FABRIC

Feasibility analysis and development of on-road charging solutions for future electric vehicles

User needs, system concept and requirements for ICT solutions

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
CG	Core Group (of partners within FABRIC)
CH	Clearing House
CI	Charging Infrastructure (Electric Vehicle Supply Equipment – EVSE)
CIO	Charging Infrastructure Operator
DSO	Distribution System Operator
DSRC	Dedicated Short Range Communication
Dxx.x	Deliverable xx.x
EC	European Commission
ER	Energy Retailer
ERG	External Reference Group (of the FABRIC project)
EV	Electric Vehicle
EVB	Electric Vehicle Backend
FABRIC	Feasibility analysis and development of on-road charging solutions for future electric vehicles
FEMP	FABRIC Electric-Mobility Platform
FEV	Fully Electric Vehicle
HMI	Human-Machine Interface
ICE	Internal Combustion Engine (petrol or diesel vehicle)
ICT	Information and Communications Technology
ITS	Intelligent Transport Systems
OBU	On-Board Unit
OEM	Original Equipment Manufacturer

RO	Road Operator
SME	Small and Medium-sized Enterprise
SP	Sub-Project
UC	Use Case
V2G	Vehicle to Grid
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VMS	Variable Message Sign
WP	Work-Package

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EXECUTIVE SUMMARY

The FABRIC Integrated Project (EC Grant agreement no: 605405) aims to open the way for large deployment of electro-mobility focusing on the technological feasibility, economic viability and socio-environmental sustainability of dynamic on-road charging of electric vehicles.

This is the first deliverable within FABRIC Sub-Project (SP) 2, dealing with the Information and Communications Technology (ICT) solutions required in order for on-road electric charging (wireless power transfer – WPT) to work.

The report introduces the user needs, which are completed by the first stakeholder survey, in which 71 responses were received. This survey, as well as consortium discussions and reference to other projects (e.g. eCoFEV), aided the completion of user needs, which are presented for each main user group.

The FABRIC modules are presented, which are the main physical elements making up the FABRIC system. The functional requirements of a future year (2030 or beyond) FABRIC system are then explained. The purpose is to provide a vision of how FABRIC should look in the future in order for the partners to then select the elements that are necessary and feasible to build and test the demonstrations during the lifetime of the project. There is not a one-to-one relation between the modules and the functions, as each module covers several functions and several of the functional requirements are fulfilled by more than one module. The functional requirements are categorised into six classes:

- A: User accounts, booking and billing;
- B: Dynamic routing for Electric Vehicles (EVs)
- C: Vehicle identification, charging lane access control and management/enforcement
- D: Wireless Power Transfer (WPT)
- E: Driving assistance while charging
- F: Distribution Supply Operator (DSO) and grid management.

The functional requirements are presented in a series of tables describing the requirement, its goal, and priority (High = essential for FABRIC to function; Medium = important to enable an interoperable and user-friendly service, but not essential at least for an early FABRIC prototype; Low = “nice to have” optional extras). The tables then cross-reference to related use cases (if any) from FABRIC D43.1, define the validation and acceptance criteria, the relationship with other requirements and a risk analysis (what happens if the requirement is not properly fulfilled).

1. INTRODUCTION

1.1 Introduction to FABRIC and to SP2: ICT Solutions

Electro-mobility is expected to be an essential component in the pursuit of the decarbonisation of road transportation and mobility. Issues concerning current on-board battery packs (high weight and cost) limit the usage of fully electric vehicles (FEVs) predominantly to urban/local trips. For this, on-road power transfer solutions are being investigated, since they would allow practically all of the drawbacks of on-board battery packs to be avoided or circumvented.

In this context, the principal motivation for the FABRIC project is the feasibility assessment of on-road charging solutions, including their technological feasibility, socio-economic viability and environmental sustainability from all perspectives. The ultimate aim of FABRIC is to provide a pivotal contribution relevant to electro-mobility in Europe, identifying the expected benefits and required costs so that the investments required for research, development and implementation in each of the components of the mobility system of the future can be fully understood, quantified and ratified.

FABRIC is undertaking an in-depth assessment of user and technological requirements across the main areas which this technology could impact, such as road and energy infrastructure, and will identify gaps between current capability and what is required for such a system to succeed and provide the anticipated benefits.

