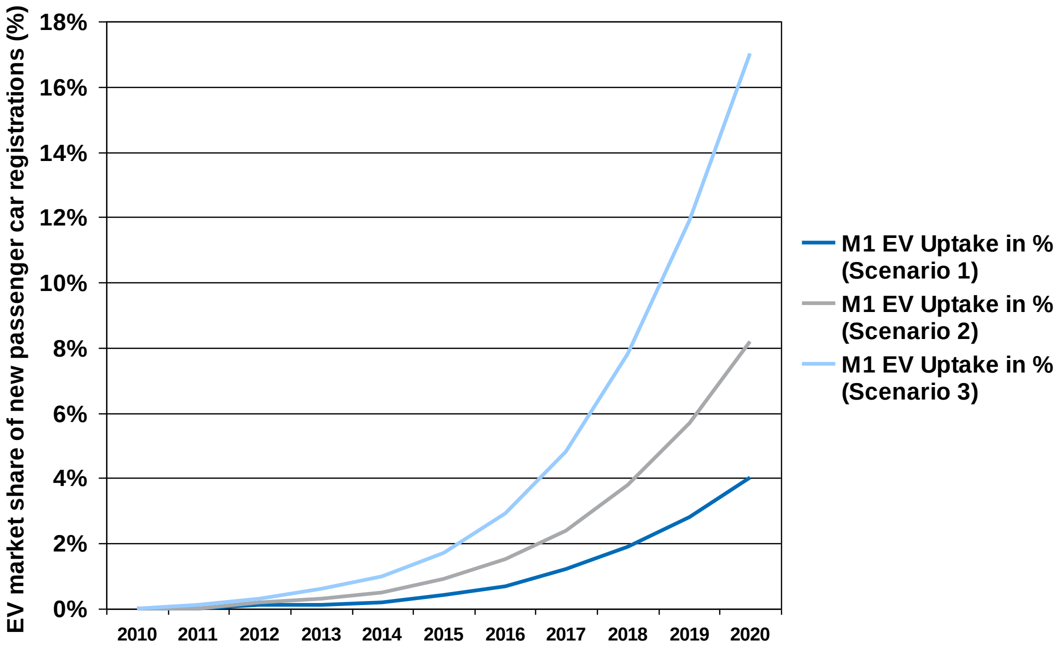

Figure 21: Market share of EV in new passenger car registrations, 2010-2020

Figure 22 shows the market share of EV in new passenger car registrations over the following ten years, from 2020 to 2030. Scenario 1 shows a continued exponential growth pattern, achieving 15% market share of new passenger car registrations by 2030. Scenarios 2 and 3 show EV growth continuing to rise but passing an inflection in the middle of the period as the technology passes the midpoint of a technology adoption model (“S-curve”), with Scenario 2 ultimately achieving 27% of the new passenger car market in 2030 and Scenario 3 achieving just over 50% - although neither scenario has peaked by then so growth is likely to continue into the following decade, albeit at a lower annual rate.

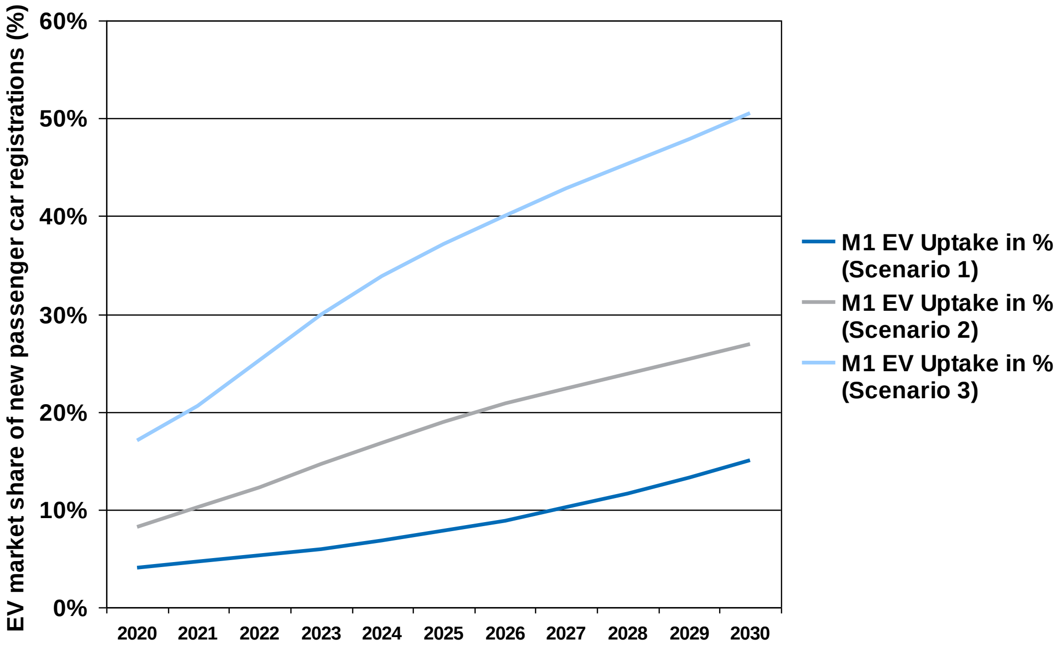

Figure 22: Market penetration of EV in new passenger car registrations, 2020-2030

Further detail on these scenarios and the full set of assumptions that drove them is available in the deliverable for Task 3.2, which is D3.2.

8 STRATEGIES AND SERVICE PROVISION

8.1 Charging

Task 1.1 investigated the hardware and communications requirements for EV charging systems. A range of charging powers and connector types were discussed and rated, as was a range of communications protocols for use in charge management, metering and billing. Three ranges of charge rates were defined for the purposes of the task, although standard definitions of charging levels have yet to be agreed by the many stakeholders. It is likely that one set of standards will be developed to represent standard domestic supplies, higher power domestic supplies and very high charge rate units that will aim to fully charge an EV battery in under one hour.

It is likely that EV produced in the next decade will have 3 kW on-board charging units that will plug into standard domestic electricity supplies, as this requires no further investment on the part of the consumer. Larger vehicles, such as N2 commercial vehicles are likely to make use of higher-rated power supplies in industrial areas, which will allow them to charge larger batteries in a similar time to that taken to charge passenger cars' batteries at a slower rate.

Very high charge rates are not attractive for mass market applications at present as the cost of chargers is prohibitively high and many battery chemistries cannot accept charge at very high rates. High voltage DC supplies cannot be incorporated into existing domestic supplies and would require significant changes to the infrastructure, not just of the vehicle owners' houses, but to the local power distribution networks to avoid significant voltage drops and losses.

At present, conductive charging will be the dominant technology and it would require a step change in inductive charging technology to provide sufficient efficiency, cost effectiveness and safety considerations to allow it to compete with conventional conductive chargers.

8.2 Energy storage

Task 2.1 investigated battery chemistries, capacities and charge rates for the full spectrum of EV available on the market today. Although there is currently a range of battery chemistries available – lead acid, nickel metal hydride, lithium ion and ZEBRA – it is likely that lithium ion based chemistries will become the standard choice for EV applications due primarily to their superior energy densities and improving cost.

Battery capacities are likely to be sized for specific ranges as this will be easy for consumers to understand and visualise. For example many PHEV will have EV-mode ranges of 20-40 miles (32-64 km) and BEV will have ranges of about 100 miles (160 km). For the first ten years of EV adoption, it is likely that these ranges will not increase in line with reducing battery costs as the additional value of incrementally-increasing range will not be noticeable to most consumers, as it follows a law of diminishing returns, and passing on the reduced battery cost to the consumer would be more valuable.

There may be an opportunity for standardisation of battery management systems (BMS) as this would allow for easier integration of the battery into the control system of the vehicle, although this would have to be able to accommodate different battery chemistries, which need different charge management strategies.

Battery life is likely to be a significant focus of battery development in the near term as current battery lifetimes are likely to be lower than consumers may demand, particularly if the battery life is reduced due to harsh duty cycles or operating conditions. This creates an opportunity for a battery leasing business model, which separates the cost of the battery from the cost of the vehicle and reduces the amount of investment required by the consumer up-front. This is discussed in section 8.3.3.

The proportion of a battery's energy capacity that can be used – its maximum allowable depth of discharge (DoD) – is currently in the region of 50-70%. If this proportion can be increased, it would proportionally reduce the cost of the battery for a given range and would also proportionally reduce the battery mass and thus effectively increase the battery energy density. This will also be a focus of research in the coming decade.

8.3 Services provision

The mass adoption of EV technology may generate a range of new business models, opportunities and service offerings that will support the new EV market and fleet. The primary models that will be discussed relate to how vehicles are recharged, how batteries are paid for and maintained and what potential new revenue streams may become available to the EV owners to offset the additional cost of their vehicles compared to equivalent conventional vehicles.

8.3.1 Charging stations

Conventional refuelling stations may choose to install high-power fast charging points to offer recharging to EV similarly to refuelling gasoline and diesel vehicles. This may be an option for service stations that already have high power supplies, such as where they are built beside a garage or industrial complex.

Motorway service stations would be likely to adopt this model before service stations in other locations, as this would allow EV users completing long journeys to recharge their vehicles during rest stops, which would allow for a longer range. It is also likely that drivers stopping for breaks at motorway service stations would accept a recharging time of about an hour, as they may wish to stop to eat at the same time, while drivers stopping at other service stations may not wish to wait more than a few minutes where fewer facilities are available.

However there would be significant challenges to overcome if a service station was to offer fast charging to multiple vehicles at the same time, as this would cause a significant voltage drop in the distribution system, which would reduce transmission efficiency and create high transient loads.

The survey for Task 1.5 showed that there is little interest in this model at present, but this may be due to the technology being unproven as of yet. As with any aspect of a developing technology, the business models and technologies that become dominant are likely to present themselves as the market develops.

8.3.2 Swapping stations

An alternative and faster means of replenishing a vehicle's range than charging would be to replace a depleted battery with a fully-charged battery. This model is being developed by a company called Project Better Place, which proposes a network of battery swapping stations, at which standard vehicles could have a battery swapped by a robotic system in a number of minutes.

This would achieve similar refuelling time to that of a conventional vehicle and would reduce the transients on the grid if batteries could be charged more slowly over longer periods of time. This charging would have to be intelligently managed so that an adequate supply of fully-charged batteries is available when consumers arrive at the station, but without having to carry excessive stock of batteries to meet the demand.

This model would require a significant change in the warranty structure of batteries compared to conventional vehicles as the responsibility for maintaining batteries must lie with the swapping station company rather than the manufacturer or vehicle owner. This may also create synergy with battery leasing models, which are discussed in section 8.3.3.

A successful battery swapping station infrastructure could potentially eliminate range anxiety, provide a refuelling time equivalent to that of conventional vehicles, remove the issue of battery life as a concern for the consumer and separate the cost of the battery from the cost of the vehicle.

Project Better Place has pilot projects in operation in Israel, Japan and Australia.

8.3.3 Battery leasing

As the primary on-cost of an EV is the battery, some manufacturers may lease the battery to the consumer. This removes the issue of battery life as a concern for the consumer as the manufacturer would take responsibility for maintaining the battery and significantly reduces the purchase price of the vehicle, potentially to a level comparable to that of a conventional vehicle.

However this significantly lengthens the time it takes for manufacturers to recoup their costs, as the battery will not be paid for until years into its life, and the risk of battery ageing is borne entirely by the manufacturer.

8.3.4 Grid balancing and ancillary services

EV may be able to provide ancillary services to the electricity distribution system, either by reducing charging load, referred to as demand-side management (DSM) or, by acting as a distributed energy source providing energy to the grid, referred to as vehicle-to-grid (V2G) energy flow.

If vehicles can provide power directly to the owner's house without having to synchronise to the grid, it may be possible to run a house's peak demand from the battery and charge overnight. This is referred to as vehicle-to-home (V2H) energy flow. This would be more efficient than providing energy to the local distribution system (V2G) due to fewer energy conversions and would be a technically more straightforward solution as it would not interfere with metering and billing and may not necessarily require synchronising the inverter to the grid frequency.

There are a number of grid balancing or ancillary services that EV could potentially provide, either by DSM, V2H or V2G:

1. Peak shaving – this involves reducing the home's load during the peak electricity usage times. This could be achieved by delaying charging until late in the evening or overnight, or more actively by allowing the vehicle to power the house during the peak period (V2H) or supplementing supply to the local distribution network (V2G).

2. Response to high system frequency – this involves increasing EV load charging when there is more supply than demand in the electricity system. This could be achieved through the EV grid inverter interface that, if it includes a frequency control droop mode, is capable of responding immediately to the increase in frequency. For those situations where frequency stays above the nominal value for large periods of time, the system operator can send a set point to the EV, through the aggregator, which could be interpreted by the battery management system to mean that the EV may start charging early if it is plugged in and had been waiting to charge at a later time, or it could increase its charge rate if it is already charging at a rate lower than its maximum charge rate.

3. Response to system low-frequency and provision of reserve – this involves decreasing load (DSM or V2H) or providing power to the grid (V2G) in response to a frequency change in the electricity system or in response to an instruction from the transmission system operator (TSO). Again this can be achieved in two ways:

    a. through the EV grid inverter interface, responding immediately to the decrease in frequency by lowering the battery charging rate and/or

    b. by disconnecting the EV battery charger or by decreasing its charge rate for the situations where frequency stays under the nominal value for large periods of time. In these latter situations, a set point will be sent to the EV by the System Operator, originating from the Automatic Generation Control (AGC) functionality housed at the central dispatch centres. These set points should be conveyed to the EV through the aggregators that are thus providing reserve to the system.

Peak shaving, using DSM or a combination of DSM and V2H has a direct economic benefit to the vehicle owner if a cheaper night-time electricity rate is available. Using this model, the vehicle owner either saves money on the cost of charging the EV by simply charging overnight when it is cheaper, or powers his house in the evening from energy remaining in the battery then charging the battery overnight, which effectively provides the power for EV charging and the power for the evening peak at the night-time rate.

However it is also possible that participation in certain grid balancing systems, such as delayed charging to avoid increasing the evening peak, could be required by regulation. Alternatively, a business model may emerge whereby the EV owner could be compensated by the TSO, the distribution system operator (DSO) or a third party agent for the loss of convenience or, in the case of V2G, for the increased battery degradation caused by providing power to the grid.

9 CONCLUSIONS

- This report examined the role of the automotive industry in the new EV marketplace
- Technology and product roadmaps, legislative drivers and historical trends were combined to create a picture of why the automotive industry is proceeding with increasing electrification of its fleet and how this will assist it in achieving its long-term aims
- The analysis performed in creating this report fed into Task 3.2 to generate a set of scenarios of how EV will penetrate in each of the European regions under study in the period 2010 to 2030
- Strategies concerning charging and energy storage were discussed, although these technologies are defined in significantly more detail in Task 1.1 and Task 2.1, respectively
- Potential new or alternative business models were discussed, and the role of the automotive industry in these business models was discussed where appropriate
- The business models discussed are battery charging stations, battery swapping stations, battery leasing models and grid balancing or ancillary services

10 RECOMMENDATIONS & FUTURE WORK

- The findings of this study have fed into the penetration scenarios in Task 3.2
- These scenarios should now be used in the computational modelling of the impact of EV on Europe's power grids in later tasks in the MERGE project

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MOBILE ENERGY RESOURCES

IN GRIDS OF ELECTRICITY

ACRONYM: MERGE

GRANT AGREEMENT: 241399

WP 5
TASK 5.1
DELIVERABLE D5.1
APPENDIX III

ANALYSIS OF POTENTIAL EV OWNERS' BEHAVIOR – ACCEPTANCE OF RECHARGING ALTERNATIVES

04 FEBRUARY 2011

REVISION HISTORY

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AUTHORS

Sandro Fengler	s.fengler@consulting4drive.com
Nora Hartmann	n.hartmann@consulting4drive.com
Colum Joyce	colum@imrworld.org

CONTRIBUTORS

APPROVAL			DATE
Project Coordinator	PPC	N. Hatziargyriou	04/022010
Technical Coordinator	INESC Porto	J. Pecas Lopez	04/022010
Work Package Leader	Comillas	T. Gomez/M. Rivier	04/02/2010

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- [x] Final Version (deliverable, approved)

TABLE OF CONTENTS

1 INTRODUCTION & OBJECTIVES

When changing from a car with an internal combustion engine (ICE) to a battery electric vehicle (EV), several aspects of the consumer's mobility habits will need to change. This report focuses on two of them.

When it comes to recharging an EV, this means a different process than refuelling a car with an internal combustion engine (ICE). Depending on the way in which an EV can be recharged, the consumer will need to take more or less efforts than he usually would when refuelling his conventional car. These differences and the customers' willingness to accept them shall be investigated. How uncomfortable may the recharging process be in order to still not discourage potential buyers?

As a preparation of the in-depth analysis of this very specific area, a rather broad outline of the consumer perception of EVs will be provided.

To conclude, this report has two objectives. First, it shall provide an initial overview of the current state of EV acceptance among consumers of the EU member states. This mainly includes main motivators for buying an EV in the future, but also factors which might prevent the consumer from choosing an EV. The second objective is to identify how from a consumer perspective, the ideal recharging process would look like. This includes both general conditions with factors like density of the charging point infrastructure as well as the design of the preferred charging process.

2 APPROACH

This report contains two consumer surveys. The first survey investigated the consumers' general attitude toward EVs and their motivation to decide in favour of an EV when buying their next vehicle. After this rather general overview of the situation, there will be a more specific investigation on the potential customers' perception of the future charging process and its enabling or hampering impact on the mass introduction of EVs.

Therefore, in a first step, the current situation will be analysed. This includes a description of the traffic infrastructure in three selected markets. Moreover, the currently accepted ICE-vehicles shall be examined with respect to their fuel consumption and ranges and the driving habits of the customer segments they serve. On this basis, the requirements for a competitive charging interface for EVs will be defined.

In the subsequent chapter, a trend analysis of charging alternatives will be executed via literature references and expert consultation. The prerequisites for market success defined earlier will be taken into account. Furthermore, a typical refuelling process will be defined by means of observation and opposed to the future recharging practice.

The empirical part will then investigate the refuelling habits of conventional car drivers and compare these to three alternative recharging concepts for EVs. This will be survey driven. In the end, there shall be a recommendation on how designing the EV charging process in order to allow for maximum usability and customer acceptance.

3 ANALYSIS OF POTENTIAL EV OWNERS' BEHAVIOUR – GENERAL FRAMEWORK FOR CONSUMER ACCEPTANCE OF EVS

3.1 Introduction

The electrification of EU transport is a core strategy in reducing the material and energy intensity of the EU economy through 2020 and beyond.

This strategy in conjunction with the increased use of alternative energy sources also looks to reduce the strategic exposure of the EU in relation to fossil fuels and other primary high value raw materials such as "rare earth" metals.

Such a strategy imposes significant challenges on all actors in the manufacturing, transport, infrastructure (physical and social) and energy sectors. The key challenge is preparing, initiating and managing the inevitable changes in the consumption and usage patterns of consumers.

Vehicle purchases are the second biggest investment that most consumers make in their life after housing. Fossil fuel vehicles are directly (own use) or indirectly (supply of goods and services) integrated in daily life of EU consumers. They are indispensable to the maintenance of basic social wellbeing (distribution of goods and services) as well as providing personal transport when desired or needed by vehicle ownership.

Such vehicles are also a major contributor to Green House gas (GHG) emissions that threaten negative environmental damage within a couple of decades.

Electrification of transport is seen as a key mechanism to reduce GHG emissions whilst also reducing strategic resource exposures of the EU.

This survey sought to look at the consumer and their attitudes to Electric Vehicles (EV). The uptake of EVs by individual consumers will be a critical success factor in addressing environmental issues at all levels of the EU and Member States.

To do so, consumers must be convinced and incentivized to move from a proven, convenient and familiar transport capability to one that is new, unproven and, at present, significantly more expensive (in lifecycle terms) to adopt than purchasing a replacement fossil fuel vehicle.

How this transition is prepared and implemented will have far reaching implications for the EU and its efficiency and environmental strategies.

3.2 Methodology

The survey was designed using an analysis of a selection of previous studies that have addressed the issue of "alternative" vehicle acceptance and management by consumers.

Further input was received from the MERGE partners in order to identify issues and develop insights on the core motivators (positive and negative) that need to be considered when planning the support of consumer transition to EV purchase and integration to daily life.

The survey was translated into French, German, Spanish, Portuguese, Greek and Norwegian. It was then sent to partners to be issued to their client base in order to gain responses.

Response rates were poorer in many countries than with the first survey run using this methodology. Less than 400 responses were received to date whereas over 1,500 were received in the first survey on travel patterns. Multiple reminders and follow ups were requested to be made to elicit greater response rates. The survey will remain open until November 2011 when a final analysis cycle will be carried out.

The initial 400 responses received were treated as a single pool and analysed as such. This was possible because there were few significant differences across the countries that provided the bulk of responses (UK, Germany, Spain, Portugal, Greece).

The results of the analysis were graphed and then compared and supported (where supporting information was located) to provide a broader context to the results. Supporting information was drawn mainly from EU and Member state resources but was also compared to non EU information where available and relevant.

Where relevant and possible, results and possible actions by actors were mapped to EU strategic policies in relation to transport, consumer rights, consumer protection, data access, information and data protection, energy policy and inclusiveness.

Recommendations were then generated to be included in the report.

3.3 Summary

Convincing a consumer to purchase their first Electric Vehicle will require significantly improved levels of reasoning, proof of technical maturity, life cycle cost information, transparency, support and value addition.

These information support resources are not just the responsibility of utility companies.

They are the responsibility of the entire supply and support chain that is emerging to introduce, inform and integrate EVs into the market. This includes governments, urban authorities, urban planners, car manufacturers, vehicle support facilities, refuelling points, house designers, electricians, driving instruction facilities, sales, marketing and customer support (all actors).

The key challenge is convincing consumers to move from a proven, familiar and flexible set of transport technologies to one that is “new”, unfamiliar, costly, the subject of media reports on poor comparative performance and has a history of being aesthetically wanting. They are also seen as being trendy and “green” neither of which has proven to be a market winner in the past in any product category.

A consensus level of EV penetration rate of between 1% – 2% of total vehicle sales by 2020 was found across analysts and car manufacturers. Nissan / Renault were outlier with a projection of 20%.

Even at these low penetration rates the scale and impact of successfully addressing this initial penetration level should not be underestimated. This is why the 2010 Cisco report finding that 84% of Utilities surveyed did not consider EVs to be a key priority is a concern. To support even 1 – 2% of EV vehicles in a national vehicle mix requires the entire grid and electrical infrastructure (supply, management, and customer support) to be EV support capable. This is because EV purchases will diffuse across the market with initial clusters emerging where recharging infrastructures are already available.

Consumers aim to maintain as many of their purchasing, use and financial behaviours as possible when considering the purchase of an EV. Price, range and recharging are key concerns.

What did emerge, was a surprising openness to share information on the use/ operational efficiency data on their EV when buying it. That purchase decision would be made by 66% of the respondents only when “the technology was proven”. Such proof is highly subjective but revolves around purchase price, range, technical reliability and cost of operation.