Sub-Project 2 (SP2) of FABRIC is one of four technical SPs in the project. It deals with solutions related to Information and Communications Technologies (ICT). This includes user needs and system concept/functionalities (the subject of this Work Package 22 deliverable) and further tasks concerning technical benchmarking of ICT solutions (WP23), architecture and system specifications (WP24), design of ICT applications (WP25) and verification (WP26). WP22, for which this deliverable is the main output, therefore feeds into these other Work Packages within SP2, as well as other SPs, i.e. SP3 (Charging Solutions), SP4 (Integration, Infrastructure and Testing), and SP5 (Assessment).

1.2 Task description, purpose and contributions to other tasks in FABRIC

WP22 – User needs and requirements – is composed of two tasks, as described below.

Task 2.2.1 on ***user needs for ICT solutions*** identifies such needs in the context of on-road wireless power transfer providing a longer range and increased confidence to the EV driver in a seamless environment. This task was parallel with the user needs task within SP3 (Charging solutions: WP32 User needs and requirements) and also links closely with WP43 on use case definitions.

Task 2.2.2 on ***system concept and functionalities*** defines the functions required for FABRIC but based on a longer term vision (year 2030+). This provides a basis in other WPs in order to select which of the functions defined for the long term will need to be met during by the FABRIC project itself in order to develop and demonstrate prototypes appropriate for the objectives, scope and duration of the project. The concept involves selecting ICT modules and their boundaries, as well as defining functional requirements.

The modules and the classes of functional requirements are not the same: modules relate to groups of physical systems such as the vehicle, road, grid, etc, while the functional classes (e.g. booking of an electric charging slot) can cover more than one module.

The FABRIC DoW mentions the identification of components and also interoperability requirements as part of this task. However Task 2.3.1 (WP23) identifies and reviews existing ICT solutions: i.e. systems, applications, services, platforms, sensors and protocols. Components essentially follow on from this latter task, as they cannot be defined before the ICT systems or solutions are identified. Furthermore, Task 2.3.2 covers interoperability issues. Hence, to enable a clearer distinction between WPs 22 and 23, it was decided to keep WP22 (this Deliverable D22.1) at a more generic and functional level, without covering individual components, their interfaces or interoperability requirements. The components and interoperability are then dealt with in Deliverable D23.1 and interfaces are covered under the ICT architecture in D24.1.

As mentioned above, these tasks tie in closely with the Charging Solutions tasks in SP3, as well as with WP43 – Final use case definition. Indeed the preliminary user needs findings have already contributed to the first use case definition and in turn these use cases are used in this report as a basis for defining the system concept and functionalities.

1.3 Deliverable approach and structure

Chapter 2 of this deliverable provides a definition of user groups based on the use cases developed in WP43 (D43.1 FABRIC final use cases), to which SP2 partners contributed. Before exploring more deeply their requirements, we first report on the findings and implications of the first user needs questionnaire, which gathered 71 responses, as some of the responses contributed to improving the user requirements and filling gaps.

As FABRIC is a relatively young project at this stage, the user consultation has been at a more generic level, with the intention to delve deeper into functional, organisational and technical aspects with more selected stakeholders at a later stage which requires these stakeholders to be presented with (and understand) the different proposals and strategies from FABRIC. It was not considered appropriate to ask detailed questions at this stage as the robustness of responses could not be guaranteed due to different levels of knowledge of the respondents.

Following the questionnaire outcome, the user needs are finalised. These also relate to the use cases developed in D43.1.

In parallel, a set of ICT modules (Chapter 3) and system functionalities (Chapter 4) is presented, based on information from the use cases in D43.1 and, where relevant, outcomes from the survey.

This report is intended to be a guidance and discussion document rather than a precise blueprint for the rest of the FABRIC project, as at the time of writing the precise scope of the FABRIC demonstrations has not been finalised, so ICT needs may vary. This document therefore presents a vision for the year 2030+, illustrating different options for the system concept, from which essential functionalities can be selected for further development in later WPs and deliverables. In effect, it follows on from the D43.1 use case deliverable and provides a basis from which to select and analyse ICT solutions (WP23) and define a first architecture (WP24).

2. USER NEEDS AND STAKEHOLDER CONSULTATION

2.1 User groups

FABRIC involves a number of stakeholders covering different domains who, in some cases, have had relatively little experience of close cooperation until recent developments in electro-mobility. At a high level, stakeholders can be divided into providers/operators, end-users (people wishing to charge electric vehicles), infrastructure operators (in case they are not already the same as the service provider) and regulators (legal framework, including safety and financial aspects).