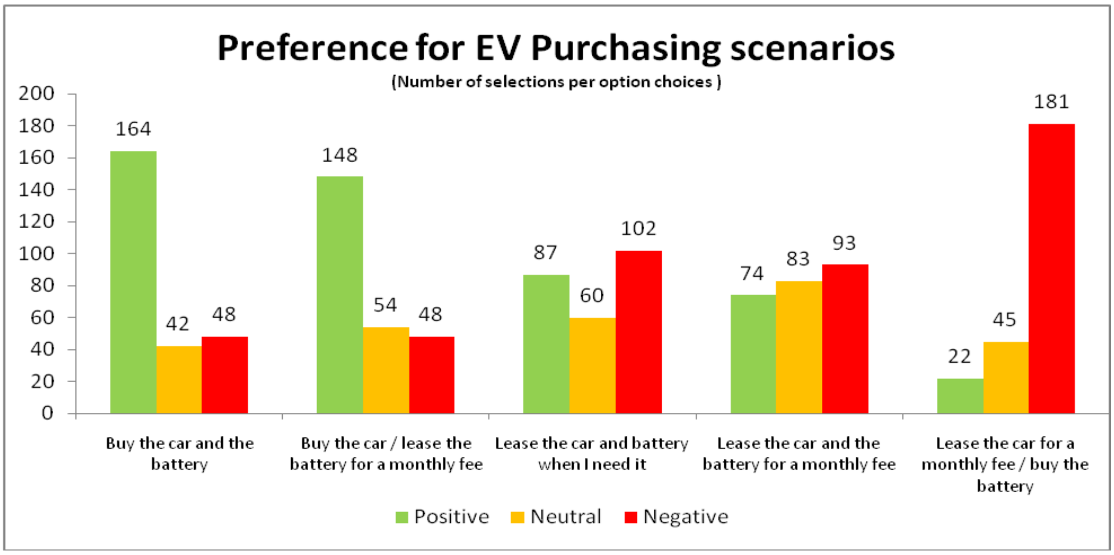
Cost offsets are an opportunity. Consumers show a willingness to share both vehicle data and access to the battery for grid use but at a price. They expect to be explicitly rewarded with bill reductions, payments or some other reward.

They also show a strong wish to maintain separation of transport energy use from that of domestic energy use. This can be observed in their desire to have EV power consumption, whether at home or elsewhere, to be billed and paid for separately. This has important implications for the manner in which utilities bill consumers because “bill shock” has proven to be a source of great interest by the EU in relation to mobile roaming and data charges, internet usage charges and other areas of unexpected poorly managed rises in charges. If poorly managed, the issues related to billing could cause a severe backlash against not just utilities but also EU energy efficiency programs in the period up to 2020.

3.4 Survey Results

Purchasing Preference for electric vehicles (EV)

The option presented in the survey looked to identify which purchase or lease options (car, battery or both) would be considered by consumers.
This is important because it has future business model implications for commercialization of EV. These future models could imply different business relationships between utilities, manufacturers and retail actors in the EV lifecycle.



The most popular option is the existing model where the consumer buys the entire vehicle. In EV terms this is an integrated unit consisting of car and battery. This model maps well to existing vehicle commercialization, supply chain models and actor value chains. Would such a model emerge as the predominant one there would be high reuse of existing car retail facilities, personnel and processes. It provides low opportunities for extension of utility services upstream from the supply of power (fuel) to the purchased units.
The second most popular option was to buy the car and lease the battery for a monthly fee. This would indicate a risk management strategy by consumers where they consider the car being familiar but the battery being a new element in the ownership of a vehicle. Leasing gives responsibility for the supply, maintenance and management of the battery to another actor in the supply chain. This could be the vehicle manufacturer, the battery manufacturer or a specialized third support entity. As battery life cycles are (at present) shorter (100,000 miles / 8 years for the Nissan Leaf)[i] than those of a median car ownership (17 years)[ii] they could be required to be changed up to 3 times during the present lifetime of a car. Leasing removes this future additional cost from the consumer. Leasing of the battery could lead to new supply and value added services being developed between the different actors of the EV supply chain and lifecycle management process.

Ad hoc leasing (leasing battery and car only when needed) or monthly leasing of the car and battery were viewed with the same lack of enthusiasm.
However the least popular option was to lease the car and buy the battery. This had by far the greatest negative rating of all and it even exceeded the positive ranking for the most popular option which was to purchase the car and the battery outright.
A high initial purchase price will be a powerful disincentive to a consumer who purchases the car and the battery. The Nissan Leaf will go on sale in selected US markets in December 2010 for a sticker price of € 21,800 ($ 32,700 after the $ 7,500 (€ 5,000) government subsidy). In Japan the cost on broad market availability in 2011 will be € 29,993 ($ 44,900). The price in Europe on its release in 2011 has yet to be revealed.
A high initial purchase price will be a powerful disincentive. Renault has however sought to address this issue. For their Fluence Z.E. they sell the car (22,000 Euros ($ 30,300) (no subsidies) and rent the battery for € 67 Euros per month ($ 92) for 10,000 kilometres per year (6,200 miles) before VAT.
In the United States there are many and varied federal and state incentives plus tax breaks to encourage EV purchases or vehicle conversions.

In the EU, incentive schemes are also being introduced for EV purchases and use. Electrification of transport figures prominently in the Green Car Initiative (GCI), included in the European Economic Recovery Plan. There are measures to promote efficient vehicles in the Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles and in the Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services.

Many EU countries are actively promoting EV adoption. Some examples are shown below.

Ireland – In Ireland, Green Party minister for Energy, Eamon Ryan announced a scheme to deploy 1,500 electrical recharging stations for use with EVs. In addition, 30 high voltage fast charging units will be deployed, providing a high speed recharge facility every 60 km on interurban routes. Electricity supplied by these recharging points will be free initially. Additional incentives towards the purchase of EVs were announced, including a € 5,000 capital grant. Series production electric vehicles have been exempted from VRT. Annual motor tax for electric vehicles is € 104. The Government has set a target of 10% for all vehicles on Irish roads to be electric by 2020.

Finland – In Finland the prime minister of Finland Mr. Matti Vanhanen has mentioned that he wants to see more electric cars on Finnish roads as soon as possible [and with any cost to the governmental car related tax incomes. Charging at home from motor and cabin heating outlets (common in all Nordic countries) has been determined to be a possible load on the grid. If all cars in Finland run totally on electricity, it will add 7-9 TWh annually to the load, which corresponds to 10 % of Finland's annual consumption. On-line route planners like http://www.uppladdning.nu/ list a daily growing number of free charging outlets set up by merchants and private individuals, making it possible to drive an EV for free from Helsinki through Sweden all the way to Copenhagen.

France – In France the purchase of EVs will be encouraged with 5,000 Euros per EV. The government is also placing heavy emphasis on state and state business adoption of EVs as fleet vehicles to spur initial demand and economies of scale.

Denmark – Denmark is planning to introduce a greater number of battery driven electric cars on the streets — charged on renewable energy from the country's many windmills. Petrol cars are taxed at 180% + 25%; however, EV cars (max. 2,000 kg total weight) are only taxed at 25%. Free parking is also offered to EVs in Copenhagen and other cities, and there is free recharging at some parking spaces.

Germany – "National Electric Mobility Platform" (NEMP) is a German government initiative to develop Germany into a leading market for electric mobility, with about 1 million electric vehicles on its streets by 2020. As the latest development (October 2010) DBM Energy's electric Audi A2 completes record setting 372 mile drive on a single charge.

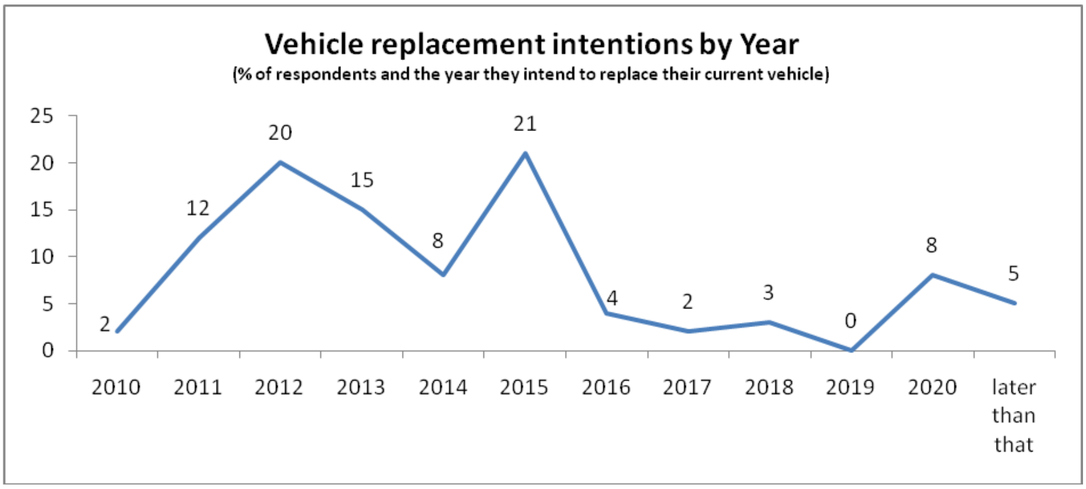
Portugal – The Portuguese Government launched in early 2008 a national Programme for Electric Mobility called MOBI.E. MOBI.E has an open-access and market-oriented philosophy. It allows any individual the access to any provider of electricity in any charging point explored by any service operator. There is a “Managing Authority” which acts as Clearing House and intermediates the financial, information and energy flows among users, electricity sellers, operators of charging points, and the providers of any other associated service. This ensures transparency, low entry barriers and competition along the value chain, with the goal of attracting private investors and benefiting the users, contributing to a faster expansion of the system.
Several measures were taken to increase the demand for EVs in Portugal: (1) EVs are fully exempt from both the Vehicle Tax due upon purchase (Imposto Sobre Veículos) and the annual Circulation Tax (Imposto Único de Circulação); (2) Personal Income Tax provides an allowance of EUR 803 upon the purchase of EVs; (3) EVs are fully exempt from the 5%-10% company car tax rates which are part of the Corporation Income Tax; (4) The Budget Law provides for an increase of the depreciation costs related to the purchase of EVs for the purpose of Corporation Income Tax; (5) the first 5,000 EVs to be sold in Portugal will receive a 5,000 € incentive fund, and the Cash-for-Clunkers program grants an additional 1,500 € fund if a internal combustion engine vehicle built before 2000 is delivered when acquiring the new EV; (6) The Portuguese State did also commit to play a leading role and ordered that EVs will have a 20% share of the annual renewal of public car fleet, starting in 2011.
Portugal is one of the first countries in the world to have an integrated policy for electric mobility and a national charging network for Electric Vehicles. By the first quarter of 2011, a wide public network of 1,300 normal and 50 fast charging points will be fully implemented in the main 25 cities of the country, thus allowing electric vehicle users the ability to travel throughout the country in all comfort and safety.

Spain – Spain's government aims to have 1 million electric cars on the roads by 2014 as part of a plan to cut energy consumption and dependence on expensive imports. Spanish consumers will benefit from a 20% subsidy of the purchase price, tabled at maximum 6,000 € per car. Other Spanish incentives are discounts on the price of recharging vehicles at night and credit lines for companies being active in the development of EV technology.

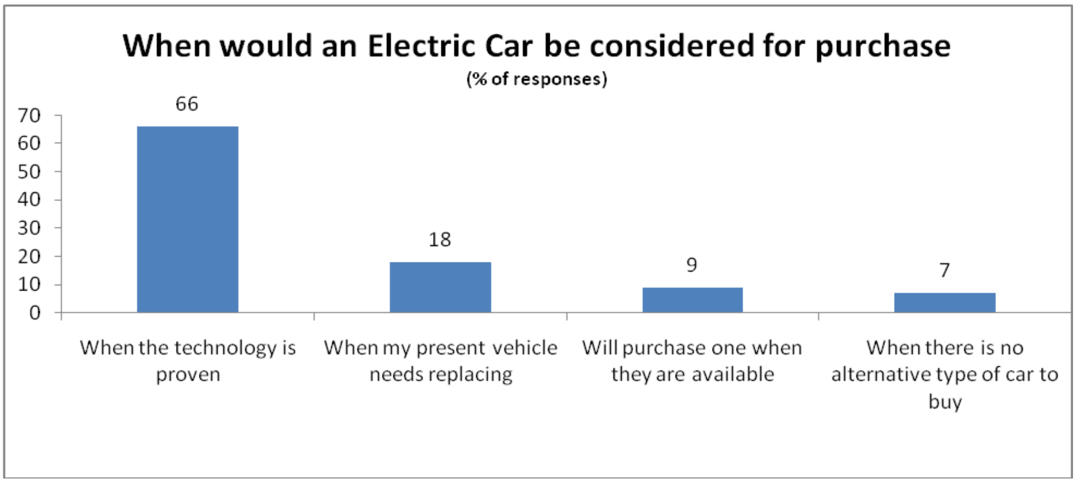
United Kingdom – In July 2010, the UK also announced it would honour a grant starting in January 2011 to give EV buyers a discount of 25%, of up to £ 5.000 when buying an electric vehicle.
This follows the October 2008 the then UK Prime Minister Gordon Brown pledged £ 100 million in government money to support electric, hybrid and other more environmentally friendly car projects over a five-year period to make Britain "the European capital for electric cars".
One of these projects was the Plugged-in-Places initiative which was a UK government incentive to encourage the take up of electric vehicles. London, Milton Keynes and the North East were selected in the first round to receive £ 30 million funding from the Office of Low Emission Vehicles to install 11,000 recharging points and help shape the future of UKs electric vehicle infrastructure.

Replacement cycles and EV purchase timing

Personal automobile stock takes, under normal circumstances, need between 15 and 17 years to be completely replaced.
In the survey two main peaks in replacement intentions were found in 2012 (20%) and 2015 (21%).

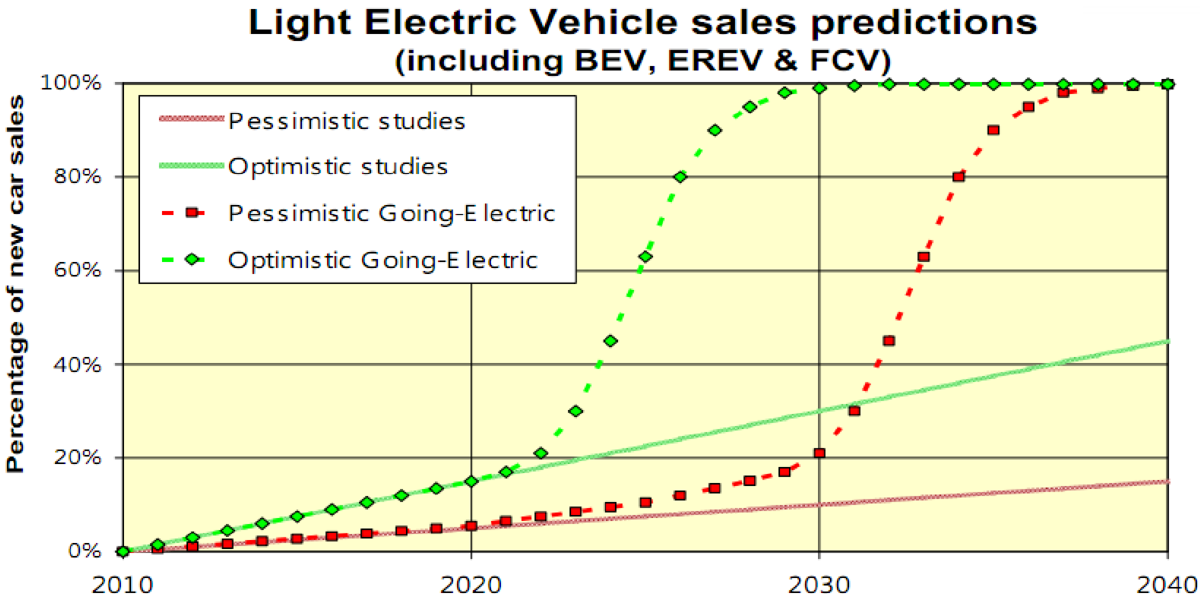


In the period up to and including 2012, 34% of the respondents stated they intended to replace their personal vehicle. Up to and including 2015 the intention to replace a vehicle rose to 78%.
Whether or not the replacement will be an EV is open to question as the majority of respondents (66%) stated that they would only buy an EV "when the technology is proven". This is a subjective judgment by individuals. Whether the level of "proof" is adequate by 2012 – 2015 will have a strong impact on the replacement cycle.



The 18% stating that they would purchase an EV when their present vehicle needs replacing and the 9% who said they would buy an EV when they are available are likely to find such an approach challenging as supplies of EVs are likely to be constrained until 2020.

The chart below is taken from the Association for Electric Vehicles in Europe presentation to the Plug-in EV Infrastructure Europe 2010 conference November 16



2010

Manufacturers and analysts vary widely on their projections of the EV market share through to 2020. Most take a pessimistic view with Ford and Toyota 1% > 2% and Daimler projecting less than 1% and J D Power also project global EV sales to represent less than 2% of global sales by 2020.[iii] Nissan however have projected 20% of total vehicle sales by 2020.
Irrespective of the levels of production the majority of vehicle owners are likely to have a first encounter with EVs through company / government fleets (The Ford company strategy) In France for example, the government itself is expected to order around 100,000 EVs to stimulate demand. Another 50,000 electric vehicles are supposed to be ordered by a group of 20 companies comprising i.a. the French power company EDF, the French railway company SNCF, Air France, France Télécom and the post.
A further early exposure is likely from rental companies or in city car rental schemes such as Paris (Autolib), London and Berlin (Daimler has an experimental fleet of 100 battery-powered Smart cars being offered for monthly lease in London and expects to launch a similar program in Berlin by year's end), Manchester (Manchester City Council and City Car Club, provides the city with a Pay By The Hour car hire scheme).
Irrespective of their first experience of an EV, early adopters are likely (without incentives and subsidies) to pay a considerable premium over the purchase price for a fossil fuelled car. As price competitiveness was considered in the survey as top positive (good price encourages purchase) and top negative (High price will discourage purchases) the price position of EVs will be critical to their early and ongoing adoption.

The decision to purchase an EV will introduce an additional set of considerations to the normal conventional car purchase decision. These revolve around the lifecycle costs and usage support of the EV.

Key elements of this will include:

- Initial purchase price
- Availability of recharging sites
- Ease / practicality of changes needed for home / apartment block recharging of EV
- Cost of home installation of EV charging capabilities
- Cost of smart meters (if any)
- Electricity and billing costs
- Maintenance and breakdown facilities / costs
- Insurance costs
- Purchase incentives, road taxes and congestion charges
- Depreciation and resale value for car and battery
- Recycling and disposal costs

This is in effect, a new cost of ownership calculation with EV specific elements that may impose additional costs on the early adopter of EVs and dis-incentivise a more rapid uptake of EVs across the market.

Lifecycle costs are notoriously difficult to calculate. Without easy to understand EV real cost information price will continue to drive the majority of consumers buying decisions.

Most consumers are unlikely to make "rational "choices because at the time of purchase they will not have the necessary information or easy to use tools to make such a rational choice. Consumer evaluation of a product was / is thought to trade off price, functionality and long term cost V benefits. This is highly unlikely considering the complexity of calculating such tradeoffs as illustrated by the lifecycle cost calculation method shown below.

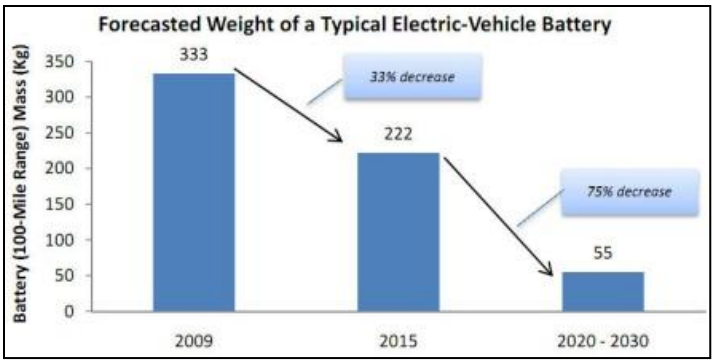
Payback period	$\Delta P + \sum_{1}^{Pay} \Delta Ot = 0$
Payback period if Operating cost is fixed (Used by most rational consumers)	P = - $\frac{\Delta P}{\Delta O}$
Life Cycle Cost	LCC = P + $\sum_{I}^{N} \frac{Ot}{(L+r)t}$
Present Worth Factor	PWF = $\sum_{I}^{N} \frac{1}{(L+r)t} = \frac{1}{r}\left[1 - \frac{1}{(L+r)n}\right]$
Variables	P= Price, O= annual operating cost, n = life time in years, r= discount rate, t = time

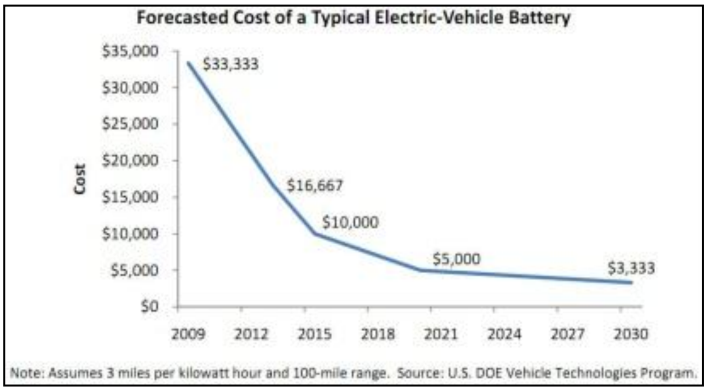
These are simplified calculations and provide some indication of the complexity that any consumer has in arriving at a "rational" decision on what vehicle to purchase.

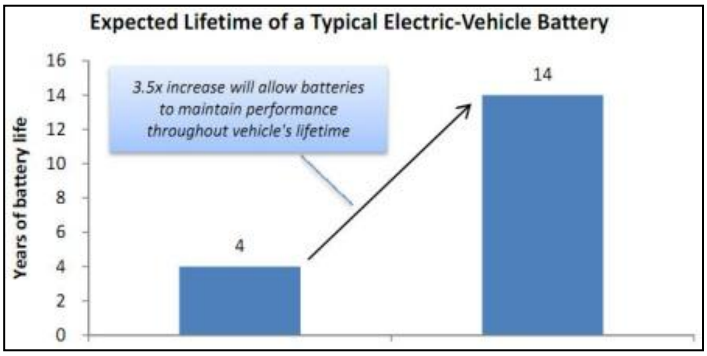
One of the limitations of a total cost of ownership calculation is that four vital pieces of information are not known at the time of EV purchase:

- The cost to establish a charging capability at home
- The time the product will be owned for
- The energy price in the future
- The actual discount rate

These cause the TCO to change throughout the life of the product. There is also impact of the wear and tear on components which can also impact efficiency and hence energy costs of using the product over time.
This is why pure price is attractive to consumers. It is simple to understand and use. Providing efficiency and environmental information that is just as simple will be needed if it is to compete with price in buying decisions.
However the lifecycle costs of EV vehicle ownership are set to fall considerably in the coming decade. A key driver of this will be driven by changes in battery capacity, weight and usable lifetime. The department of Energy in the US issued a report in July 2010 on the projected changes in battery characteristics until 2030. The major projections are shown in the charts below.



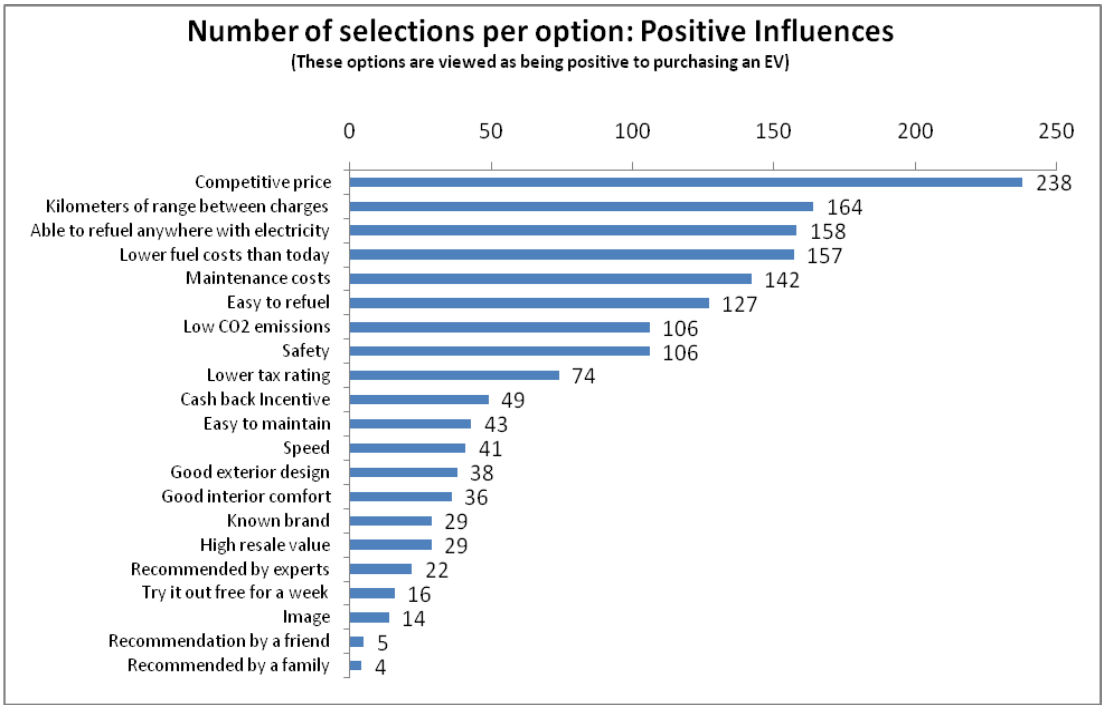




Decreased battery weight will allow EVs to be engineered to use less weight. This will impact wear on components with a concomitant reduction in lifecycle maintenance costs. It will also increase range per charge. The projected fall in battery price (due to economies of production scale and the introduction of alternative battery types) will decrease the initial cost of purchase to the consumer. Most importantly is the extension of usable battery life (based on full recharging 1.5 times a week). Extending the battery lifecycle to 14 years brings means it would match the median time a vehicle remains in use in the market.

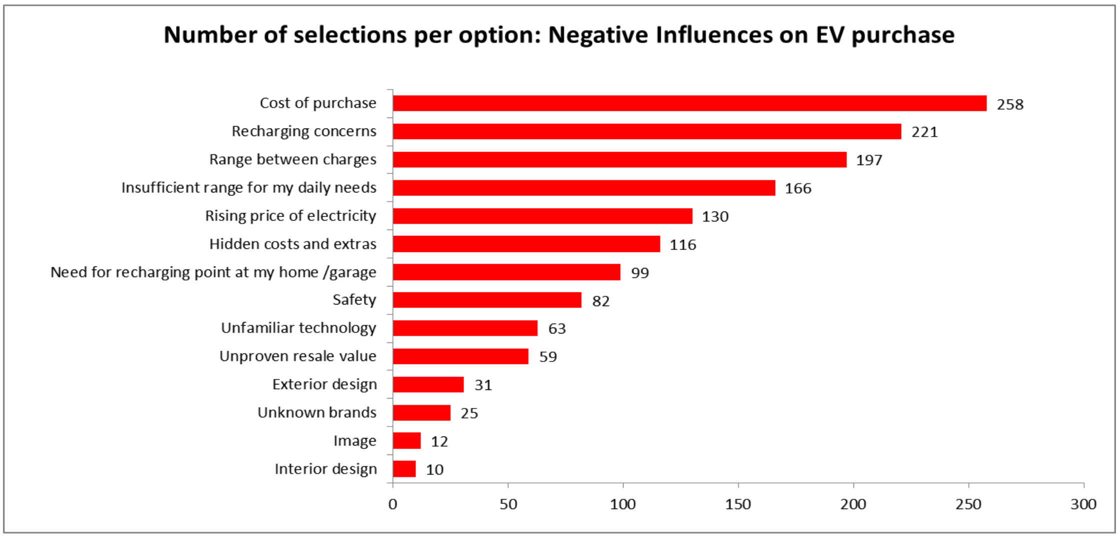
Positive and negative influences on EV purchases

What is evident is that the top concerns all deal with cost of ownership and its management. Here, the greatest positive influence on EV adoption can be exercised.
Price, range and ease of refuelling are the key areas where consumers need to be reassured. EV infrastructure investments and pricing incentives will play powerfully to the potential EV purchaser.



Lower taxes sit on its own as an incentive that is ranked at a medium level. Cash back, emissions, ease of maintenance, safety, speed, design, comfort and resale value are all lower rank positive influences. These interestingly group as areas already legislated for (safety, emissions) or existing common operating / expected practices (speed, design, comfort, cash back and resale value).
The lowest rankings of all refer mainly to recommendations whether from experts or friends or family. Image enhancement and the ability to try out the vehicle also rank in the lowest groupings. This would indicate that the potential buyer sees the process of decision to be highly personal and one that will be made with little influence given to external actors.
What will be influential is ensuring that present entry and ownership costs and convenience related to conventional vehicles are maintained or replaced by alternatives that impose no additional overheads on EV owners.

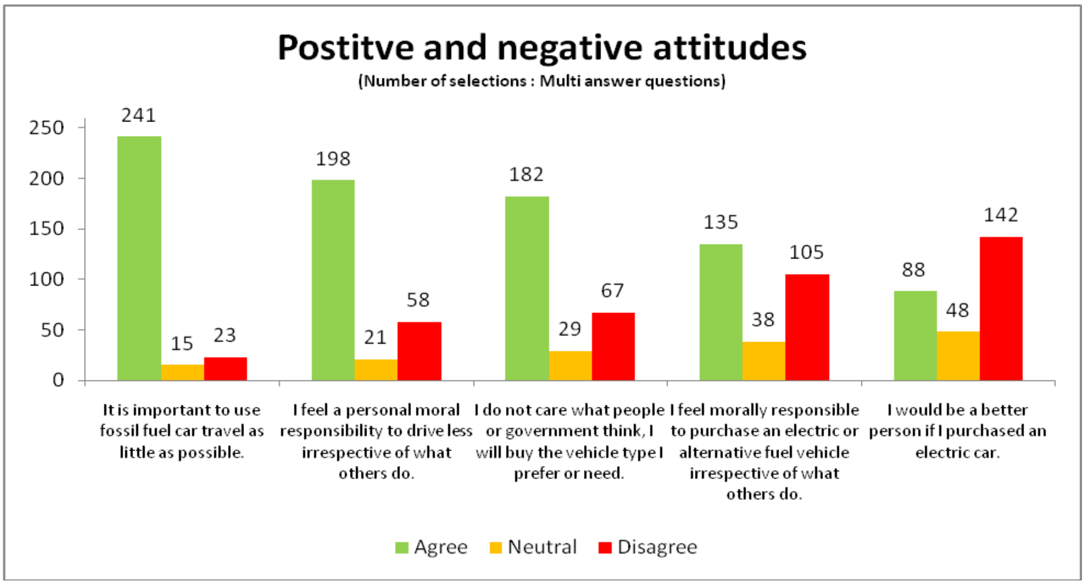
In looking at the negative influences on EV adoption respondents were asked to select areas that, if not addressed, would most negatively impact their decision to purchase an EV.



Cost of the vehicle was the top priority and was followed by a closely grouped set of concerns over range and recharging.
Further concerns on costs followed. These related to a future rise in electricity prices and hidden costs / extras that an EV would bring. This points out strongly the necessity to provide a transparent cost of ownership/lifecycle tool for potential EV purchasers.
The need for a recharging point at ones own residence was ranked in mid table along with safety. This would indicate that consumers are aware that there may be the need for additional domestic infrastructure to address recharging and range issues.
Issues with levels of knowledge of the technology and also visibility on the resale value both ranked closely at the lower half of the respondents concerns. Brand was not a great concern and respondent did not see an unknown brand as a big issue.
Equally image and design were not seen as major issues. This is a change from past research where the “utilitarian” look of EVs was seen as a distinct disadvantage to potential buyers. Recent models are either more conventional or “futuristic” which possibly accounts for this change.

EV purchase: A moral choice?

Consumer attitude to external or moral pressure when deciding to purchase an EV was examined. This was included because of the increasing levels of moral and ethical content in argumentation related to environmental and efficiency lifestyle choices especially from mainstream religious organizations.



What is clear is that responsible use of existing vehicles is seen as being good both in terms of the intensity of use and also as a personal moral position.

However attitudes to purchasing replacing a vehicle are diametrically different. Here, very strong resistance to any moral, organizational or peer pressure to purchase an EV was expressed.

The strongest negative reactions were found about what government or other people think of the replacement decision and also any intimation that the replacement choice reflects on the “goodness” of the person making the choice.

The results could be related to the fact that personal vehicles are the second biggest purchase that a person decides on. The decision can have a high long term impact on finances and the vehicle must be fit for purpose (family or personal). As such the replacement decision is unique to the life style / life structure circumstances of each individual. These circumstances, not external pressures, are the core variables in the replacement choice.

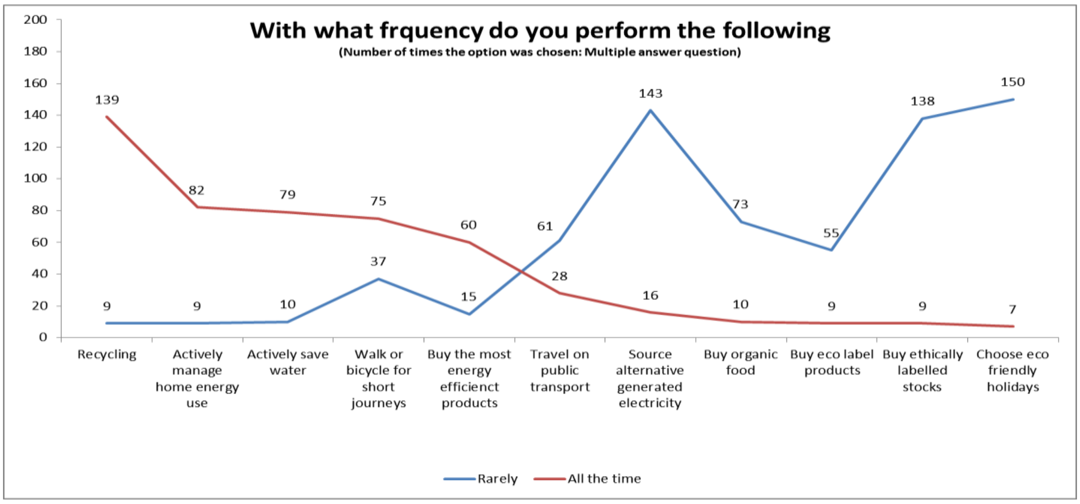
The position in relation to vehicle use is quite a different matter. Here the owner of a vehicle has dual reasons for responsibly managing the use of his vehicle. The first is the management of costs of transport within personal or family life. The second is a realization that responsible vehicle use can contribute to reduced environmental impact. Responsible usage behaviours established when owning fossil fuelled vehicles are highly likely to be maintained when an alternative fuel vehicle is purchased. This is especially likely where the purchase decision and responsible use are seen to be “good” through exposure to reinforcing messages from government, media and peer group contacts and information.

It may also be that “range fear” could also further reinforce existing responsible driving behaviours even as range disappears as an issue due to technological and support infrastructure advances. An example of this type of reinforcement is found in e-commerce where security has always been a concern for governments, traders and consumers. However, e-commerce is now far safer and better protected than any physical world use of payment methods, provision of personal information or commercial interaction. However, the issue of security is so ingrained as an "urban myth" it continues to be one of the top 3 concerns for online commercial actors[iv]. This means that retailers and consumers remain highly vigilant and continue to adapt their behaviours even though the online threat levels are lower than ever.

From the results it is likely that objective criteria (cost, capability, performance and fit for purpose) will drive purchase decisions whilst subjective reasons (responsibility, concern for environment, family and other pressures) will have a greater impact on the usage of such vehicles.

Environmental behaviour

EVs will be purchased and integrated into personal and household environments that already have varying degrees of concern and action related to the environment. What respondents already do in relation to the environment will influence how EVs are purchased and used.



What is striking about the results is how active the respondents are in managing areas that have a controllable domestic cost and those where they have discretion or are remote from the management of daily domestic environment.

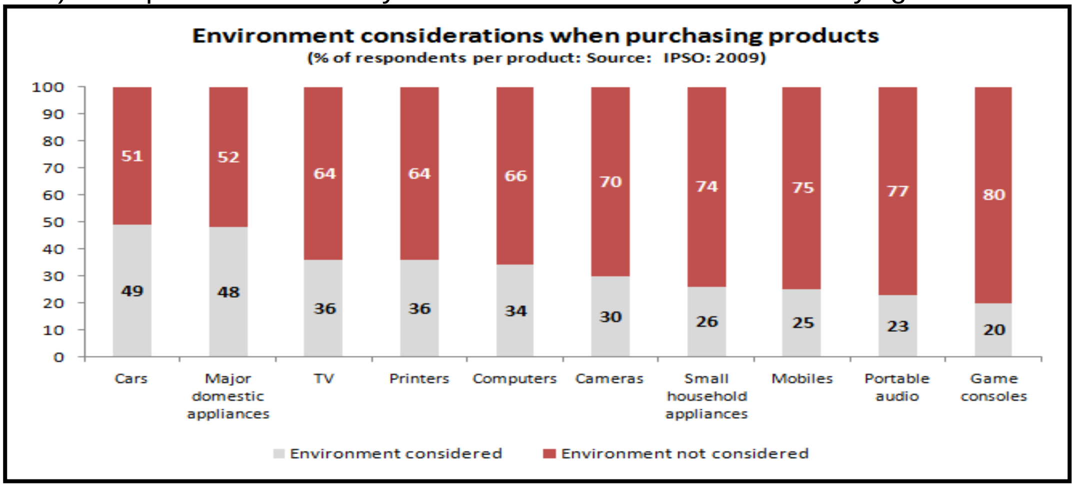
Recycling stands out as an exception. Recycling is an increasingly imposed on consumers by authorities and the incentive to recycle is provided by the high costs (financially and sometimes legal) of not recycling.

High levels of active management of domestic costs related to energy, water and short distance travel were found. All these have a visible cost and are manageable by the individual or family unit.

The cross over comes on the issue of use of public transport. Whilst offering one of the most cost effective and environmentally friendly methods of transport it is found to be unattractive to the respondents. It is a highly discretionary cost to a car owning consumer. It is also seen as an "additional" cost when one owns a car and is often considered not to offer the flexibility and convenience of car ownership.

Respondents showed a low propensity to consistently choose alternative energy or goods/services that are "ECO" labelled. This is not surprising considering the lack of verifiable standards for the vast majority of products and services that are available on the market. Most eco or efficient products or services are uncertified, self certified or certified in ways unlikely to engender great confidence.

The environmental considerations taken by consumers in relation to various products are shown below. Cars have one of the highest ratings but less than half (48%) of all purchasers actively consider the environment when buying a new car.



The size of the challenge related to labelling data and information is illustrated in the "Sins of Green washing report 2009" issued in the US.
It clearly shows challenges that policy makers and consumers face in giving credence or trust to business efficiency and environmental claims.

	Products examined	Claims made by products	Product with no issues	% of all Product with no issues
USA	1721	3890	15	0,87
UK	787	1612	0	0
Canada	1331	2980	10	0,75
Australia	866	1937	5	0,58

The servicing of consumers is lacking transparency, truth and trust. It is therefore unsurprising that consumers have not yet begun to significantly change their consumption behaviour.
The report simply measured 8,544 claims, made by 3,872 products in a number of countries, against 7 criteria. These are listed below:

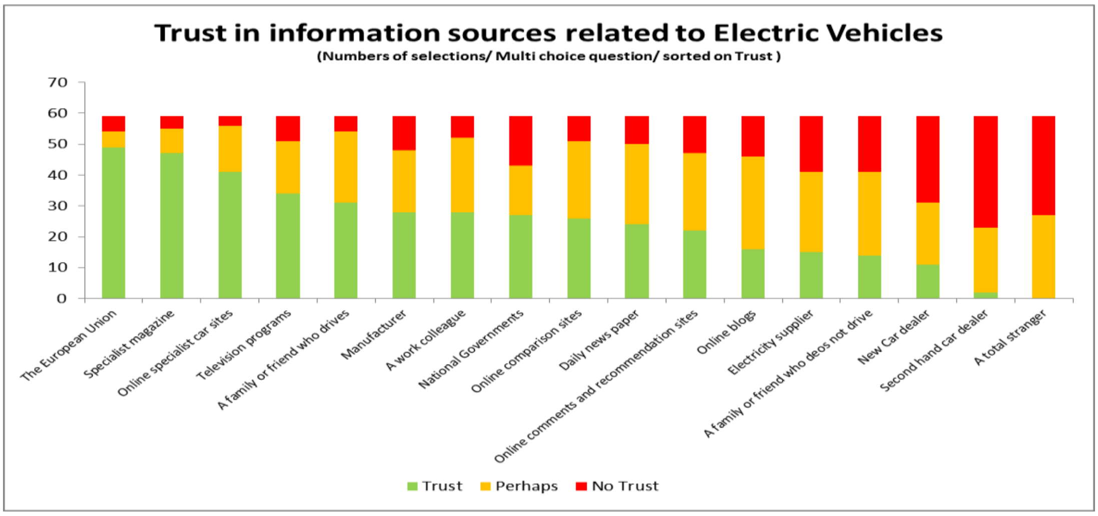
1. A claim suggesting that a product is 'green' based on a narrow set of attributes without attention to other important environmental issues
2. An environmental claim that cannot be substantiated by easily accessible supporting information or by a reliable third-party certification
3. A claim that is so poorly defined or broad that its real meaning is likely to be misunderstood by the consumer.
4. A product that, through either words or images, gives the impression of third-party endorsement where no such endorsement exists
5. An environmental claim that may be truthful but is unimportant or unhelpful for consumers seeking environmentally preferable products
6. A claim that may be true within the product category, but risks distracting the consumer from the greater environmental impacts of the category as a whole

7. Environmental claims that are simply false. The most common examples were products falsely claiming to be Energy Star certified or registered

Less than 1% of the product claims on efficiency and the environment proved to be true against all of these criteria. Of the 8,544 claims made by 3,872 products examined 98% of all products fail on one or more of the criteria. No country exceeded 1% of totally supportable product claims.
This would imply that, to be market credible, any ECO positioning by EV manufacturers or supporting businesses need to be well considered, properly audited and transparent in methodology.

Information trust and sharing

The most trusted sources of information on EV were examined.



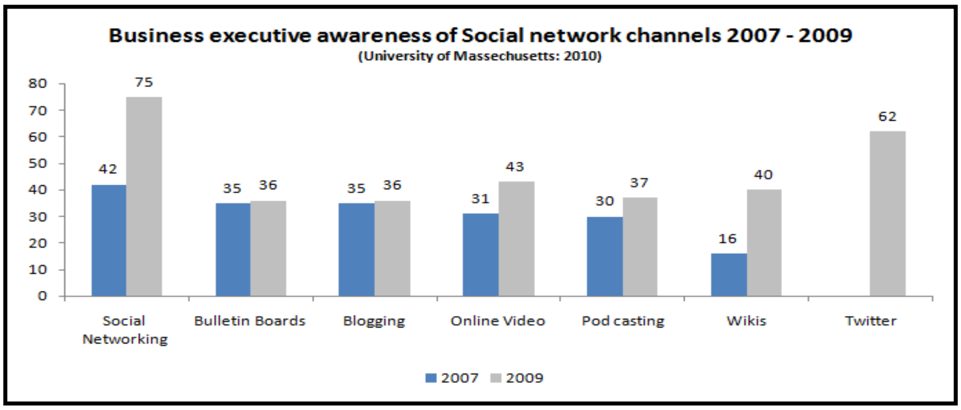
The EU emerged, as it consistently does when examining trusted sources of efficiency and environmental information, as the most trusted source available. Specialist sources emerge as the next most trusted sources of information.

Manufacturers come in mid table as do comparison sites and work colleagues. Electrical suppliers come just above non drivers and second hand car dealers but ahead of total strangers as sources of trusted information on electrical vehicles.

In addition to trust in the information the channels used to provide information to consumers is critically important. Businesses and governments have proven to be less adept at the use of new channels than have consumers. The rate of business adoption of new media and Internet technologies seems to be related to the understanding and importance that a business's senior management team places upon them.

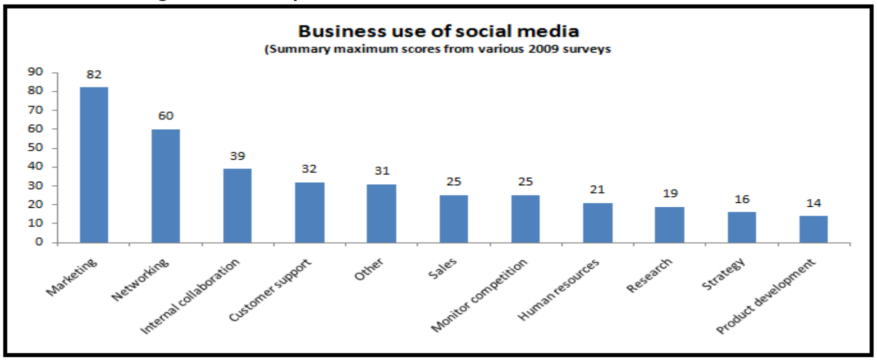
A key indication of this importance is their knowledge of them or their existence. Social network site executive awareness has increased between 2007 and 2009. Wikis and podcasting have seen growth but are less well known. Twitter however has become very widely known in a very short time.

It is also the simplest of the technologies examined by the 2010 University of Massachusetts in the study shown below.



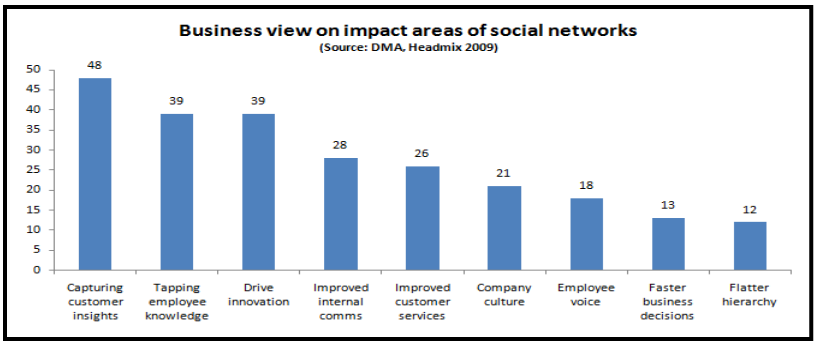
The use that businesses put social media to tends, at present, to focus strongly on internal communications and communications tasks.

How business management exploit social media is shown below.



Social media is still used mainly for projecting marketing information and business to business networking. Its use for consumer interaction has yet to become a mainstream business activity.

In the 2009 Direct Marketing Association / Headmix survey[v] illustrated below again shows this very strong focus on internally facing business use of social media. Whilst "capturing customer insights" was the most important of all the categories to respondents it still only selected by 48% of the respondents.