The following is the high level categorisation of FABRIC users (people or organisations) that was defined in Deliverable 43.1 “FABRIC Final Use Cases”:

1. Drivers (passenger car drivers, bus and truck drivers), who directly interact with the systems (in-vehicle and infrastructure)
2. Vehicle owners (fleet owners, e.g. freight/logistics, buses, taxis, car hire companies)
3. Transport planners
4. Road operators (and other infrastructure operators where relevant, e.g. car parks, bus stations, freight terminals)
5. Toll collectors
6. Distribution System Operators (DSO) (grid providers), including smart grid authorities
7. Energy suppliers/retailers
8. Billing service operators
9. FABRIC operator (this may also be one of the other categories, e.g. the road operator or grid provider, or it may be a separate entity)
10. Map service providers.

The following additional stakeholders were also defined in D43.1 (some have been merged or omitted, e.g. where they are already included in one of the ten categories above), in order to achieve a more consolidated list:

11. Car manufacturers/OEMs
12. Technology providers and suppliers (including automotive/OEM suppliers, ICT/ITS providers and integrators, renewable energy solutions, smart metering providers, etc.)
13. Service providers (in addition to map service providers and billing service operators listed above)
14. Standardisation bodies
15. Local / regional / city authorities
16. National governments (legislative framework and regulations). Note that functions such as enforcement (e.g. police) and traffic management may be at this level or at the local/regional level above, depending on the institutional structure of each country.

17. Construction industry (road builders and maintenance contractors)
18. Other road users (non-users of FABRIC): vehicles, cyclists, pedestrians, etc.
19. Sales agents for cars and commercial vehicles.

The following sub-sections present the outcome of the first user consultation exercise, before returning to the user needs at the end of Chapter 2 (which takes account of some of the comments made by questionnaire respondents).

2.2 Approach to Stakeholder Consultation

The approach adopted for this stage of the project was an open self-completion questionnaire aimed at a general interested audience, comprising all stakeholder categories. This was partly as the process of inviting stakeholders to become involved with the project is ongoing and partly as a tool to raise awareness of FABRIC. It was not considered feasible at this stage to ask potential respondents detailed questions on scenarios, use cases or technical aspects, as they would need to absorb a certain amount of information beforehand in order to give a useful and informed response. To have required external stakeholders to read detailed descriptions of FABRIC and to become familiar with the different issues and challenges involved would have reduced the response rate to a very small group.

The purpose was to identify what respondents considered to be the shortcomings of present day conventional (plug-in) charging arrangements, to what extent the availability of on-road WPT (wireless power transfer) would increase the shift towards electro-mobility and what are the main expectations of such a system (which are the essential elements and which are not considered so important). Questions focused more on policy than on ICT issues, but some “light” (i.e. multiple choice and non-technical) questions relating to ICT and charging aspects were included. The questionnaire was developed by SP2 partners, with contributions and validation from key partners in SP3.

2.3 Stakeholder Questionnaire survey execution and response

2.3.1 Design

In order to get a good response at the beginning of the project, where there is relatively little to comment on, and also to target a wide variety of stakeholders with different roles and levels of expertise, a generic questionnaire survey was developed which could be completed in approximately 15 to 20 minutes and which contained both closed questions (multiple choice and Likert scale) and open questions (free text comment). Because respondents of different backgrounds and levels of knowledge were solicited to respond to the questionnaire, all multiple choice questions gave a “don’t know” option and respondents were encouraged to use this if unsure, rather than guess an answer and thus provide unreliable responses.

The survey was developed online using the SurveyMonkey tool in order to allow the questionnaire link to be sent to potential respondents by email and also to feature it on

websites and social media pages. Responses were anonymous, although respondents were given the option to sign up to the FABRIC mailing list, any information they gave about their identity (email, etc) is not used in the analysis of their answers.

The questionnaire design was as follows (full questionnaire is shown in Annex I):

Part 1: Factual questions on the respondent and their organisation/company:

- Organisation type of respondent and main function(s) in organisation;
- Country of respondent;
- Level of experience and expertise in different fields (transport planning/operations, ITS/ICT, intelligent vehicles, electro-mobility, energy supply/distribution);
- Role of company/organisation regarding EVs (if any).