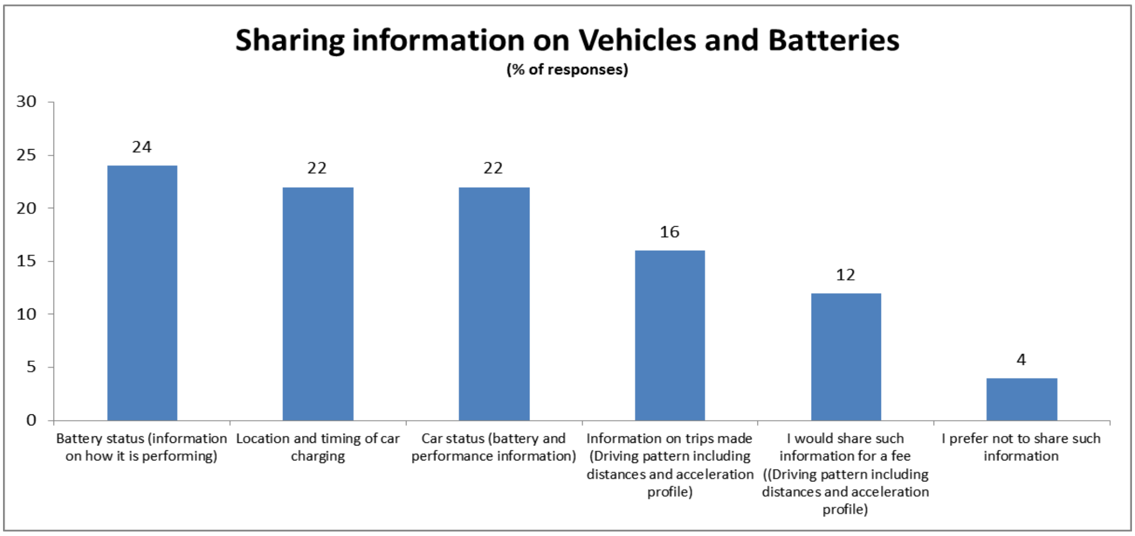
Seven of the nine categories of social media impact are seen as being internal to the company with the second and third areas of importance being seen as tapping employee knowledge and drive innovation.

Better business understanding of who, what, why, when and where consumers are using social media will be essential to help drive awareness of EV and inform them of products and services changes in capability, reliability and range as well as efficiency and environmental implications of such changes.

When it comes to the sharing of data generated during the use of the EV there are distinct changes likely in the attitude of consumers.

Today conventional vehicles have limited onboard bi directional communications capabilities related to performance. Access to information related to the computer controlled functions of the vehicle requires it to be taken to a service facility. Data is extracted with the explicit permission of the owner because the vehicle cannot be adequately analyzed or serviced without such data.

However for EVs there is an emerging wish to be able to monitor the EV especially the state of the battery and is efficiency / performance. EVs will be highly sophisticated technological vehicles and are likely to have high levels of communications capability based on WiFi, GSM or other emerging communications capabilities to help with these monitoring tasks. The attitudes to sharing such data with a third party were examined.



Only 4% of the respondents said they would be unwilling to share any information related to the vehicle and its battery performance.

There are greater levels of comfort regarding sharing of information when it related to only the performance of the battery or the car. When location, trips, diving behaviour and timings are included there is less willingness to share information. These types of information, being pattern based, can be analyzed and used for other purposes. This is a highly controversial practice and increasingly the subject of tighter data monitoring and protection legislation especially in the EU. Great care needs to be taken to ensure that any proposed data collection, storage or sharing strategies and tactics are transparent, honest and fully compliant with existing and proposed data protection legislation.

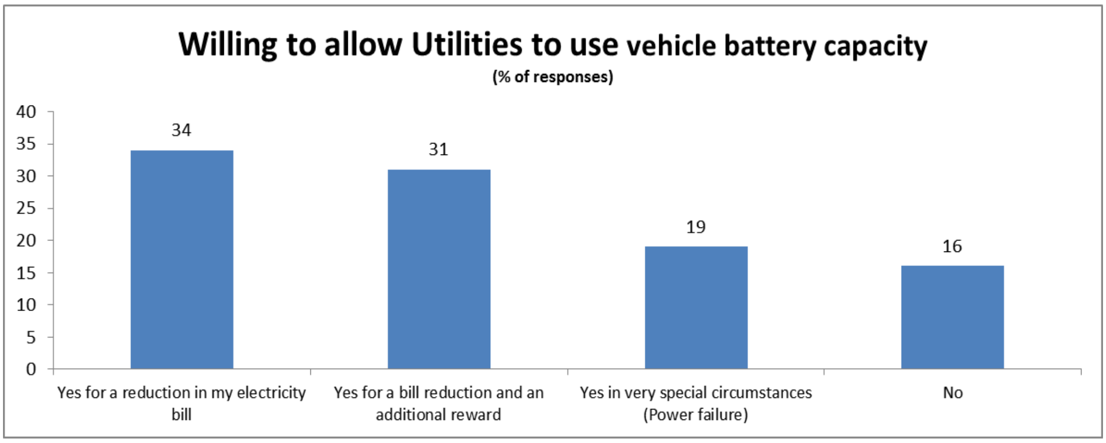
Battery sharing with Utilities

Grid operators usually have to keep 1% of their total capacity ready to help with frequency regulation (Frequency is the number of times per second that alternating current (AC) is transmitted over the electrical grid.). This is costly and highly inefficient financially and environmentally. To assist with frequency regulation and to manage the irregularity of increasing supplies of wind power EV batteries are increasingly seen as an option.

The use of EV batteries frequency regulation does not need the battery to be totally emptied. In fact the battery is used to supply small amounts from each battery to keep the grid running at an optimized frequency level. In return for this the utility reimburses EV owners for the use of their batteries. This can help offset any premium costs of ownership of the EV and also reduce the consumer's monthly electricity bill.

The use of vehicle to grid (V2G) opportunities will depend on the regulatory framework within which the utilities operate and the willingness of EV owners to allow their vehicle batteries to be managed for grid use (storage or frequency regulation).

The survey looked at the willingness of respondents to allow their vehicle battery to be used by the utilities.



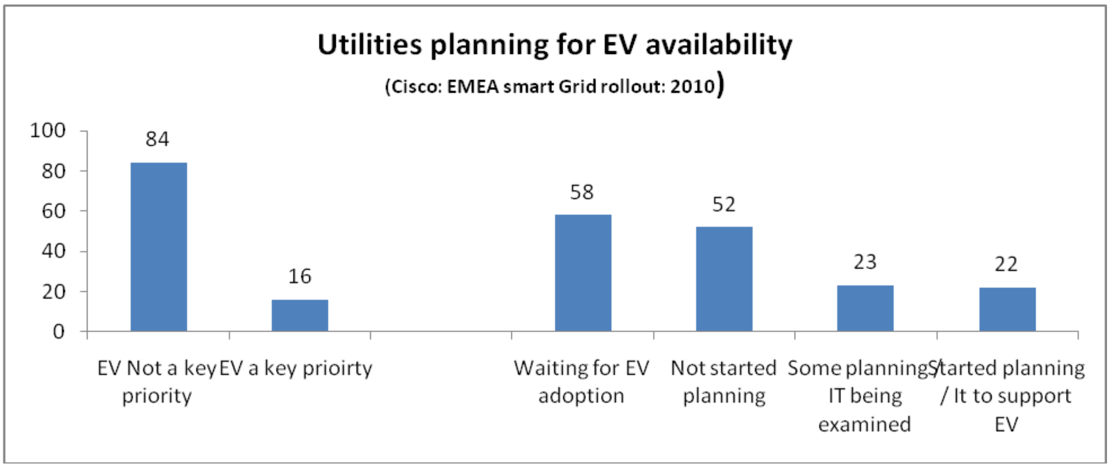
16% said they would be unwilling to allow their batteries to be accessed by utilities for grid management purposes. A further 19% said they would only allow such access in times of special circumstances such as a power failure.

The remaining 65% of the respondents stated that they would be willing to allow such access in return for a reward. Such rewards could be a reduction in their electricity bill and / or an additional reward. This is in keeping with the posited business models for the access to EV batteries for grid management.

In the early stages of EV penetration the major likely source of battery capacity is likely to be fleets of EV vehicles such as school buses, postal delivery vehicles, car fleets and other high volume EV opportunity areas. Such fleets run at predictable times and are available to relatively fixed schedules. This allows a known capacity to be available for grid use whether that is for excess power storage (Wind power etc) or frequency regulation.

Consumer level EV battery access poses management issues for is problematic because of the irregularity with which the vehicles are attached to the grid. In the

initial stages of EV growth they will also be highly dispersed throughout a given grid area and unlikely to prove a significant grid resource.
The regulatory regime in relation to electricity storage and supply to the grid will be critically important and any assumption that EV battery capacity will be available needs to be examined in relation to the legal and fiscal framework in operation in any market. In addition the education and preparation of the consumer base needs to be carefully planned. This will be primarily the responsibility of the utilities (not EV or battery manufacturers) as they will have the commercial relationship with the consumer in relation to battery use for grid management purposes.
The Cisco report on smart grid preparations by Utilities revealed that EVs were a low priority for senior utility manager and that proactive preparations were the exception not the rule.

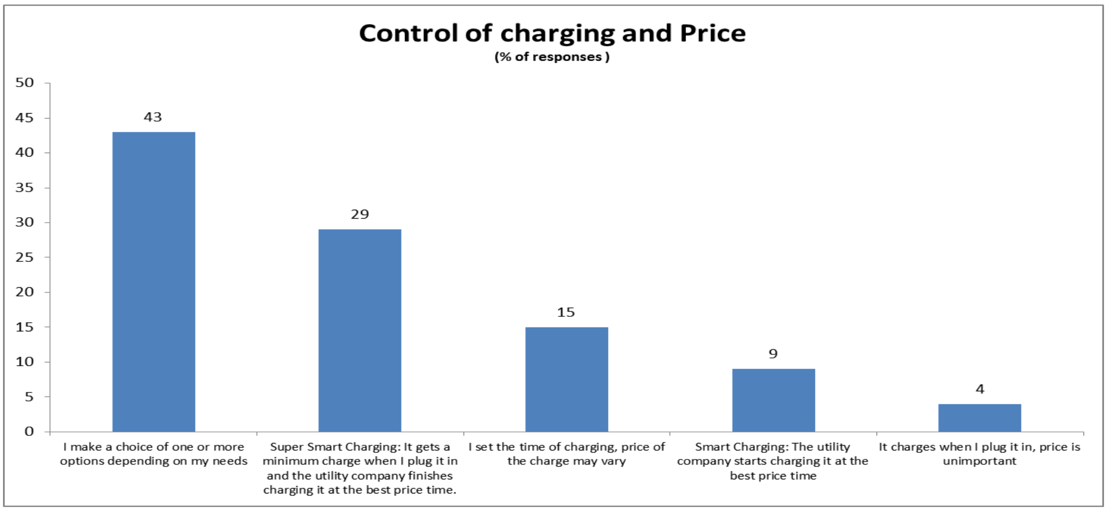


In order to be able to benefit from the availability of the grid opportunities offered by EV utilities need to begin to prepare clear and comprehensive marketing that explains exactly what is done, how it is managed, the benefits and the lack of disruption to consumer lifestyles from them providing access to the battery capacity of their EV.
In addition it is likely that third party storage business models will emerge as the cost of batteries falls and their capacity / life time increases. The purchase of large numbers of batteries is conceivable to provide contracted storage capacity to utilities. For wind farm operators (owners) this is a significant value added opportunity especially where “used” batteries come available on the market after the first EV generation and battery usage cycle begins to end is compete. This could radically change the consumer level compensation model because stable, high capacity resources are available at a lower management cost / unit of power cost to the utilities.

Charging and Billing

Consumers see energy cost control as a key way to manage their household budgets. Purchases of the most efficient domestic appliances, management of lighting, standby and general electrical consumption are key energy and cost management strategies for them. The introduction of EV charging costs is likely to be an electrical “Bill Shock” unless carefully managed.

The survey looked at the attitudes of respondents to the timing and cost of the type of charging that they could have available to them.



43% said that they wished to have a series of options available to them that they would choose depending on their perceived needs.

The most unpopular choice was charge at any time irrespective of the cost (4%) and the next least popular was charging that is controlled by the utility using price as the key decision variable (9%).

The ability of the consumer to set the time of the charging process and an awareness of the pricing difference was seen by 15% of the respondents as being a good option.

However 29% said that they were open to a process where the EV got a minimum charge when it was plugged in by the consumer and then the charge was completed by the utility at the best price position available.

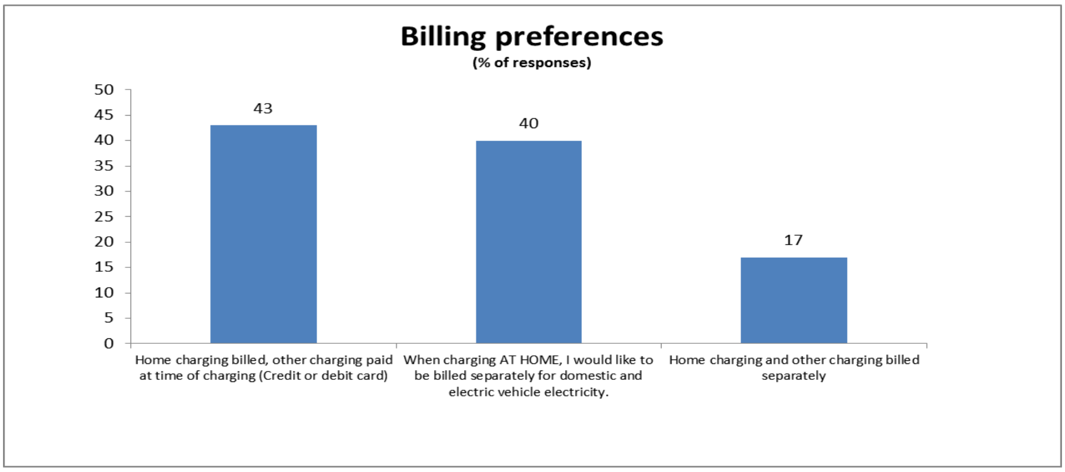
What emerges is a wish for the consumer to remain in control of the charging process because they know when they are likely to need their car and want to reduce the risk of not having an adequate charge to fulfil their transport needs.

Once this is ensured then the consumer is far more likely to allow external control of the charging process especially if it is done in the least cost way by the utility.

This may have a major implication for any smart meter based strategy that seeks to allow / permit utilities to manage other energy using devices inside the domestic households such as washing machines, driers, dish washers etc.

When it comes to how consumers prefer to be billed for their electrical consumption it is clear that consumers wish to:

1) Ensure that domestic and non-domestic charging are billed separately
2) Non domestic billing is managed like fossil fuel purchases today: Via credit or debit cards.



This indicates that consumers will continue to clearly segment their overall energy expenses into domestic and transport whilst further segmenting their domestic electrical consumption into domestic and transport related energy costs.

The method and frequency of billing will be critical. In situations where electricity billing is on an average monthly basis calculated on the consumption of the preceding year the consumer is likely to have a nasty surprise on receipt of their first revised monthly bill. Indeed because such billing strategies also back date the calculation to take into account additional consumption the consumer would also have to pay a lump sum to make up the shortfall between actual and average consumption since they purchased their EV.

For actual consumption electricity bills it will be easier to introduce and educate consumers as to the impending changes in their electricity bill. This strategy also reduces the “lump Sum” issue and where adequately detailed and transparent will not undermine the consumers’ confidence in the efforts they are / can make in reducing overall domestic electrical energy use. Should the introduction of EVs undermine efforts to restrain electrical energy use in the domestic environment it could be a major setback to EU and national policies of conservation and reduction of energy use. It could undermine the savings available from smart meters that are rolling out in the period up to 2020: exactly the time when EVs are predicted to become a mainstream personal transport option.

This would cause a serious divergence from existing EU actions on billing, transparency and consumer switching.

A European Commission study (An energy policy for Consumers) [vi] found last month that EU consumers could save around €13 billion or €100 per household each year if they were to shop around for energy prices and switch to the cheapest tariff available to them. However, less than one in three consumers actually does so. Liberalization of the electricity market will therefore not be as beneficial to consumers as it could be, the study concluded. Consumers must be "properly trained and educated," according to the energy ministers, who underlined that "the energy bill is one of the most important means of information to the consumer".

In addition to these issues are those related to hidden or unexpected extra costs. There are suggestions that the EV would / could be required to have a separate smart meter to manage its domestic charging. Considering that the consumer is likely to already have and *be paying* for a household smart meter any requirement to have a proprietary smart meter and added cost because they own an EV. It will be a very interesting commercial, marketing and fairness challenge to convince consumers that smart meters are not smart enough to manage the charging of the EV especially as the same utility is providing electricity to the house and car.

3.4.2 Recapitulation

From the survey above, the following conclusions can be drawn:

- **EV market preparation strategy –** preparation of the EV market needs to be coordinated across all supply and support (private and public) actors to ensure consumers receive coordinated, consistent and current information.
- **EV market preparation –** actors in the EV area need to identify what are exactly the criteria consumers use to decide whether the EV technology is proven.
- **EV and range –** Range concerns are a key issue for consumers. It is likely to establish as an Urban Myth that EVs are incapable of adequate range. This needs to be forcefully and factually countered as soon as possible.
- **Utilities and EV Preparation –** Utilities need to fully integrate EVs into their smart grid, smart meter strategies and planning processes due to their strategic importance to grid frequency management and establishment of viable vehicle to grid business models.
- **Utilities and market Image –** Utilities need to be aware that they run the danger of image damage as they replace oil companies as the main transport energy suppliers especially in an environment where rising energy prices are common.
- **Utilities and Lifecycle costs –** Utilities and the other EV actors need to provide clear transparent information on the lifecycle and ownership costs for EVs.
- **Utilities and business Models –** Utilities need to examine the impact of home generation on any EV driven business model. Falling generation technology prices and changing regulations may seriously erode EV driven business models.
- **Utilities and recharging technologies –** Utilities and other actors need to consider carefully and analyze the impact of proprietary technologies that could be interpreted as creating market distortions through (real or perceived) restrictions on the consumers ability to switch energy suppliers, operate vehicles cross borders or access multiple support and recharging infrastructures within countries and across the EU.
- **Utilities and smart meters –** Utilities need to carefully analyse the impact of any strategies based on the need for consumers to have a second smart meter to manage home charging.
- **Utilities and batteries –** Consumers express a preference to buy the car but rent the battery. This should be examined as a new business opportunity for utilities and should be examined for fit to long term business strategies.
- **Utilities and Information sharing –** Consumers express a willingness to share information on the performance of their vehicle. Utilities need to ensure that information sought or sourced is fully compliant with existing and emerging data protection and consumer protection legislation at national and EU levels.
- **Utilities and Battery sharing –** Consumers are willing, for a price, to allow their batteries to be used for grid management purposes. The correct levels of sustainable reward / costs have to be established.

- **Utilities and Batter sharing –** Consumers have poor information on exactly what battery sharing implies. Information and clear explanations of how it works and what it implies for the consumer need to be created and communicated.
- **Utilities and Billing –** Billing processes need to be tailored to avoid “bill shocks” especially where monthly average billing is used to bill domestic electricity.
- **Utilities and Billing –** Utilities need to carefully analyze the impact of billing strategies so that they do not negatively impact on energy efficiency activities of the EV owner. This should include the analysis of increased electricity use and its impact on efficiency incentives that are awarded on the downward trend in electricity use in domestic situations.
- **Utilities and billing –** Billing capabilities will have to be able to provide separate bills to EV owners. One for their domestic electricity and one for their EV home charging.
- **Utilities and Billing –** Utilities will have to establish commercial relationship with credit card and other popular mechanisms of point of sale payments.

4 ANALYSIS OF POTENTIAL EV OWNERS' BEHAVIOR – ACCEPTENCE OF RECHARGING ALTERNATIVES

4.1 Introduction & Methodology

This second part of the consumer behaviour analysis will identify how the ideal recharging process – from the consumer perspective – should look like. It focuses on three EU countries: Spain, Germany and the UK.

In the beginning, the current automobile-related infrastructure is investigated from which requirements a future charging infrastructure can be drawn. Then the current refuelling process is analysed by means of observations at two representative gas stations in Germany and analysed in its single sequences which are opposed to the three recharging alternatives which are also being analysed. These findings, which rely very much on desk research and own observations, build the basis on which the second survey has been designed asking potential customers for their opinion how the recharging process should look like.

Finally, the conclusions and recommendations from both surveys will wrap up this report.

4.2 The current situation

This chapter analyses current road traffic infrastructures in three selected countries. These have been picked exemplarily due to their different preconditions concerning area size, road infrastructure, number of inhabitants and climate conditions determining battery performance and therefore represent a good choice within in the heterogeneous European Union.

- Germany is a central-European country with a highly developed road infrastructure and a long automobile tradition. It is densely populated and provides moderate climate conditions. Germany is part of the mid-latitude and warm-temperate pluvial climate zone (Deutscher Wetterdienst 2010). However, the average winter temperature may reduce battery lifetime and performance by 30 % and impede charging.
- Spain belongs to the most Southern EU-countries. It provides warmer and dryer climate conditions than Germany. Therefore, battery lifetimes are expected to be longer and charging should be more feasible than in Germany. The Spanish road net is less dense and the number of vehicles is lower due to the fact that Spain has little more than half the number of inhabitants than Germany.
- The UK is located in the North of Germany and Spain. It belongs to the pluvial climate zone with high humidity coming from the Atlantic and frequent rain. The climate is mild, volatile and cool (BBC 2010, p. 1). The road network in the UK almost equals the one in Spain; however, the country's area size is much smaller.

4.2.1 Infrastructure

In a first step, several rather general figures shall be compared among the countries: area sizes, road networks and populations will be related to the number of registered vehicles and available gas stations. Based on theses findings, requirements for an EV-charging infrastructure will be derived.

Germany – In 2008, the number of gas stations in Germany added up to 14,826 with 379 of them being located near the Autobahn (Mineralölwirtschaftsverband, p. 37). On the other hand, Germany's 82 million inhabitants (Statistisches Bundesamt Deutschland 2010 [1], p. 1) own (Kraftfahrt-Bundesamt 2010, p. 1) 41,7 million registered vehicles. Relating these figures to one another, this means that in 2008, every gas station supplied 5,531 inhabitants on average. Furthermore, with a total of 231,200 km of German road infrastructure (Statistisches Bundesamt Deutschland 2010 [2], p. 1), this complies with one gas station each 16 km. On Germany's 357,050 km² total area (Auswärtiges Amt 2009 1], p. 1), there is one gas station supplying 25 km².

Spain – For the Spanish market, figures look different. In 2008, 9,046 gas stations have been counted. Related to the country's road infrastructure, there is a gas station every 18 km (diarioDirecto 24 May 2009, p.1) of the 166,011 km road network. Taking into account the 46.1 million inhabitants (Auswärtiges Amt 2010 [1], p. 1) and 21,760,174 cars, every Spanish gas station supplied 5,096 inhabitants or 2,831 cars. For the country's total area of 505,990 km², this means that there is one gas station in every 56 km².

UK – The UK provides 174,970 km of road infrastructure (European Commission Mobility & Transport 2010, p. 148). This figure includes motorways, main or national roads, and secondary (regional) roads. In 2008, 61.4 million UK inhabitants (Auswärtiges Amt 2009 [2], p. 1) possessed 29,279,000 cars. Consequently, 8,921 gas stations (UKpia 2009, p. 2) are located every 19.6 km. On average, each of them serves 6,883 inhabitants and 3,282 cars distributed over an area of 27.33 km².

4.2.2 Recapitulation

Comparing the selected countries to one another made obvious that we are dealing with three different scenarios:

- Figure 1 shows that with about 15.000 gas stations, Germany provides a denser net of petrol stations than Spain or the UK with almost 9,000. Compared to the countries' number of inhabitants, Germany and Spain provide similar conditions: some 5,000 people "share" one gas station, while British petrol stations serve almost 7,000 people on average.

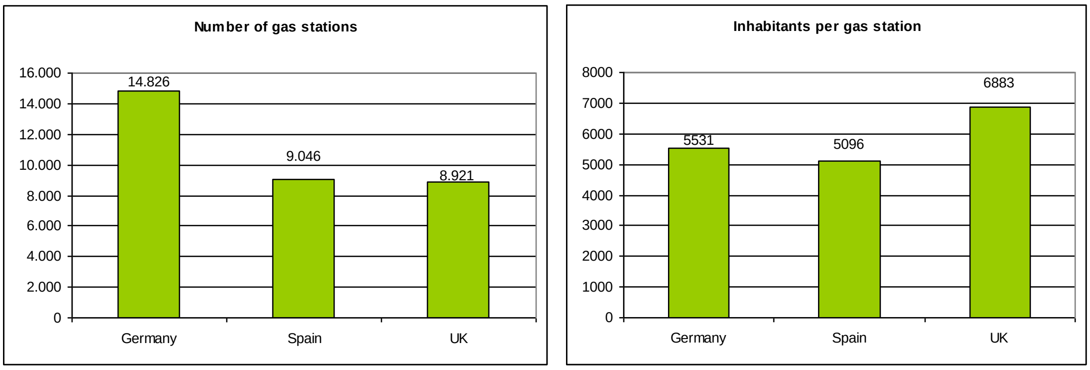


Figure 1: Number of Gas Stations & Inhabitants per Gas Station

- The area of Spain doubles the size of the UK. Therefore, its density of square kilometres per gas station is the least. At the same time, Spain's road network covers almost the same length as the British one does. Consequently, the number of gas stations per road kilometre more or less equals the one of the UK (Figure 2).

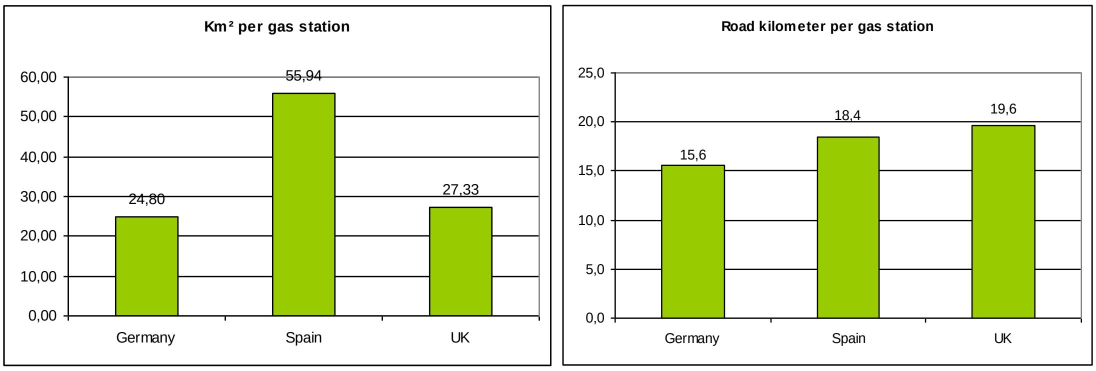
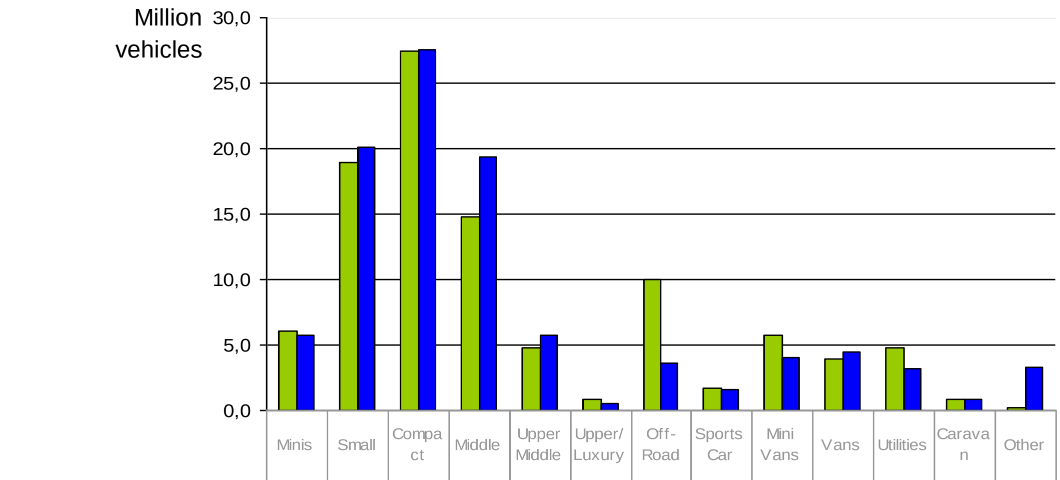


Figure 2: Square Meters & Road Kilometres per Gas Stations

4.2.3 Vehicles and Driving Patterns

Having investigated the external conditions in which vehicles are used in Germany, Spain and the UK, this chapter gives priority to the vehicle itself and observes the customers' driving habits.

Figure 3 shows the current German car park and the development of new registrations.



	Minis	Small	Compact	Middle	Upper Middle	Upper/ Luxury	Off-Road	Sports Car	Mini Vans	Vans	Utilities	Caravan	Other
New Registrations in June 2010	6,1	18,9	27,5	14,8	4,8	0,8	10,0	1,7	5,7	3,9	4,8	0,8	0,2
Current Fleet in January 2010	5,7	20,1	27,6	19,4	5,7	0,5	3,6	1,6	4	4,5	3,2	0,8	3,3

Figure 3: Current German Fleet and Newly Registered Vehicles per Segment[1]

The green graph indicates that over 60 % of the new registrations in Germany are mini, small, compact and medium-size cars (Kraftfahrt-Bundesamt 2010, p. 1). In the UK, the corresponding figure is 71.2 % (SMMT 2010, p. 7). The current German car fleet (blue graph) also mainly consists of these vehicles. The survey executed in WP 1.5 undermines the relevance of this finding for the European market. Within at least six European countries, three quarters of car drivers use a mini, small, compact or mid-size vehicle as their primary car. Moreover, the trend toward EVs applies best to these vehicles as they are designed for urban traffic and e.g. require less space for downtown parking. A Technomar et al. (2009, p.13) study furthermore reveals that consumers, too, expect EVs to belong to the mini, small or compact segment. Consequently, this chapter will reflect on these cars by summing them up in two passenger car clusters: small/mini (e.g. smart) and compact/middle (e.g. VW Golf) class.

Manufacturers usually declare their vehicles' consumption according to the New European Driving Cycle (NEDC) which combines urban and extra-urban consumption. Even though this is supposed to reflect the typical driving pattern of a representative driver, critics state that there is little practical relevance of these figures. Especially in the smaller segments, manufacturers' specifications deviate tremendously from reality. For that reason, the biggest German drivers' association ADAC (cited in Die Auto Experten 2007, p. 1) suggests adding 25% to the manufacturers' consumption data to gain a realistic scenario. As per manufacturer information, vehicles in the small and mini cluster consume 5.25 litres on average when driving 100 km combined (see Appendix 1B and 1C). This equals a range of almost 800 km per tankful. Following ADAC's rule of thumb, the average range of a mini or small size car should realistically equal some 600 km. In the mid-size and compact class, the cars consume 6.6 litres per 100 km. Considering the tank capacity of about 60 litres, their range averages out 885 km. With the ADAC

[1] Source: Kraftfahrt-Bundesamt [2+3] 2010, p. 1

adjustments (cited in Die Auto Experten 2007, p. 1), they come up with some 670 km on one thankful.

In all the three EU countries, 50 % of private drivers use their vehicles for 30 to 40 km rides on a daily average (Autogenau 2009). Moreover, WP 5 indicated that 85 % of the vehicles are not driven farther than 110 km a day. On weekdays, in Germany and the UK 87 % to 91 % drive up to 110 km a day, in Spain these are 64 %. On weekends, still 75 % to 89 % drive up to 110 km a day (Task 1.5.). Cars are used in regular cycles for commuting between home and work on weekdays or for irregular sport and leisure activities on weekends. For Germany, this means 62 % of all rides are private including shopping, vacation or weekends' drives. 31% of the mileage can be attributed to commuting between home and work, and only 7 % are pure business trips (Autohaus DAT 2010, p. 48). In Spain, 83.5 % of the population needs to make use of what ever kind of transport every day. Only 43.2 % of these journeys are done by car. 16.5 % of the transports on weekdays are done to commute between home and work or school/university. 44.5 % of the journeys are undertaken in order to return back home on Fridays. On weekends, 4.2 % still commute between work and home and again almost 45 % travel to their workplace and stay there. All other journeys include leisure time, shopping and accompanying children (Ministerio de Fomento 2007, table 39, 51, 60). These driving habits are also influenced by where a person lives. Figure 4 shows that 41 % of the inhabitants of inner city cycles use their car every day. Another 32 % still make use of their car on one to three days a week. In rural areas, 58 % cover daily distances by car and 31 drive their car one to three days a week. In agglomerate areas, however, the percentage of everyday car usage is highest: 60 % drive everyday, 30 % one to three days a week. In a comprehensive view, this adds up to more than half of the drivers using their car every day and one third using it one to three times a week (internal C4D sources).

To conclude, depending on the driving habits, a conventional car with an internal combustion engine provides a range (on a full tank) which is 5 to 20 times higher than the length of daily trips the car is used for.

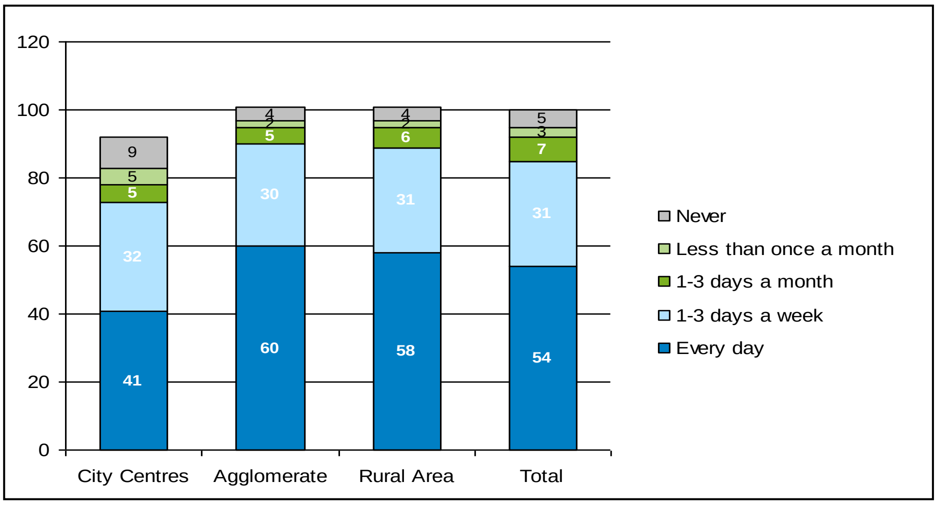


Figure 4: Driving Routines in Germany

While figure 4 reflects on how often the average driver uses his/her car, figure 5 illustrates the average annual mileage of small/mini and compact/middle size cars in the three countries of interest.

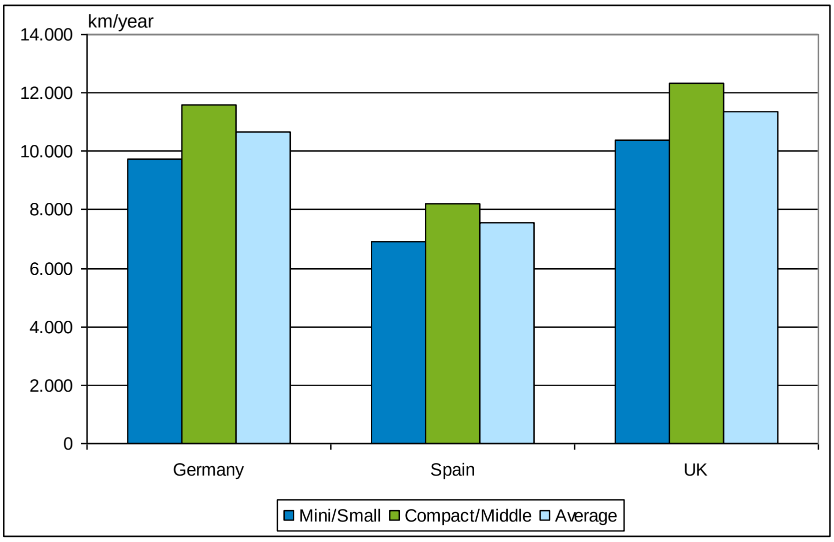


Figure 5: Annual Mileage

In Germany, small and mini private passenger cars cover a distance of 9,741 km per year. Compact and middle-size cars are driven 11,610 km (Kuhfeld 2004, p. 12), on average this equals 10,676 km per year in the lower segment. Assuming that in Spain and the UK, people drive 30 % less or 10 % more respectively, Spanish drivers of small and mid-size cars cover an annual distance of 7,555 km and British 11.395 km.

From these figures, several conclusions can be drawn: Provided that most drivers refuel their car as soon as the tank is about to get empty (see task 1.5), an average German driver needs to refuel his small/mini car almost 17 times a year or less than 1.4 times per month. For a compact/middle class car, these figures almost remain at just over 17 times a year and slightly more than 1.4 times a month. For Spain, figures look different. Depending on the vehicle size, slightly more or less than 12 refuelling processes or one per month are necessary. However, British drivers of the small and mid-size segment have to refuel their car 15 to 18 times a year or 1.3 to 1.5 times a month.

By comparison, today's average EV range is 108 km per charge, according to the manufacturers' information (see Appendix 1A). This is at least as unrealistic as the information on the consumption of conventional vehicles (Auto Motor und Sport, 2009, p. 1). Even beyond the ADAC principle of subtracting 25 % (= 81 km) the scenario remains very optimistic because the drive cycles are unrealistic and not all of these cars already exist. Furthermore, the aspired range calls for optimal surrounding conditions (e.g. temperature, humidity), perfectly arranged equipment components with low energy demand (e.g. no air condition), not too much weight, and highly adjusted driving patterns (slow to moderate velocity) (Elektroauto-Fahren 2010). From today's point of view, Consulting4Drive experts see a range of 40 to 60 km on a fully loaded battery to be realistic. With this scenario and all other things being equal, consumers would need to adjust their habits significantly when they change from refuelling to recharging. Figure 6 shows a comparison of refuelling and recharging frequencies.

	Germany		Spain		UK	
	per year	per month	per year	per month	per year	per month
Small/ Mini	16,72	1,39	11,83	0,99	15,31	1,28
Compact/ Middle	17,15	1,43	12,14	1,01	18,24	1,52
EV	213,51	17,79	151,11	12,59	227,17	18,93

Figure 6: Recharging and Refuelling Frequencies for conventional cars and EVs

From today's point of view, assuming an average range of 50 km, recharging would be necessary quite often – and for many drivers on a daily basis or even more than once a day. I.e. a British compact class driver, who used to refuel his/her car 15 to 18 times a year or once or twice a month, will now have to get used to recharging his/her EV more than 200 times a year or 19 times a month depending on the EV's range. For an average Spanish driver, still 13 charging sequences per month would be necessary to maintain the current mobility level.

For today's consumers, reliability is essential for their purchase decision (Autohaus DAT 2010, p. 22). In order to guarantee mobility at any time and minimize the risk of running out of energy under any circumstances, the vehicle would need to be charged before reaching its range limitations – which indicates an even higher recharging frequency. The fact that this might question the idea of vehicle-to-grid energy flows shall not be discussed here.

Moreover, people are used to a petrol station net with a high service station density. When driving the full range of a conventional vehicle (580 km to 680 km), it passes by 30 to 43 gas stations

	Germany	Spain	UK
Small/Mini	37,37	31,75	29,71
Compact/Middle	43,42	36,89	34,52
EV 81	2,32	3,69	3,08
EV 50	1,43	2,07	1,73

Figure 7: Required Density of the Charging Point Net for EVs

Figure 7 shows that in order to maintain this availability and service for EVs, a charging point would be needed every 1.4 km to 3.7 km (depending on the country).

4.2.4 Intermediate Results/Recapitulation

Chapter four investigated the current infrastructure in three selected European countries. It reflected the behaviour of car drivers today as observed in WP 1.5 and considered the deployment of vehicles in Europe. Linking these factors to one another, the following conclusions can be drawn:

- Half of the European drivers use their cars for every-day distances which are 15 to 22 times shorter than the range of 600 to 670 km their car could cover without being refuelled on the way. Another 35% drive distances which are still five to six times shorter than the expected range of their vehicles. This means that, currently, the majority of Europeans drive cars which provide a high range but make barely use of it. Yet, the still very limited range of EVs will bring about major changes in the drivers' mobility routines.

- Regarding current refuelling habits, it becomes obvious that EV drivers will need to recharge their car far more often than they used to refuel their conventional car. The current EV ranges may allow for travelling daily distances without recharging interruptions on the way. Yet, the refuelling frequency will rise tremendously. E.g. German car drivers will need to recharge 12 times more often than they are used to; LCV drivers even up to 16 times. The sheer number indicates the significance of designing a recharging interface and process which allows for maximum comfort on the consumer side. Otherwise future EV-drivers might be discouraged before even buying their new car.

- There is one gas station within 24 to 17 km² in the UK and Germany. In Spain, however, the situation is less comfortable with one gas station every 56 km². In this country, EVs could represent an opportunity to increase the drivers' comfort because recharging at home avoids long rides to the nearest gas/charging station

- In order to allow for similar comfort and guarantee the same mobility, the density of the charging point net has to be much higher than that of current gas stations.

  For the EV scenarios with an average range of 81 km, a charging station every 2.3 to 3.7 kilometres (depending on the country) would be necessary. For the EV 50 scenario though, charging points needed to be established on almost every 1.5 road kilometre. Beside low margins, this may be a reason for the fact that we are still lacking a valid business model for charging stations.

4.3 Fuelling vs. charging

To analyse how a future recharging process should look like, this chapter will examine how today's refuelling process is structured and accepted by the customer. After that, this structure will be compared to various recharging concepts which shall also be introduced in this chapter.

4.3.1 The Refuelling Process Today

In order to describe the refuelling process to which today's drivers are already used, an observation has been executed. On two different days, mini/small and compact/middle-size cars were observed at two average gas stations:

- One highly frequented gas station with 12 pumps

- One less frequented gas station with 6 pumps

Both gas stations are situated at main roads in Berlin, Germany, and provide an average shopping possibility.

Figure 8 shows that an average refuelling process takes no longer than 5:02 minutes. The driver enters the ground of the gas station and approaches a pump. S/he then gets off the car and prepares the fuelling by opening the tank cap and adjusting the filler. After waiting for the tank to be filled up, the filler is removed and the driver proceeds to the cash desk and pays. Finally, the customer gets back to his/her car and leaves the gas station.

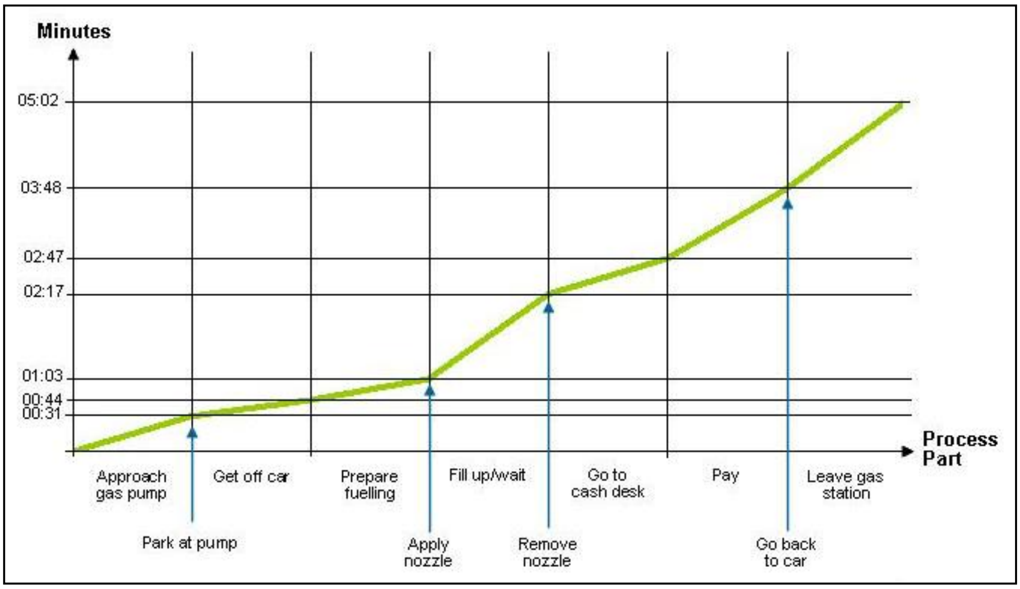


Figure 8: The Refuelling Process Today

Those parts of the process that are the longest single periods are waiting while the tank is filled up and paying. Both processes have the same length and take 1:14 minutes. However, even for small and mid-size cars, this time is too short for a complete fill-up. This indicates that many drivers only refuel several litres instead of filling up the whole tank. So refuelling more often than the vehicles range would require seems to be accepted and in practice. Moreover, after returning to their cars, many drivers seem to take a moment to reflect on their fuelling activities by filling out a driver's log or controlling their mileage. This is why it takes them almost 1:30 minutes to leave the gas stations after returning from the cash desk to the vehicle, even though this duration does not depend on external factors but on the drivers' behaviour and preferences while other parts of the fuelling process cannot be influenced.

4.3.2 Dominant Trends in Charging Concepts

When it comes to recharging an EV, several concepts have been developed so far. Figure 9 represents an overview of possible recharging alternatives and various scenarios in terms of necessary charging duration for a full battery, the need for handling devices like i.e. a connector, intelligence of metering, monthly billing or pay-per-charge and the place where charging is executed.