Part 2: Respondent's direct experience with EVs and electrical charging:

- Types of vehicle they own or drive (ICE, hybrid, FEV, other);
- Their usage (if any) of public EV charging points and, if so, level of satisfaction.

Part 3: Opinions on electric vehicles and electric charging:

- Should electrification of road transport be a strategic priority at urban level / at interurban level?
- Extent to which on-road charging (as in FABRIC) would increase take-up of EVs at urban level / at interurban level;
- Potential of urban on-road charging for different types of vehicles;
- Potential of interurban (motorway) on-road charging for different types of vehicles;
- Potential of short-term stationary rapid charging for different types of vehicles.

Part 4: Opinions on organisation, ICT and road infrastructure aspects for on-road charging (oriented towards FABRIC SP2):

- Who should be responsible for providing information on location and availability of dynamic electric charging facilities?
- Use of dynamic signs (VMS – Variable Message Signs) to inform about EV charging (as well as in-car information);
- Access restrictions for electric charging in urban areas;
- Safety risk if the wireless power transfer (charging) zone is open access;
- Location of wireless power transfer (charging) zones on motorway carriageway (which lane(s)?)
- Physical impacts of integrating an inductive system in the road.

Part 5: Opinions on grid aspects (oriented towards FABRIC SP3):

- Impact of on-road wireless power transfer on the electricity grid;
- Implications on grid in case of large scale deployment (30 year horizon);
- Need for safeguards to ensure secure operation of grid.

Part 6: Opinions on business models (oriented towards FABRIC SP5):

- Which type of organisation should develop and operate it: opinions sought on 4 example models, plus option to suggest another solution.

2.3.2 Administration and response rate

The questionnaire was disseminated via the following channels:

- Email from ERTICO to 213 persons: lists provided by ERTICO, TRL and also to members of the FABRIC External Reference Group (ERG)
- Request to all FABRIC partners to disseminate further
- Posting on the following websites:
    - www.erticonetwork.com (ERTICO news portal)
    - www.automobile-propre.com (French portal)
    - www.hyer.eu (European association)
    - www.ev-observatory.eu (European EV Observatory)
- Posting on the following LinkedIn groups:
    - ITS – Intelligent Transport Systems
    - iMobility
    - Transport Research
    - FABRIC group.

A total of 71 responses were received in a 4-week period, after which it was decided to close the survey page in order to allow for the analysis. Given that the questionnaire was posted in several networks, we cannot say how many people saw it; therefore it is not possible to give a response rate. However a figure of around 40-50 responses was targeted internally as an acceptable figure, so the total of 71 was very satisfactory (although not all of the 71 answered all of the questions: some of the later questions were answered by between 50 and 60 respondents).

2.4 Stakeholder Questionnaire responses: Respondent profile (factual questions)

The respondent profile clearly affects the responses given, hence this section is important to understand the rest of the questionnaire analysis. Where there are sufficient numbers from different sectors, the responses are analysed by sector to ascertain whether there is a noticeable difference in the opinions of different types of stakeholder.

2.4.1 Sector of activity and work

Respondents were asked to select only one sector of activity in which they are employed. The largest number of respondents (32%) work in industry (large companies, including OEMs), closely followed by 30% who work for academic institutions or research organisations, as shown in Figure 1 below. Relatively few of the respondents were from public authorities (19% overall). Overall, just over half of respondents worked in industrial or commercial companies.