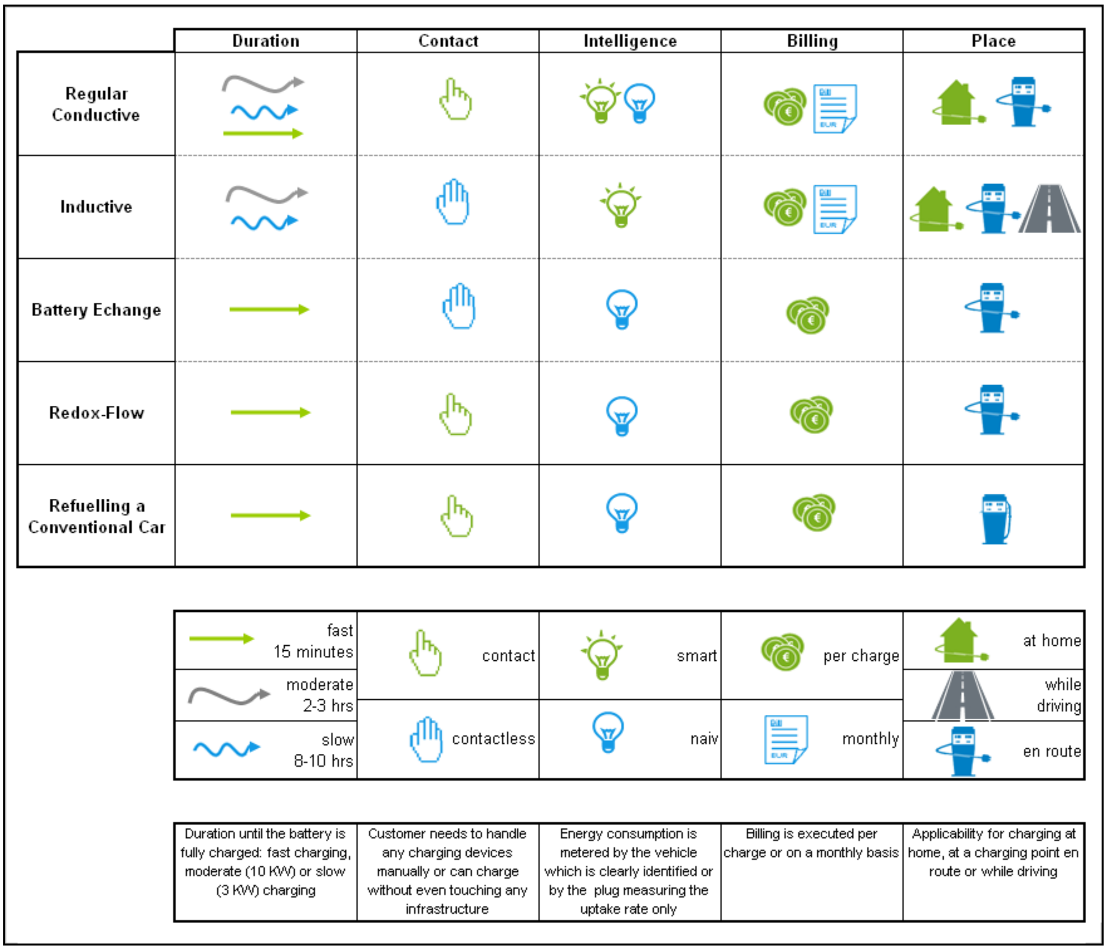


Figure 9: Recharging Alternatives

Most of the concepts introduced in this overview provide several variants. E.g. regular conductive recharging can be done at different paces: fast, moderate and slow. Inductive recharging can be done at home on a private parking place, on public parking grounds or even – in future – while driving. So summing up all alternatives, there is a multitude of possible concepts among which one or several economic and consumer-friendly choices have to be made. For the cause of this study, battery exchange and the “Redox-Flow” method will be neglected in the following because they time wise decouple interaction with the grid from the vehicle charging process. For MERGE, however, the interdependencies of the car and the grid are in focus. For the purpose of this study, three concepts have been selected which shall be compared to each other.

Concept 1 refers to conductive charging which is being executed privately. This can be with a socket installed in a garage at home or on the parking grounds of the company the driver works for. Charging pace is slow and the duration for a complete charge up is 6 to 8 hours. Vehicle and grid are connected by a connector which is placed to the socket; metering is not done intelligently. Billing takes place monthly by means of a regular electricity invoice.

Concept 2 is also a conductive way of charging. Though, this time it is executed at a public charging point similar to the fuelling stations people are used to. The concept of "fast charging" reduces the duration to 15 minutes for a complete charge up. In this scenario, metering is done intelligent but paying is done per charge. Until now, fast charging stations are hardly established because they have several disadvantages. On the one hand, it reduces the battery's life time significantly, on the other hand, the degree of efficiency decreases, too.

Concept 3 refers to public inductive charging at a moderate pace leading to a duration of 2 to 3 hours. The advantage of inductive charging is the contactless and intelligent vehicle identification. This offers high comfort for the customer as well as a monthly billing system does. The disadvantages are higher installation cost and increasing vehicle prices. Therefore, several OEMs consider inductive recharging for the premium EV market. However, additional comfort could represent the necessary buying incentive for drivers of lower segments, too.

4.3.3 Recapitulation

Bringing together refuelling and recharging in a common schematic graph reveals similarities and differences concerning the sequences that make up the whole process. Figure 10 shows that i.e. conductive recharging and conventional refuelling require similar steps of approaching the filling pump/charging point and leaving the station.

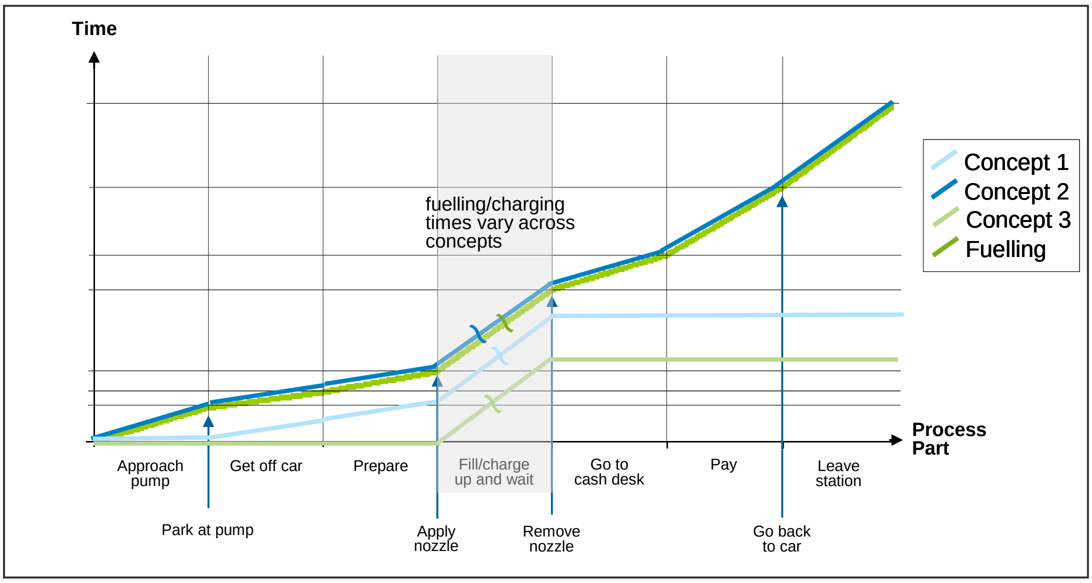


Figure 10: Fuelling vs. Charging

One of the most interesting sequences, the waiting time during the refill/recharge can hardly be modified. Unless significant technological progress is achieved, the duration of 15 minutes, 3 hours or even 8 hours has to be considered as fixed.

However, each sequence represents an opportunity to be designed according to consumer needs and compensate for other unchangeable disadvantages.

4.4 Survey Results

4.4.1 Survey Approach

Based on the findings above, a questionnaire was designed to answer the question how, from a consumer perspective, the ideal recharging process should look like. The questionnaire was made available in three languages: English, Spanish and German. The survey was conducted in a CAWI (Computer Assisted Web Interview) approach with 500 respondents from each country. For two weeks, the survey was open to interviewees who use a car from the small or mid-size segment as their primary means of transportation. Moreover, participants were selected from different regions relative to their population density. Therefore, the results can be considered to be representative. Apart from those questions related directly to the object of research, several socio-demographic factors (e.g. age, profession) have been inquired, too.

4.4.2 Evaluation

Socio-Demographic Data Collection

Figure 11 shows the distribution of responders by where they live.

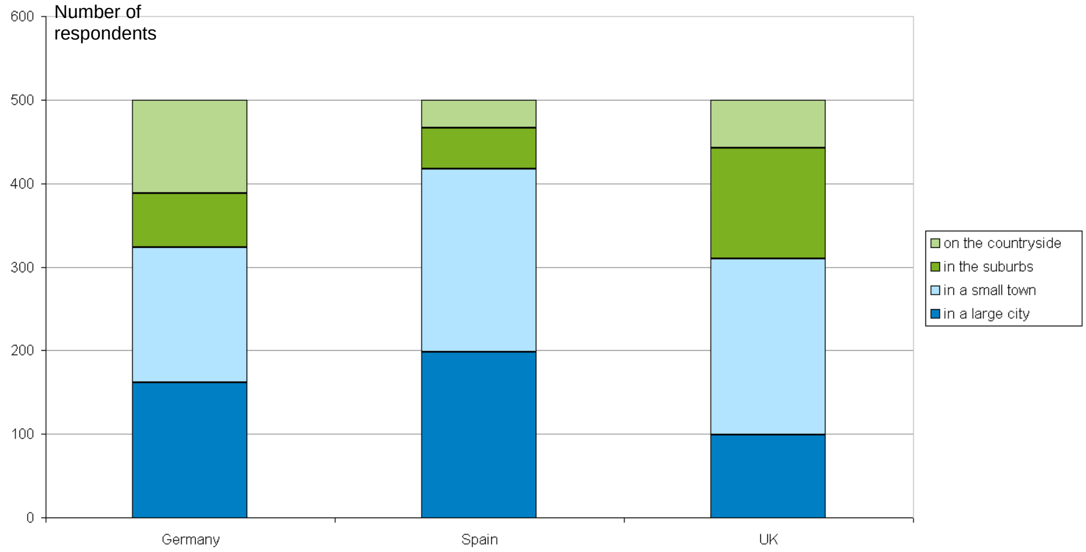


Figure 11: Distribution of where the responders live

In Germany, 23 % of the people live in the countryside, 13 % in the suburbs, one third lives in small towns and one third in a large city. In Spain, almost 40 % belong to the population of large cities while 44% live in rather small towns. The remaining 16 % live in the countryside and in the suburbs. In the UK, more than one third of the respondents come from the suburbs or the countryside, 42 % live in a small town and merely one fifth is resident of a large city.

Figure 12 reflects on the age and sex of the interviewees.

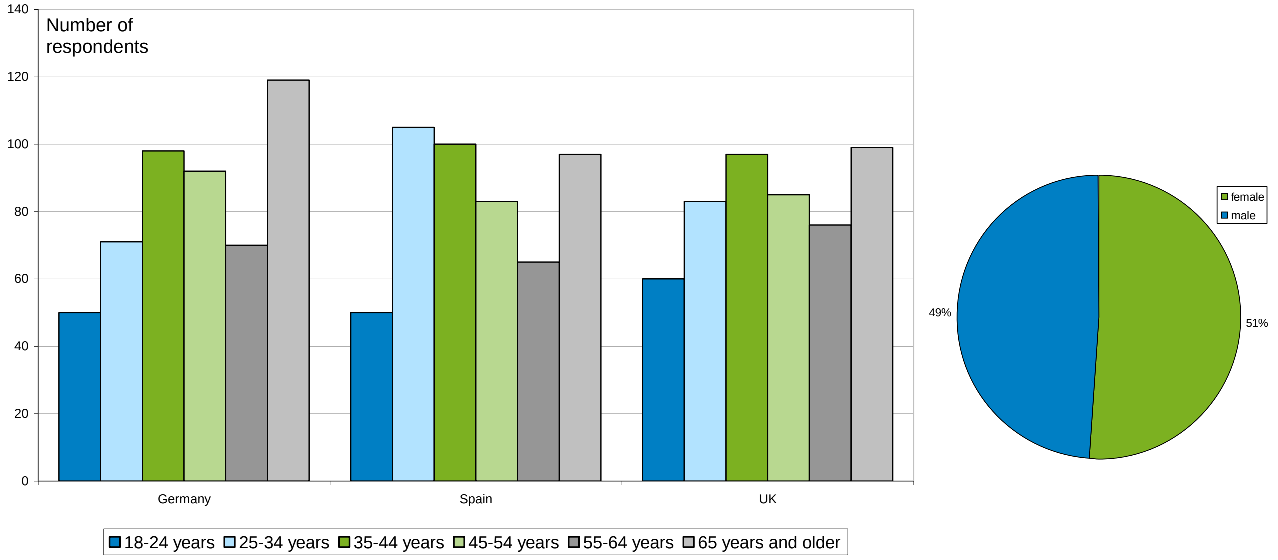


Figure 12: Age and sex of the interviewees

In all the three countries, 51 % of the respondents were female. Age was grouped in six segments: 18 to 24 years, 25 to 34 years, 35 to 44 years, 45 to 54 years, 55 to 64 years and 65 years and older. The number of interviewees in each age group was selected according to countries' age structures.

Figure 13 shows the occupation of the respondents according to the classification used in the other surveys of this report. Moreover, it gives an overview of the industry sectors the participants work in.

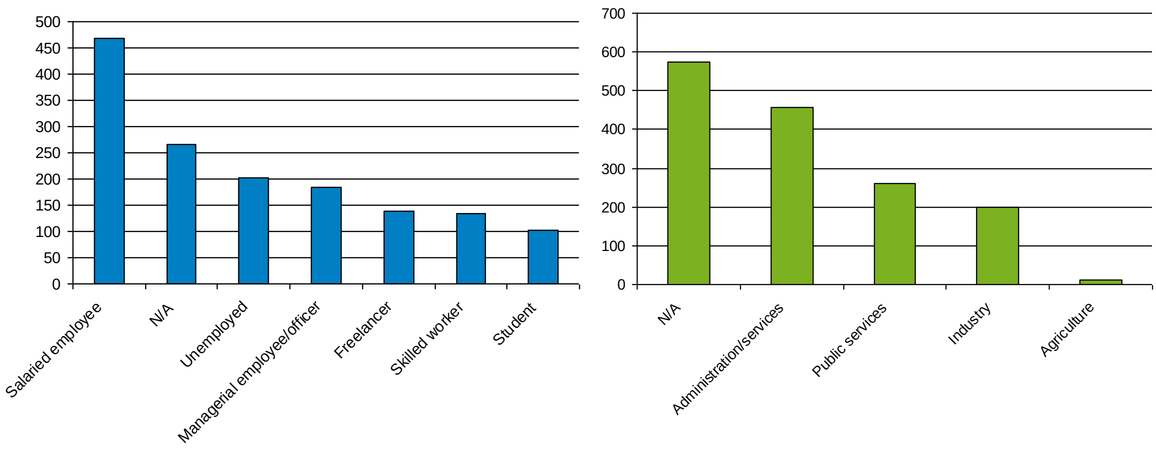


Figure 13: Occupation and Industry Sectors

One third of the interviewees work as salaried workers. 12 % work in an executive position, 9 % are freelancers or skilled workers. The minority of the respondents were students. 18 % did not reveal their occupation and another 14 % were unemployed when the survey was executed. Even though many participants did not reveal the industry sector they work in, almost half of them claim to work in administration and public services.

Figure 14 provides an overview over the vehicle segments driven by the interviewees.

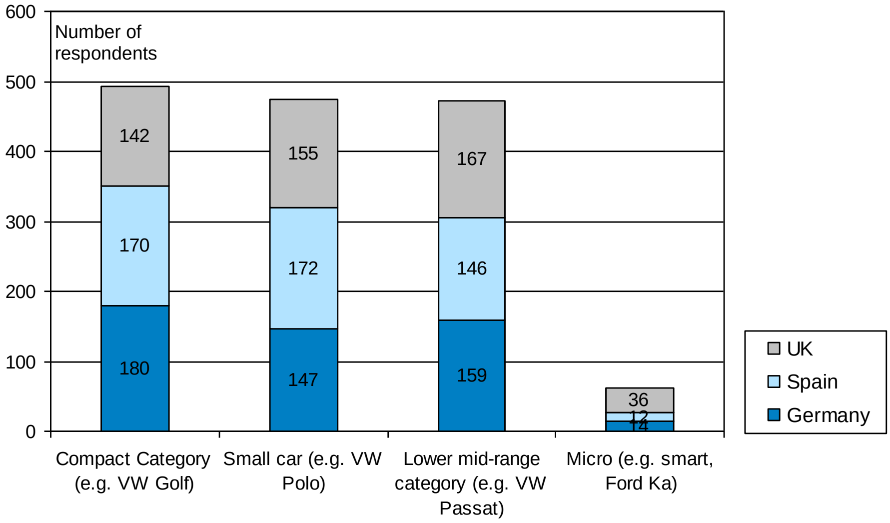


Figure 14: Car Pool of the Respondents

For the survey, only drivers of mini, small, compact or mid-class vehicle were accepted as participants. The smallest segment of the four was the micro car segment with an average of 4 % and the British being most open to it. Concerning the propulsion technology of these vehicles, just over two thirds of the cars are petrol-driven, almost one third are diesel-driven and less than 1 % is gas or other.

Figure 15 shows the annual mileage of the respondents.

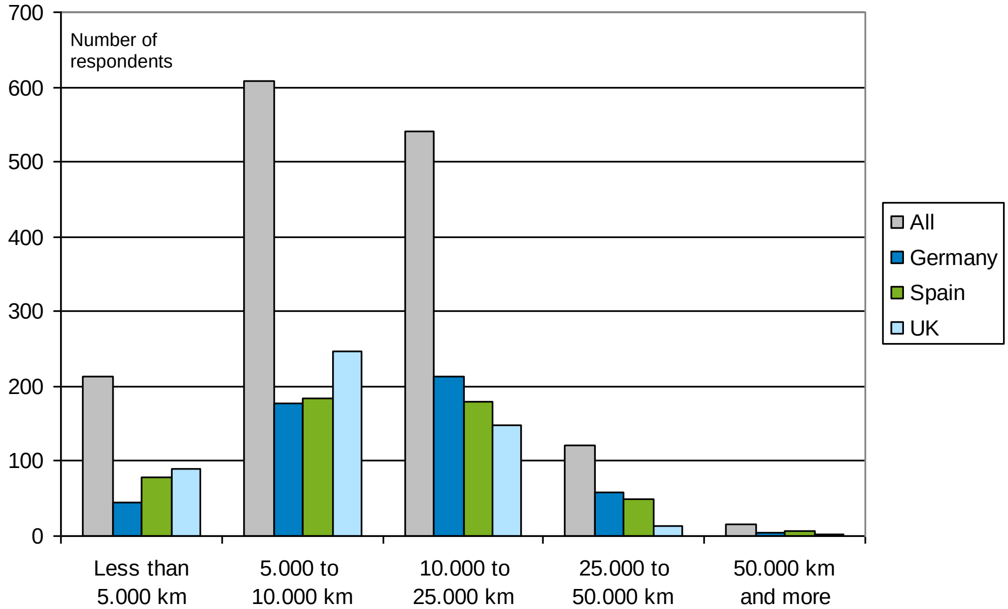


Figure 15: Annual Mileage

Most of the survey participants drive between 5,000 and 25,000 km per year. It is likely that the average mileage is around 10,000 km.

Data Analysis

Figure 16 shows that almost 80 % of the interviewees think that, in deed, there are reasons for driving an EV.

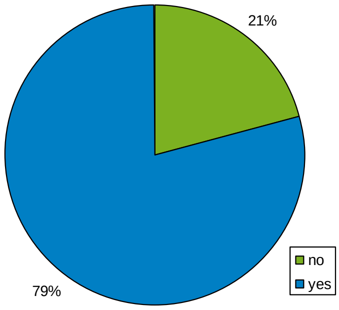


Figure 16: Reasons for Driving an EV

Figure 17 illustrates these reasons as named by the respondents.

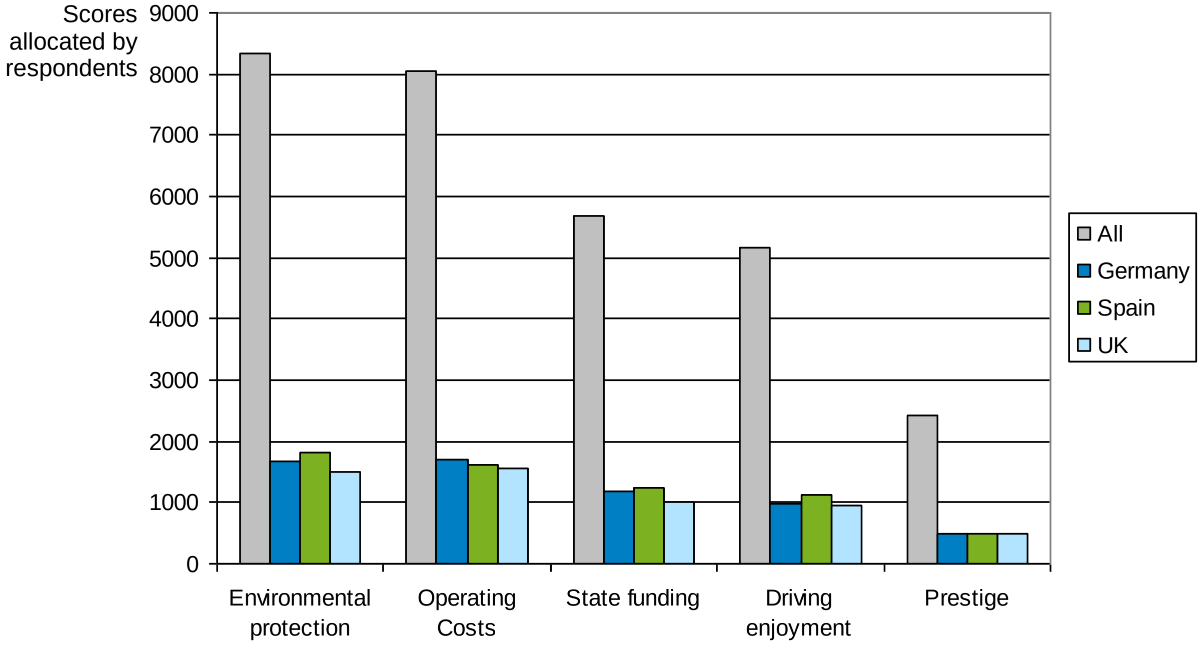


Figure 17: Reasons for Driving an EV

The participants of the survey were asked to give and prioritise reasons for driving an EV by allocating scores from one to five. In all three countries, they named environmental protection as their number one motivation for driving an electric vehicle and lower operating costs as number two. Both factors attain scores of around 8,000. Governmental funding and driving pleasure turned out to be middle-ranking criteria scoring below 6,000, while prestige hardly plays a role for most of the respondents.

Figure 18 shows the number of acceptable recharging sequences per month.

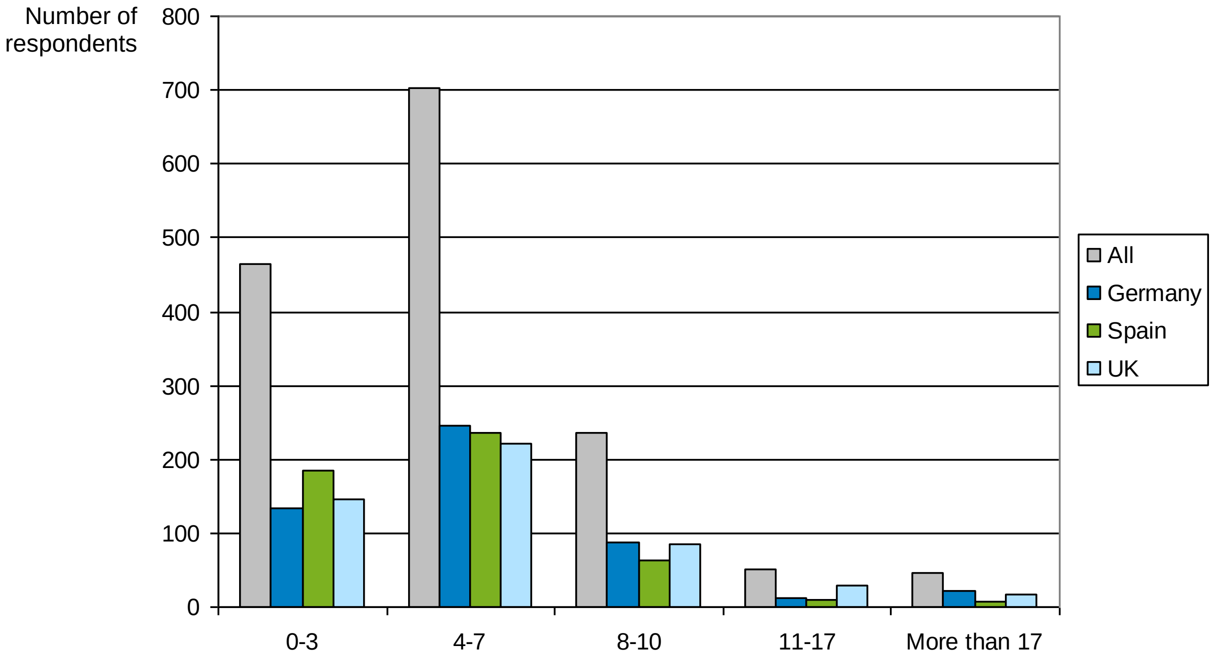


Figure 18: Number of acceptable recharging sequences

In all three countries, four to seven recharging processes per month are considered acceptable by half of the respondents. Almost one third think that merely up to three processes are acceptable. Eight or more charging sequences per month are not regarded tolerable by most of the interviewees. Noticeably, UK customers seem to be the most tolerant group, while the Spanish group is least permissive with the frequency of recharging an EV.

In addition to the frequency of recharging, the questionnaire also asked for the maximum acceptable duration of the single recharging process depending on where the charging is being executed. Figures 19 to 21 provide the figures for the different countries.

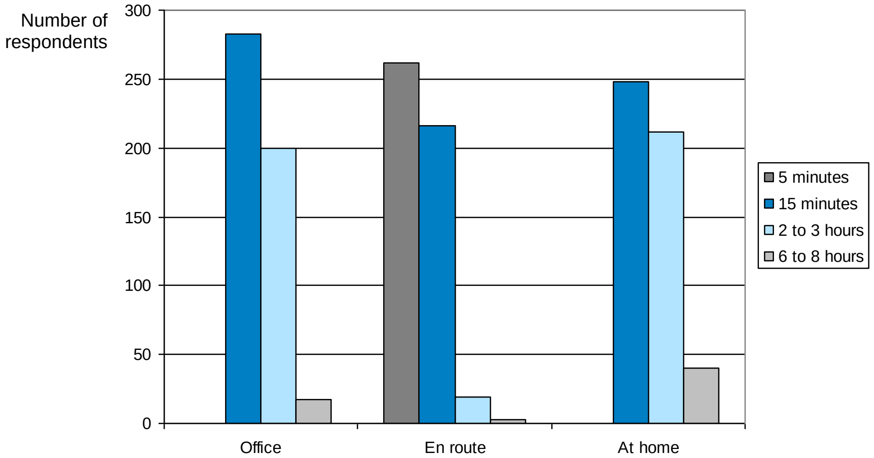


Figure 19: Maximum Acceptable Recharging Duration – Spain

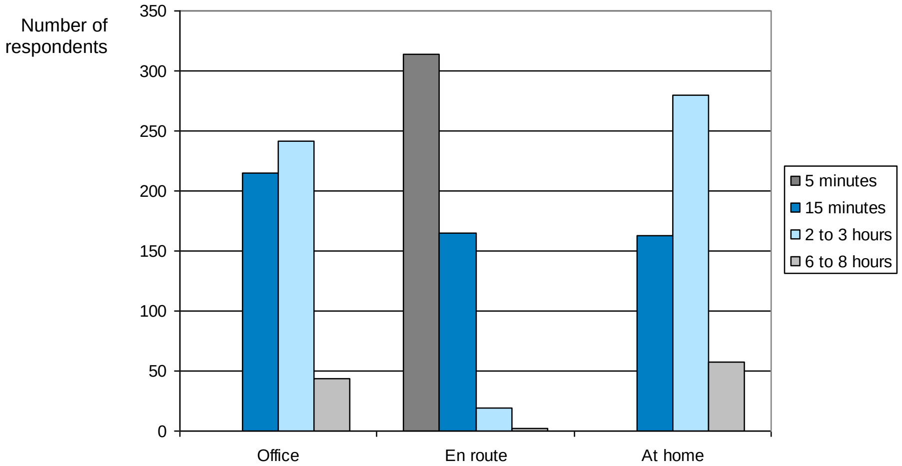


Figure 20: Maximum Acceptable Recharging Duration – Germany

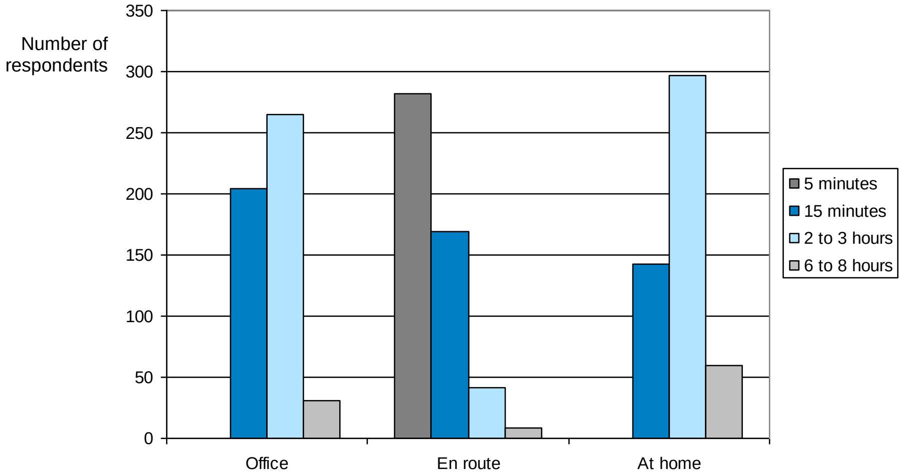


Figure 21: Maximum Acceptable Recharging Duration – UK

The graphs show similar profiles for all three counties. However, there are slight differences. When charging at the office, 40 % of the UK respondents consider 15 minutes an acceptable charging duration; in Germany, these are 43 % and in Spain even 57 %. This means that even while working more than half of the Spanish still do not want to spend more than 15 minutes charging. On the other hand, at least for Germany and the UK, two to three hours seem to be acceptable, as 48 % to 53 % agree. In Spain these are 40 %. For charging at home, figures seem to be similar.

When making an en-route charging stop, people require charging to take place quicker. Between 52 % and 62 % of the respondents expect the charging process to take no longer than five minutes – which is the duration they are used to from refuelling. For Germany, this figure is twice as high as the acceptance of 15 minutes recharging.

Interestingly, six to eight hours charging time – which is most likely from today's point of view – are inacceptable for the vast majority of interviewees.

Figure 22 refers to the willingness of the respondents to drive a detour to a charging point instead of a refuelling station in relation to their accepted charging duration.

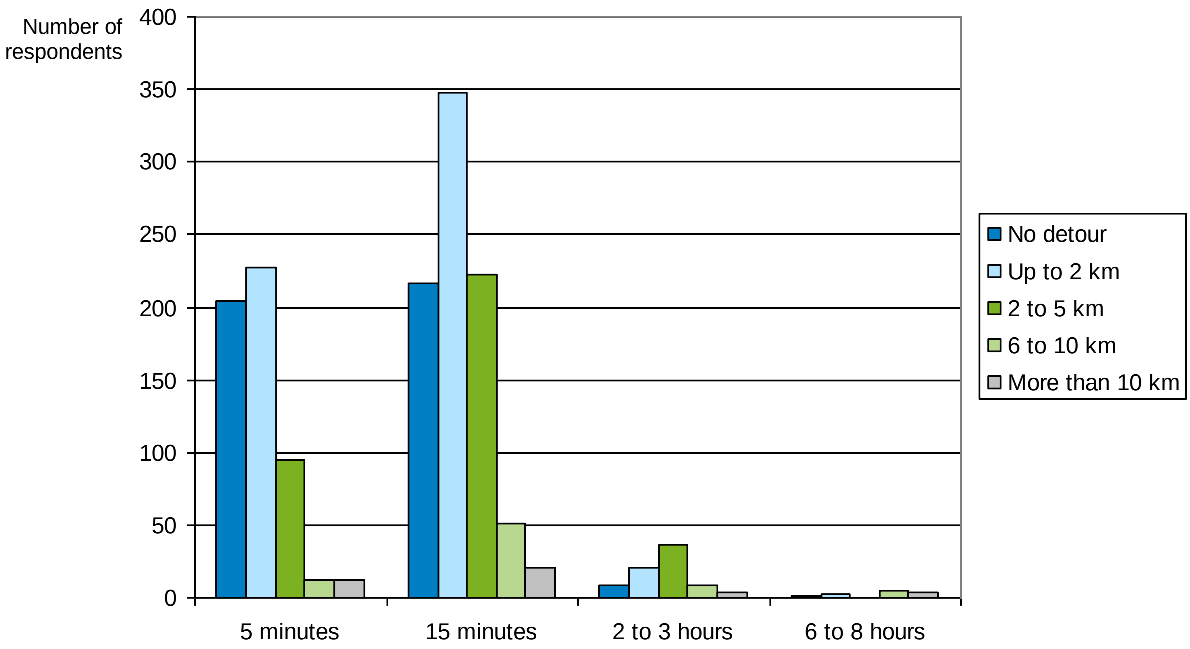


Figure 22: Maximum Acceptable Detours

Most of the respondents are willing to accept a charging duration of either five or 15 minutes. From them, 37 % would not accept driving a longer distance to a recharging point than to their refuelling station. Almost the same percentage would accept a two kilometres detour and 17 % two to five kilometres if charging requires only five minutes.

If the charging duration is longer, detours become more attractive and 41 % of those respondents willing to charge for 15 minutes would accept a two kilometres detour and still 26 % two to five kilometres. Longer detours to the charging station are hardly accepted.

Driving an EV instead of an ICE will bring about changes – in particular when it comes to recharging instead of refuelling the vehicle. In figure 23, participants of the survey were asked to allocate credits to these changes and rank them according to their significance for them personally.

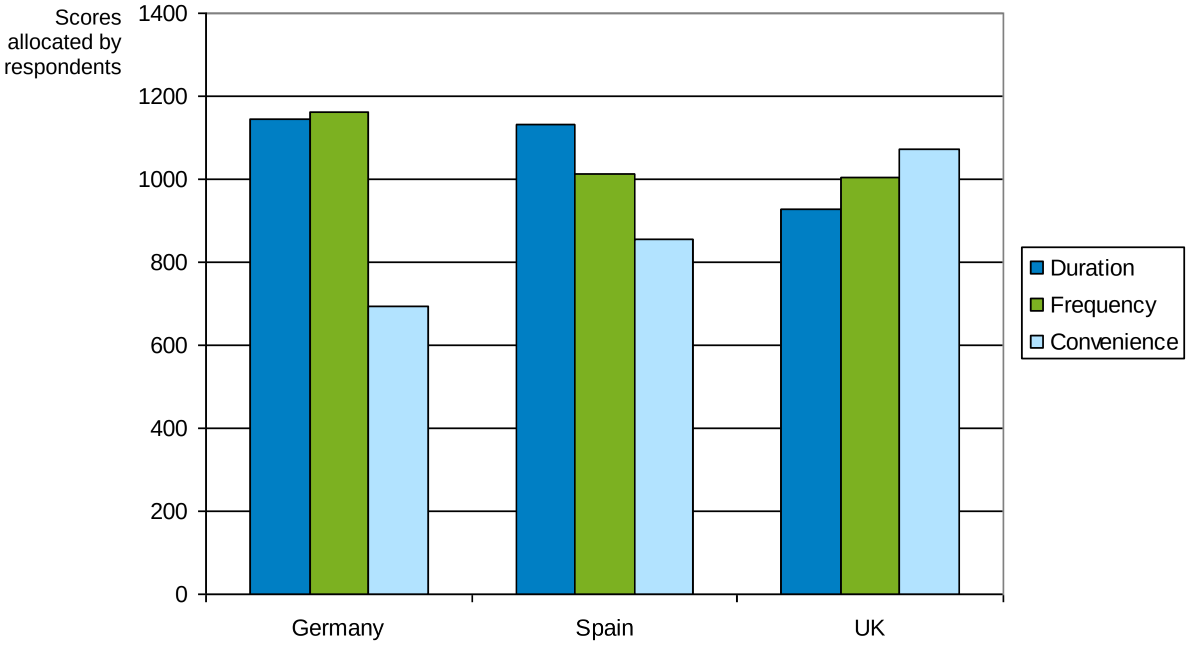


Figure 23: Significance of Changes

In Germany, the altered charging frequency and its duration affect people most. Concerning the relevance of the charging duration, Spanish respondents agree with German ones and rank it highest. The charging frequency seems to concern them less, but convenience of the process itself ranks higher than for Germans. Remarkably, British interviewees find that the charging convenience is more important than frequency or duration.

Apart from changes in general, the questionnaire also asked for the evaluation of several advantages recharging might bring about. Again respondents allocated credits according to the relevance to them personally. Figure 24 reflects the results.

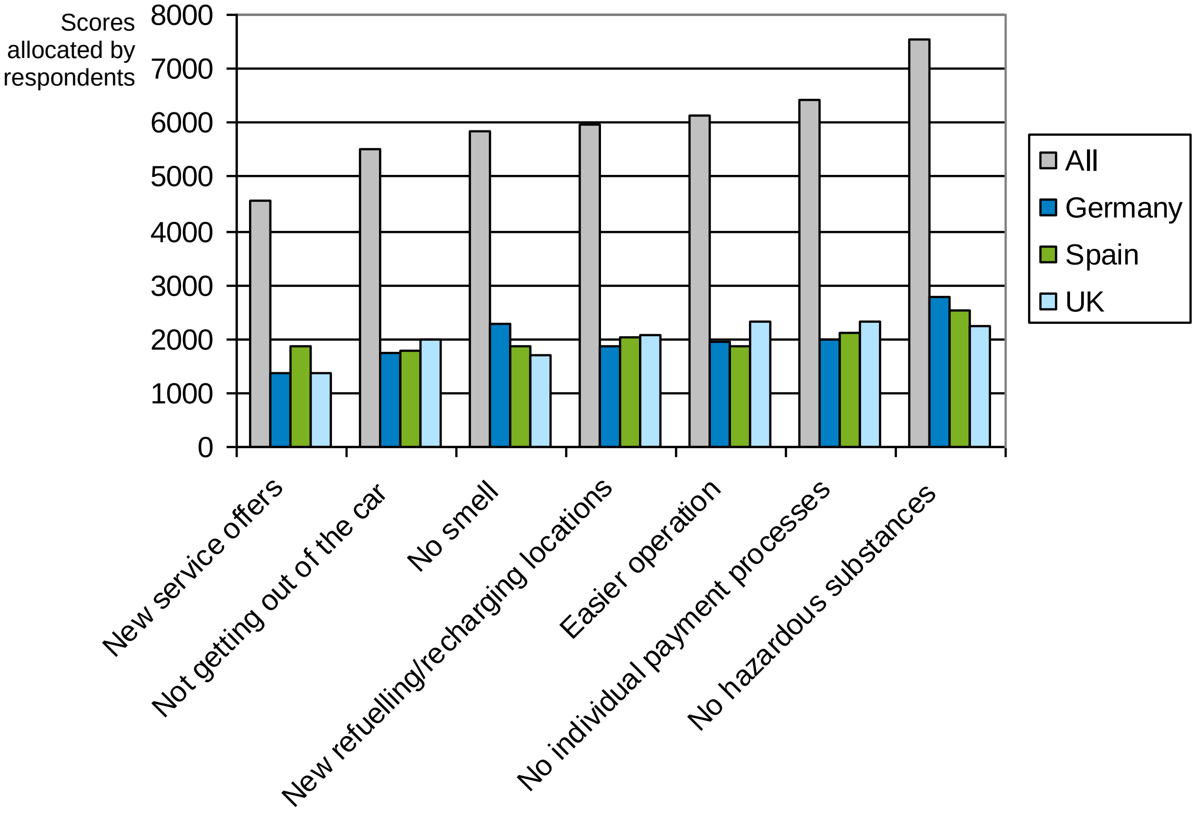


Figure 24: Advantages of Recharging

There is no significant amplitude in this section. Yet, it seems that not being exposed to hazardous substances while recharging is perceived as the greatest advantage recharging instead of refuelling brings about. This is especially true for German and Spanish interviewees. The second important advantage could be intelligent payment methods (e.g. by monthly invoicing) instead of paying each time when refuelling. Unexpectedly, new service offers were considered by far least attractive. In several sources, shopping opportunities were thought to help bridging waiting times and connect the new mobility concept with everyday life. The at-hand survey showed that this is not true for respondents of this questionnaire. They ranked new service offers the least convincing.

Figure 25 reflects on the consumers' price sensitivity.

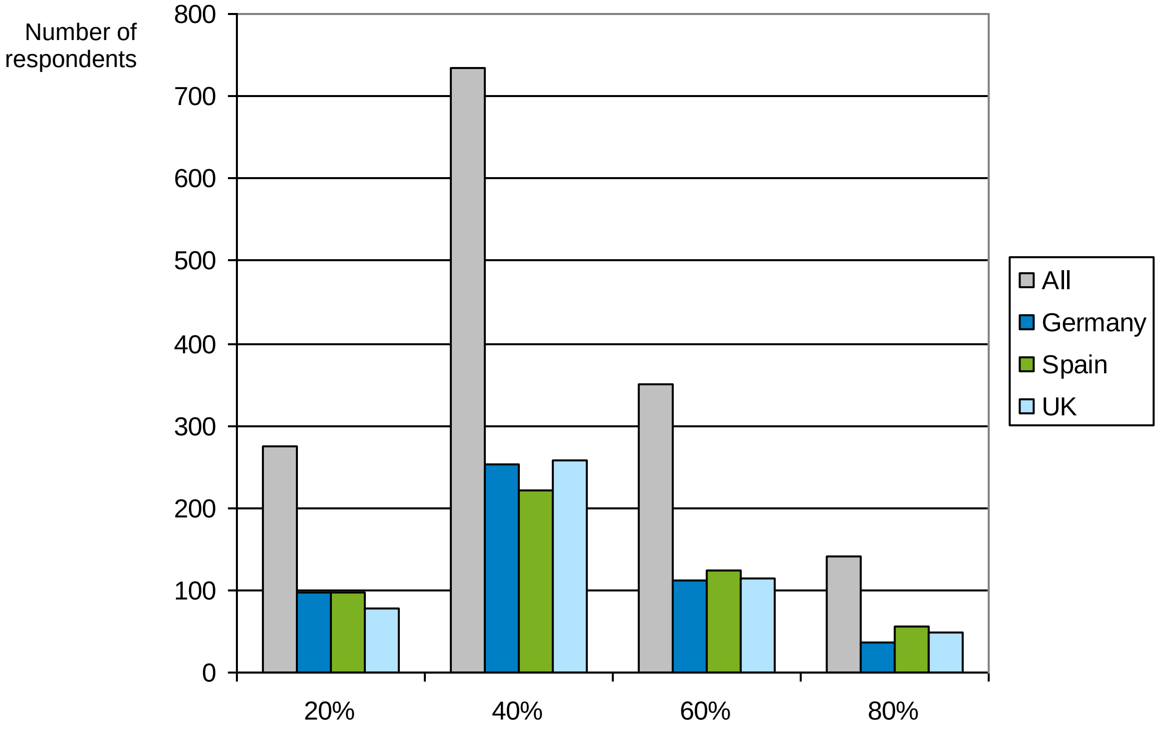


Figure 25: Price Sensitivity

When it comes to operating costs, respondents were asked to name the percentage by which driving an EV has to be cheaper than driving an ICE. It turned out that in all three countries, the majority of interviewees require that – covering the same distance – an EV should be cost advantageous by 40 %.

5 CONCLUSIONS

This study analysed current refuelling habits, the future charging process and the divers' acceptance of additional efforts. Thereby, the survey and its preparatory framework revealed differences between the state-of-the-art charging process and consumer expectations:

- Today's accepted range with an ICE and the prospected EV range differ tremendously, however, daily driven distances remain the same for all propulsions.

	Situation with ICE	Changes with EV	Acceptance of changes
Range	600-670 km	50-81 km	160
Daily km driven	35 - 110	35 - 110	35 - 110

Consequently, the minimum range of an EV should be 110 km.

- When it comes to the frequency of refuelling and recharging, there is a big gap between the number of necessary charging processes in order to maintain the current mobility level and the number of accepted sequences by the customer.

	D	ES	UK
As-is accepted fuelling processes/month	1,41	1,00	1,40
Necessary charging processes/month	18	13	19
Accepted charging processes/month	4-7	4-7	4-7

The charging process needs to be designed according to the consumers' needs in order to compensate for the delta of up to 15 charging sequences per month.

- Relative to the range of their vehicle and the length of the charging process, most respondents are willing to put up with a 2 km detour to a charging point instead of a gas station.

	D	ES	UK
As-is accepted road km/gas stations	15,6	18,4	19,6
Necessary road km/charging points	1,43	2,07	1,73
Accepted road km/charging points	1,60	2,28	1,89

The necessary charging point density will impede profitable business cases. The preferred solution must comprise a comparably low investment, low operating costs and low consumer prices.

- Costs for driving a 100 km distance by EV are expected to be significantly lower than with an ICE vehicle.

	D	ES	UK
As-is ICE cost/100 km	8,63	7,12	9,56
Expected EV cost/100 km	5,37	5,68	5,50
Accepted EV cost/100 km	5,18	4,27	5,74

If the current energy price levels can be maintained, EVs' operating costs actually can be considered attractive for the customer.

- The duration for a complete charge up is much longer than what consumers are willing to accept.

Duration of complete charge up			Δ to maximum accepted duration		
Concept 1	**Concept 2**	**Concept 3**	**D**	**ES**	**UK**
6-8 hrs.			4 to 5:45 hrs.	4 to 5:45 hrs.	4 to 5:45 hrs.
	15 min.		10 min.	10 min.	10 min.
		2-3 hrs.	1:55 to 2:55 hrs.	1:55 to 2:55 hrs.	1:55 hrs.

In order to compensate for this delta, other advantages have to be offered to customers.

The described discrepancy between the as-is and the expected situation have to be compensated for by applying what has been learnt from the survey participants who clearly formulated which aspects of the charging process they consider to be positive. It turned out that besides environmental aspects low operating costs is the main motivation for driving an EV. It also became clear that the charging net to be established needs to be quite dense. To reconcile these two requirements, any inductive charging concept (like e.g. concept 3) is inappropriate. Moreover, for most survey participants not getting out of the car for charging was not considered an attractive feature. From the remaining two conductive recharging alternatives, home charging, on the other hand, requires an initial investment from the consumer which stands against the expected cost advantage of 40 % over ICE vehicles. The survey also showed that most of the respondents prefer charging durations which are significantly shorter than what could be offered today. Charging concept 2 meets these expectations best.

6 RECOMMENDATIONS

Comparing the expected and actual customer value, there are no additional service features which could compensate for the perceived discomfort charging implies. Instead, “hard facts” (e.g. charging duration, range) need no be adapted. Yet, from the conclusions above, it was derived that from the three recharging alternatives introduced before, concept 2 meets the consumers’ expectations best. However, there are still several aspects which might give EVs a chance on the vehicle market.