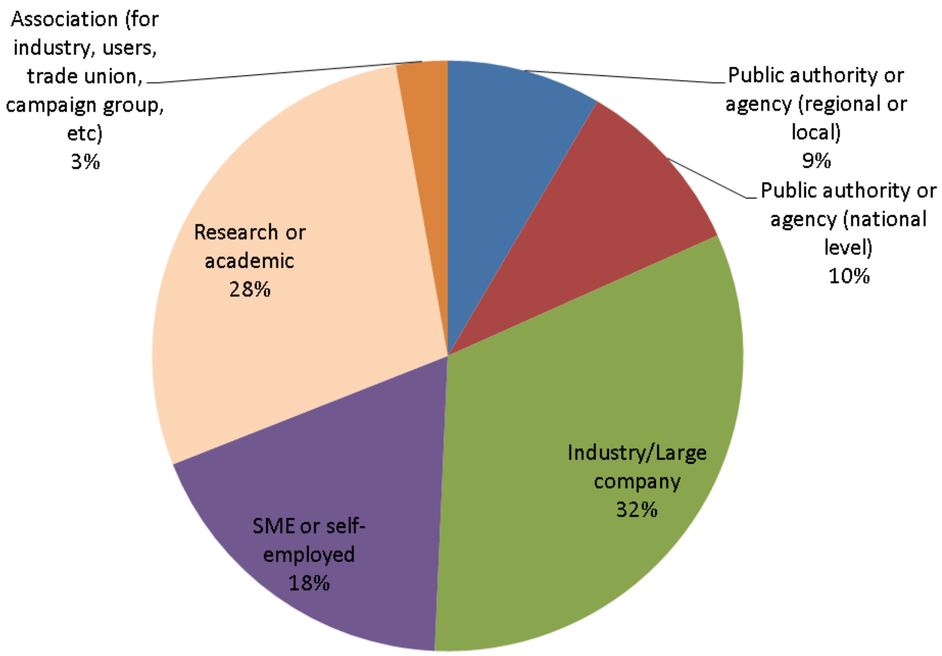

Figure 1: Area of employment of respondents

Regardless of their employment sector (public, industrial, academic, etc), respondents were asked to specify what their actual areas of work are (with multiple responses possible). Figure 2 shows the results, with researchers and academics being by far the most numerous group of respondents, followed by consultants and public policy makers/administrators. A good mix of different backgrounds and experiences is represented (OEMs, public transport, road operators, energy/grid providers, policy, suppliers, etc.). 20 of the 71 respondents work in more than one sector (often this was consultant/specialist services, or researcher/ academic, along with another sector). Hence the total number of responses was 98.

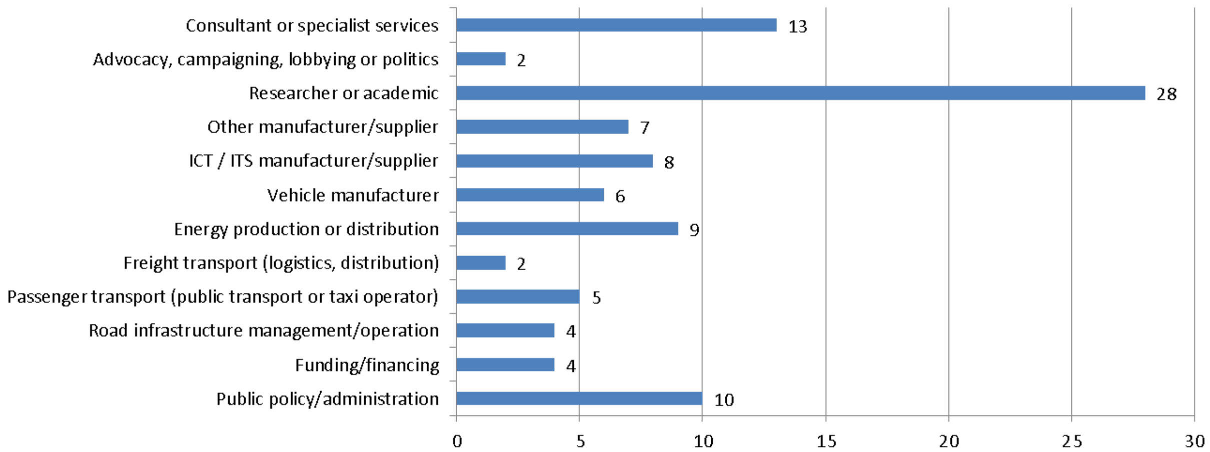

Figure 2: Sector of work of respondents

Respondents were also asked about their level of experience or expertise in five areas of relevance to FABRIC. The intention was to qualify the other responses where necessary, as a response from an expert in a certain sector would be more significant than one from someone with little knowledge of the subject. The respondents were asked if they were either an expert, had some knowledge, or had no experience in the following domains:

- Transport planning or operations;
- Intelligent Transport Systems (ICT infrastructure);
- Intelligent vehicles;
- Electro-mobility;
- Energy supply or distribution.

The following figure shows the responses for each one. Almost half considered themselves experts in electro-mobility and most of the remaining respondent had at least some experience in it. 74% had at least some experience regarding intelligent vehicles. At the opposite extreme, just over half had no experience in transport planning or operations.

In the following analysis, where a question related directly to one of the five subject domains listed above, the responses by level of experience/expertise of the respondent are given.