- In order to meet the main motivators for buying an EV in all three countries, the combination of renewable energy at a competitive price (at least 40 % less than fuel) is essential. This requires new business models, which still are to be developed.
- The current EV range has to be increased significantly.
- At the same time, current recharging durations have to be reduced. What is known today as “fast charging” is considered slow by consumers. In future, “slow charging” should take 15 minutes, while “fast charging” should not exceed 5 minutes.
- New business models need to provide a dense net of charging points which meet the service availability and expectations but still generate a reasonable return on investment.
- Moreover, there has to be a variety of charging concepts consumers may choose from. Maximum duration, charging frequency and acceptance of detours show that consumers expect full availability at any time.
- Avoiding exposure to hazardous substances unexpectedly ranked highest in all three countries and especially for German consumers. This aspect should be used as selling proposition for EV charging and driving.
- Several disadvantages of current recharging concepts have been pointed out. In order to still sustain the attractiveness of EVs, these need to be compensated by additional features that guarantee comfort (especially for the British market). At least partially, this can be achieved by means of comfortable interfaces and billing processes that facilitate the charging process.
- A billing example can be drawn from the mobile phone market. Smart phone applications could help planning the trips of business people for the whole day in advance. When scheduling various meetings on a certain day, the application already appoints times and places for charging in the calendar. Moreover, it also realizes when a certain distance exceeds the vehicles range and proposes an adequate alternative via train including time and prices.

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APPENDIX 1 – ORIGINAL QUESTIONNAIRE (IMR WORLD)

1. Welcome

Dear Sir or Madam,

You can help us to better understanding what will influence the purchase of Electric Vehicles by completing the following questionnaire.

The aim is to develop an understanding of what would positively and negatively the future purchases of electric vehicles in Europe.

This survey is part of a project called MERGE, "Mobile Energy Resources in Grids of Electricity ", which is co-funded by the European Commission's Seventh Framework Programme (FP7).

The questionnaire contains seven pages and will take about 10 minutes to complete.

The data gathered will be treated as confidential and will not be passed on to a third party.

Thank you for your participation.

2. Country and residence information

*** 1. What country do you live in?**

	Country of residence
Country	

Other (please specify)

*** 2. What gender are you?**

- Male
- Female

*** 3. What age group are you in?**

- 15-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65+

3. Household information

*** 1. What group does your occupation fit in to?**

- ◯ Legislators, senior officials and manager
- ◯ Professional
- ◯ Technicians and associate professional
- ◯ Clerk
- ◯ Service workers and shop and market sales worker
- ◯ Skilled agricultural and fishery worker
- ◯ Craft and related trades worker
- ◯ Plant and machine operators and assembler
- ◯ Elementary occupation
- ◯ Armed forces
- ◯ Unemployed
- ◯ Other (Please specify)

Other (please specify)

[ ]

*** 2. How many of your household occupants are over 18 years of age?**

[ ]

*** 3. What is the total annual income of your household, in your national currency? (if you do not wish to disclose this information, please type 'N/A' in the box below)**

[ ]

*** 4. Please indicate where you live**

- ◯ In a city
- ◯ In a town
- ◯ In a suburban area
- ◯ In the countryside

*** 5. Do you own or drive a car?**

- ◯ Yes
- ◯ No

4. Vehicle use

*** 1. What type of vehicle is your primary vehicle?**
(Please note if you have more than one vehicle, answer this survey with respect to your primary vehicle)

Other (please specify)

*** 2. How What fuel does your present vehicle use?**

- ◯ Petrol
- ◯ Diesel
- ◯ Gas (LPG /CNG)
- ◯ Flexifuel (E85 + Petrol)
- ◯ Hybrid (Electric + Petrol)
- ◯ Bio Fuel (Biogas / ethanol)
- ◯ Ethanol Hybrid (Ethanol + Electric)
- ◯ Electric Vehicle

*** 3. When are you likely to replace your present vehicle?**

- ◯ 2010
- ◯ 2011
- ◯ 2012
- ◯ 2013
- ◯ 2014
- ◯ 2015
- ◯ 2016
- ◯ 2017
- ◯ 2018
- ◯ 2019
- ◯ 2020
- ◯ later than that

5. Influences on Electric Vehicle purchasing

*** 1. When would you decide to buy an electric vehicle?**

- ◯ When my present vehicle needs replacing
- ◯ When the technology is proven
- ◯ When there is no alternative type of car to buy
- ◯ Will purchase one when they are available

*** 2. If you were buying an Electric Vehicle what would POSITIVELY influence your decision? Please select your top 5**

- ☐ Competitive price
- ☐ Cash back Incentive
- ☐ Low CO2 emissions
- ☐ Good exterior design
- ☐ Good interior comfort
- ☐ Easy to refuel
- ☐ Able to refuel anywher with electricity
- ☐ Lower fuel costs than today
- ☐ Easy to maintain
- ☐ Maintenance costs
- ☐ Speed
- ☐ Safety
- ☐ Image
- ☐ Kilometers of range between charges
- ☐ Known brand
- ☐ Recommended by experts
- ☐ Recommendation by a friend
- ☐ Recommended by a family
- ☐ Try it out free for a week
- ☐ Lower tax rating
- ☐ High resale value

*** 3. If you were buying an Electric Vehicle what would NEGATIVELY influence your decision? Please select your top 5**

- ☐ Cost of purchase
- ☐ Recharging concerns
- ☐ Exterior design
- ☐ Interior design
- ☐ Range between charges
- ☐ Image
- ☐ Safety
- ☐ Unproven resale value
- ☐ Rising price of electricity
- ☐ Unfamiliar technology
- ☐ Unknown brands
- ☐ Hidden costs and extras
- ☐ Insufficient range for my daily needs
- ☐ Need for recharging point at my home /garage

6. Your effciency information sources and actions

*** 1. To what degree do you agree or disagree with the following statements. (1 = strongly disagree 5= strongly agree)**

	1 Strongly disagree	2 Disagree somewhat	3 No opinion	4 Agree somewhat	5 Strongly agree
It is important to use fossil fuel car travel as little as possible.	○	○	○	○	○
I feel a personal moral responsibility to drive less irrespective of what others do.	○	○	○	○	○
I would be a better person if I purchased an electric car.	○	○	○	○	○
I feel morally responsible to purchase an electric or alternative fuel vehicle irrespective of what others do.	○	○	○	○	○
I do not care what people or government think, I will buy the vehicle type I prefer or need.	○	○	○	○	○

*** 2. How often do you engage in these environmentally friendly activities?**

	1 Rarely	2 Irregularly	3 When I am told	4 Regularly	5 All the time
Recycling	○	○	○	○	○
Buy organic food	○	○	○	○	○
Buy eco label products	○	○	○	○	○
Source alternative generated electricity	○	○	○	○	○
Actively save water	○	○	○	○	○
Actively manage home energy use	○	○	○	○	○
Buy the most energy efficienct products	○	○	○	○	○
Buy ethically labelled stocks	○	○	○	○	○
Choose eco friendly holidays	○	○	○	○	○
Travel on public transport	○	○	○	○	○
Walk or bicycle for short journeys	○	○	○	○	○

*** 3. How much would you trust information on Electric Vehicles you received from the following sources?**

	No trust	Some trust	Might possibly trust	Somewhat trust	Fully trust
The European Union	◯	◯	◯	◯	◯
National Governments	◯	◯	◯	◯	◯
Manufacturer	◯	◯	◯	◯	◯
New Car dealer	◯	◯	◯	◯	◯
Second hand car dealer	◯	◯	◯	◯	◯
Electricity supplier	◯	◯	◯	◯	◯
Specialist magazine	◯	◯	◯	◯	◯
Daily news paper	◯	◯	◯	◯	◯
Online specialist car sites	◯	◯	◯	◯	◯
Television programs	◯	◯	◯	◯	◯
Online blogs	◯	◯	◯	◯	◯
Online comments and recommendation sites	◯	◯	◯	◯	◯
Online comparison sites	◯	◯	◯	◯	◯
A family or friend who drives	◯	◯	◯	◯	◯
A family or friend who does not drive	◯	◯	◯	◯	◯
A work colleague	◯	◯	◯	◯	◯
A total stranger	◯	◯	◯	◯	◯

7. Charging and Billing

* 1. Car batteries can be charged at different speeds. The faster the charge the more expensive the cost of the technology to do it. Please rate your preference of the solutions and pricing scenarios listed below (1 = best option, 5 = worst option)

	1	2	3	4	5
Slow home charging but normal electricity price	◯	◯	◯	◯	◯
Fast home charging but higher cost per charge	◯	◯	◯	◯	◯
Fast recharge at a recharge station but higher cost of charge	◯	◯	◯	◯	◯
Slow recharge at a recharge station normal electricity price	◯	◯	◯	◯	◯
It will vary with my need, price will be relativly unimportant	◯	◯	◯	◯	◯

* 2. Recharging an electric car can be managed in a number of ways. These can impact the price of the charge depending on when the charge is done. Which method would you prefer?

◯ It charges when I plug it in, price is unimportant

◯ Smart Charging: The utility company starts charging it at the best price time

◯ Super Smart Charging: It gets a minimum charge when I plug it in and the utility company finishes charging it at the best price time.

◯ I set the time of charging, price of the charge may vary

◯ I make a choice of one or more options depending on my needs

* 3. Which of the following information would you be willing to share with the utility company?

☐ Information on trips made (Driving pattern including distances and acceleration profile)

☐ Location and timing of car charging

☐ Battery status (information on how it is performing)

☐ Car status (battery and performance information)

☐ I would share such information for a fee ((Driving pattern including distances and acceleration profile)

☐ I prefer not to share such information

*** 4. Electric cars can be charged at home or at another recharging point. How would you prefer to be billed for ALL your recharging?**

- ◯ When charging AT HOME, I would like to be billed separately for domestic and electric vehicle electricity.
- ◯ Home charging and other charging billed separately
- ◯ Home charging billed, other charging paid at time of charging (Credit or debit card)

*** 5. You could allow the power in your car battery to be used by the utility company when additional electricity is needed by the grid. Would you be willing to do so?**

- ◯ Yes for a reduction in my electricity bill
- ◯ Yes for a bill reduction and an additional reward
- ◯ Yes in very special circumstances (Power failure)
- ◯ No

*** 6. Batteries will be a major cost of the price of an electric car. A number of options are being looked at to help consumers manage this cost. Please rate your preference of the solutions listed below (1 = best option, 5 = worst option)**

	1	2	3	4	5
Buy the car and the battery	◯	◯	◯	◯	◯
Buy the car / lease the battery for a monthly fee	◯	◯	◯	◯	◯
Lease the car for a monthly fee / buy the battery	◯	◯	◯	◯	◯
Lease the car and the battery for a monthly fee	◯	◯	◯	◯	◯
Lease the car and battery when I need it	◯	◯	◯	◯	◯

8. Thank you

Thank you for participating in this survey

Please click the done button to submit your answers

APPENDIX 2 – VEHICLE RANGES

2A – Ranges of EV passenger Cars

	Range (km per full battery)
Opel Ampera	60
Smart Pure Elettrica	100
Citroen Saxo électrique	80
Peugeot iOn	130
smart fortwo electric drive	115
Toyota FT-EV	80
VW Golf Blue-E-Motion	150
VW e-up!	130
Greeny AC1	50
Nice Mega City	75
Mitsubishi i-EV	130
Fiorino electric	140
Mycar	80
Reva i	120
Kamoo 500 Elektra	120
Kamoo Panda Elektra	120
Kamoo Twingo Elektra	145
Stromos	100
Mega e-City	65
Tazzari Zero	140
Bellier Opale 2E	135
Average	**108**
- 25% as suggested by ADAC	**81**
C4D and IAV experts expectations	**50**

2B – Range of ICE passenger cars – mini/small segment

	Range (km per tankful)	Consumption (litres/100 km)	Tank Capacity (litres)
Citroen C1 1.0 Advance	777,78	4,5	35
Fiat 500 1.2 8V Pop	686,27	5,1	35
Ford Ka 1.2 Trend	686,27	5,1	35
Mitsubishi Colt 1.1	854,55	5,5	47
Nissan Pixo 1.0 visia	795,45	4,4	35
Peugeot 107 70 Petit Filou	777,78	4,5	35
Renault Clio 1.2 Campus Authentique	847,46	5,9	50
Renault Twingo 1.2 60 Authentique	727,27	5,5	40
Skoda Fabia 1.2 HTTP	762,71	5,9	45
smart fortwo coupe 1.0 mhd pure softip	750,00	4,4	33
Toyota Yaris 1.0	840,00	5,0	42
VW Polo 1.2 Trendline	818,18	5,5	45
Average	**776,98**	**5,11**	**39,75**
- 25% as suggested by ADAC	**582,73**	**6,39**	

2C – Range of ICE passenger cars – compact/middle class

	Range (km per tankful)	Consumption (litres/100 km)	Tank Capacity (litres)
Alfa Romeo Giulietta 1.4 TB 16V	909,09	6,6	60
Audi A3 1.2 TFSI Attraction	1000,00	5,5	55
BMW 116i	868,85	6,1	53
Fiat Bravo 1.4 16V Active	920,63	6,3	58
Ford Mondeo 1.6 Ti-VCT Trend	972,22	7,2	70
Mercedes A 160 BlueEFFICIENCY Classic	900,00	6,0	54
Opel Astra GTC 1.4 Twinport ecoFlex Selection	852,46	6,1	52
Peugeot 308 125 Millesim 200	923,08	6,5	60
Renault Megane 1.6 16V 100 Authentique	895,52	6,7	60
Skoda Octavia 1.4 Tour	808,82	6,8	55
Toyota Avensis 1.6	923,08	6,5	60
VW Golf 1.4 Trendline	859,38	6,4	55
Average	**902,76**	**6,39**	**57,67**
- 25% as suggested by ADAC	**677,07**	**7,99**	

2D – Ranges of EV Light Commercial Vehicles

	Range (km per full battery)
Smith Edison Panel Van	240
Iveco Daily 35 C/E	120
Bluebird QEV70	64
Bluebird XDV	95
Eco Carrier EL	80
Ford Transit Connect Electric	130
FUMO E1	100
ISEKI Mega Van	60
Modec Box Van	80
Average	**108**
- 25% as suggested by ADAC	**81**
C4D and IAV experts excpectations	**50**

2E – Range of ICE passenger cars – compact/middle class

	Range (km per tankful)	Consumption (litres/100 km)	Tank Capacity (litres)
Mercedes Benz Sprinter	892,86	8,4	75
Renault Master	879,12	9,1	80
Opel Movano	860,22	9,3	80
Ford Transit	1355,26	7,6	103
Fiat Ducato 120 Multijet	1012,66	7,9	80
CITROEN Jumper 40 L4H3, 157 PS	1058,82	8,5	90
VW Crafter	757,58	9,9	75
Average	**1063,99**	**8,36**	**85,60**
- 25% as suggested by ADAC	**797,99**	**10,45**	

APPENDIX 3 – ORIGINAL QUESTIONNAIRE (C4D)

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Projektspezifikation

D Fragebogen/CAWI-Vorlage - UK

Version E02 = FINAL

Einleitung

Dear Participant,

Thank you very much for taking the time to take part in our representative survey on the subject of "electric vehicles". Your views are of great importance to the success of our research project and make a contribution to allowing the car industry to align its future developments in an even more customer-oriented manner.

Answering the questions will take only around 5 minutes of your time.

Naturally, all your data are provided voluntarily and shall only be analysed in conjunction with those of other respondents, so that any inference about your person is excluded and the anonymity of your data is assured. Data security is assured by means of 256-Bit-SSL encryption. The survey is subject to the guidelines of data protection legislation and ESOMAR (European Society for Opinion and Marketing Research). Questions on the appraisal of certain issues are not intended to query your actual knowledge, but, as far as we are concerned, are regarded as your personal valuation. Please answer all questions honestly and in full.

Thank you very much in advance for your support.

Jörg Rademacher

Trendfish Marketing GmbH
Market Research
Lornsenstrasse 48
D-24105 Kiel

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Projektspezifikation

Screening

To begin with, we need some statistical data to control the extent to which you are representative.

S01 Where is your place of residence?

Je Land Liste der Regionen aus Quotierung übernehmen. Darstellung als Dropdown-Auswahlliste.
Nur Einfachnennung.

S02 Where do you live?

Nur Einfachnennung.

In a **large city**	1	☐	
In the **suburbs**	2	☐	
In a **small town**	3	☐	
In the **countryside**	4	☐	

S03 What is your gender?

Nur Einfachnennung.

Female	1	☐	
Male	2	☐	

S04 How old are you?

Nur Einfachnennung.

14-17 years old	0	☐	→ Screenout.
18-24 years old	1	☐	
25-34 years old	2	☐	
35-44 years old	3	☐	
45-54 years old	4	☐	
55-64 years old	5	☐	
65 years old or more	6	☐	

S05 Which of the following means of transport do you personally use?

Mehrfachnennung möglich. 0 = Nein; 1 = Ja. Zufällige Reihenfolge der Items S05A-G.

S05A	**Local** public transport (bus, tram)	0/1	☐
S05B	**Long-distance** public transport (bus, tram)	0/1	☐
S05C	Car (passenger)	0/1	☐
S05D	Car (driver)	0/1	☐
S05E	Motorbike (passenger)	0/1	☐
S05F	Motorbike (driver)	0/1	☐
S05G	Bicycle	0/1	☐

WENN S05D <> 1 → Screenout.

S06 Which type of car do you mainly drive?

Nur Einfachnennung.

Micro (e.g. smart, Ford Ka)	1	☐	
Small car (e.g. VW Polo)	2	☐	
Compact category (e.g. VW Golf)	3	☐	
Lower mid-range category (e.g. VW Passat)	4	☐	
Upper mid-range category (e.g. Audi A6)	5	☐	→ Screenout.
Top of the range category (e.g. VW Phaeton)	6	☐	→ Screenout.

S07 What engine does the car you primarily drive possess?

Nur Einfachnennung.

Diesel-driven	1	☐
Petrol-driven	2	☐
Gas-driven	3	☐
Other	4	☐

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Hauptteil

An electric vehicle is designated below as a car operated by electricity.

F01 Environmental protection, savings on operating costs, prestige among friends/colleagues, driving enjoyment or state funding are examples of reasons for driving an electric vehicle. Which of the following statements is relevant to you personally?

Nur Einfachnennung.

For me personally, there are, indeed, reasons to have an electric vehicle. .... 1 .... ☐
In my view, there are no reasons for having an electric vehicle. .... 2 .... ☐ → Gehe zu F03A.

F02 Please place the following reasons for having an electric vehicle in order of importance. Drag the fields with reasons from left to right and arrange them in such a way that the reason you regard as most important is at the top and the least important at the bottom.

Reihenfolge F02A-E zufällig angeordnet. Variable nimmt Reihenfolgewert an.

F02A **Environmental protection** (e.g. less exhaust fumes, noise, etc.)	1
F02B **Operating costs** (e.g. lower costs per km)	2
F02C **Prestige among friends and/or colleagues**	3
F02D **Driving enjoyment** (e.g. noiseless driving, acceleration)	4
F02E **State funding** (e.g. access to downtown areas blocked for other vehicles, exemption from city toll, congestion charge etc.)	5

Note: To arrange the fields, point to one field using the mouse and drag it to the right into what you regard as the correct position by keeping the left mouse button pressed down.

F02F In your view, apart from the abovementioned reasons, are there any other major reasons for driving an electric vehicle?

Freitextfeld. Kein Pflichtfeld.

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F03A A conventional car with an internal cumbustion engine (=petrol-driven or diesel-driven car) must be refuelled regularly. An electric vehicle also has to be supplied with new electricity. "Refuelling" in case of electric vehicles is described as recharging process. How many recharging processes a month would you consider acceptable?

Nur Einfachnennung.

0-3	1	☐
4-7	2	☐
8-10	3	☐
11-17	4	☐
More than 17	5	☐

F03B What is your average annual mileage with your car?

Nur Einfachnennung.

Less than 5,000 km	1	☐
5,000 to 10,000 km	2	☐
10,000 to 25,000 km	3	☐
25,000 to 50,000 km	4	☐
More than 50,000 km	5	☐

F04A Electric vehicles may be recharged at various sites. In your view, how long should be the maximum recharging duration ("complete fill-up") when charging **<u>at home</u>**?

Nur Einfachnennung.

15 minutes	2	☐
2 to 3 hours	3	☐
6 to 8 hours	4	☐

F04B Electric vehicles may be recharged at various sites. In your view, how long should the maximum recharging duration be ("complete fill-up") when charging **<u>at your office</u>**?

Nur Einfachnennung.

15 minutes	2	☐
2 to 3 hours	3	☐
6 to 8 hours	4	☐

F04C Electric vehicles may be recharged at various sites. In your view, how long should the maximum recharging duration be ("complete fill-up") when charging at a charging point **<u>on the road (intermediate stop/charging station/electrical service station)</u>**?

Nur Einfachnennung.

5 minutes	1	☐
15 minutes	2	☐
2 to 3 hours	3	☐
6 to 8 hours	4	☐

F05 How long should be the maximum detour incurred by driving to a charging station for a [Antwort Klartext aus F04C einblenden] charging stop (instead of driving your current car to a conventional filling station)?

Nur Einfachnennung.

No detour	1	☐
Up to 2 km	2	☐
2 to 5 km	3	☐
6 to 10 km	4	☐
More than 10 km	5	☐

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Projektspezifikation

F06 Driving an electric vehicle will bring about changes - in particular, when it comes to recharging the battery instead of refuelling the tank. Please arrange the changes based on importance for you personally. Drag the fields with changes, from left to right, and place the most important change at the top.

Reihenfolge F06A-C zufällig angeordnet. Variable nimmt Reihenfolgewert an.

F06A **Duration of refuelling/recharging**	1
F06B **Frequency of refuelling/recharging**	2
F06C **Convenience of refuelling/recharging process**	3

Note: To arrange the fields, point to one field using the mouse and drag it to the right into what you regard as the correct position by keeping the left mouse button pressed down.

F07 The actual recharging process implies a series of advantages. Please place the advantages in order once again by dragging to the right side, beginning at the top with what you regard as the most important advantage.

Reihenfolge F07A-G zufällig angeordnet. Variable nimmt Reihenfolgewert an.

F07A **No individual payment processes after each refuelling/recharging**	1
F07B **Easier operation than filling ports for refuelling**	2
F07C **No smell**	3
F07D **No hazardous substances**	4

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F07E **Getting out of the car not required for refuelling/recharging**	5
F07F **New refuelling/recharging locations**	6
F07G **New service offers** ((e.g. Smart Phone Apps which automatically add refuelling/recharging times in the calendar or infotainment offers in the vehicle or combination offers, such as free charging when shopping or free KWh when buying in certain shops))	7

Note: To arrange the fields, point to one field using the mouse and drag it to the right into what you regard as the correct position by keeping the left mouse button pressed down.

F08 Covering the same distance, by what percentage rate would recharging have to be cheaper than refuelling to ensure offset of what you regard as the possible disadvantages of the recharging process?

Nur Einfachnennung.

- 20% .... 1 ☐
- 40% .... 2 ☐
- 60% .... 3 ☐
- 80% .... 4 ☐

Statistik

S08 In conclusion, please tell us your occupation?

Nur Einfachnennung.

- Freelancer .... 1 ☐
- Managerial employee/officer .... 2 ☐
- Salaried employee .... 3 ☐
- Skilled worker .... 4 ☐
- Student .... 5 ☐ → Gehe zu Verabschiedung.
- Unemployed .... 6 ☐ → Gehe zu Verabschiedung.
- N/a .... 999 ☐ → Gehe zu Verabschiedung.

S09 And which sector do you work in?

Nur Einfachnennung.

- Public service .... 1 ☐
- Administration/services .... 2 ☐
- Industry .... 3 ☐
- Agriculture .... 4 ☐

Verabschiedung

We are very grateful for you having taken the time to answer the questions. You have really supported us in our research work by doing so.

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