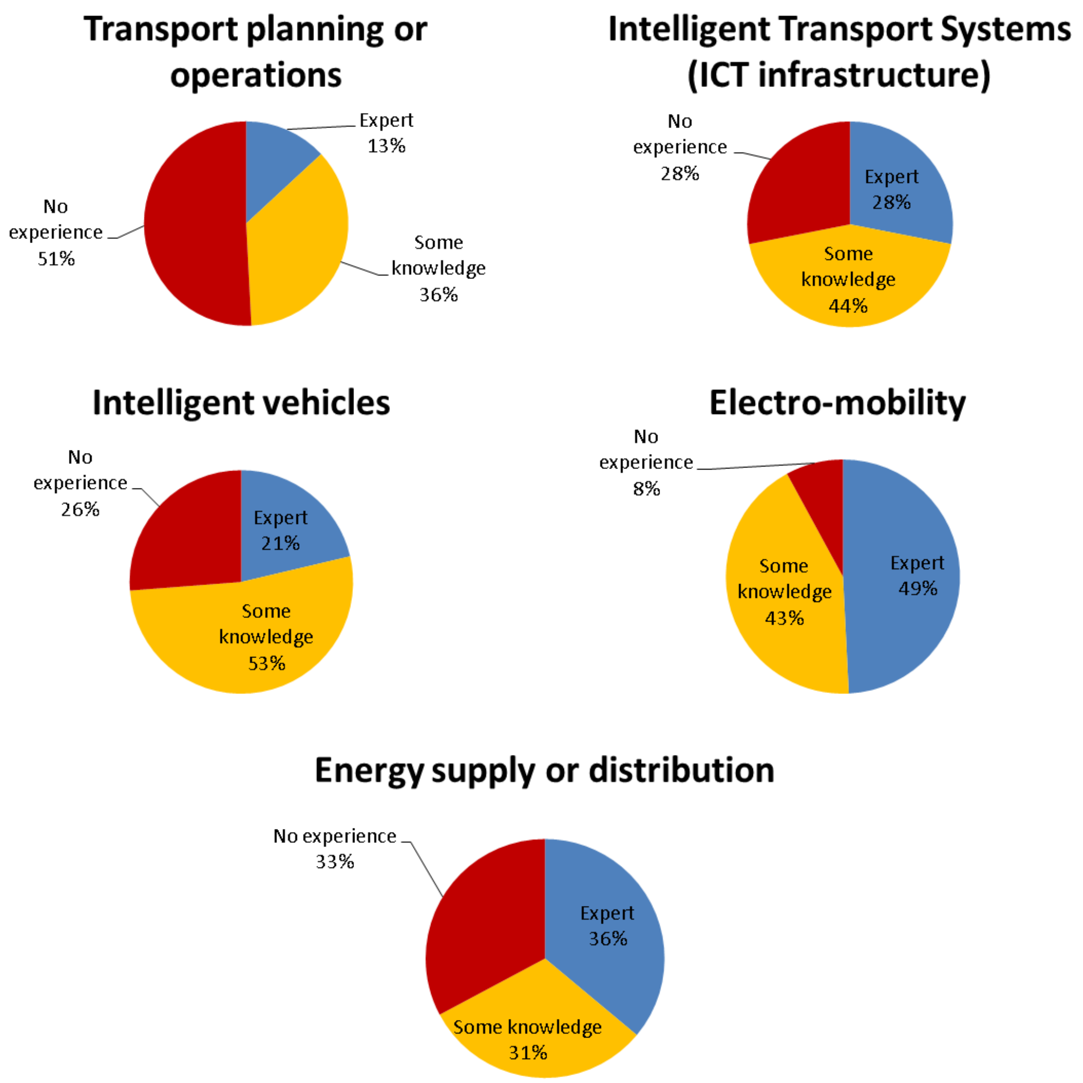

Figure 3: Expertise/Experience of respondents by sector

2.4.2 Involvement of respondents in related activities

The following list shows current or recent projects (either research/study or deployment) concerning EV charging in which questionnaire respondents are involved (either personally or their organisation).

EU projects:

1. UNPLUGGED project: http://unplugged-project.eu

National projects:

2. EV charging point installation, Manchester (UK): http://ev.tfgm.com
3. Development of Dynamic Inductive Charging system with power transfer of up to 200 kW. Usable by all road vehicle types. Developed in Lathen (Germany): www.initis.de

4. Elways AB is developing conductive dynamic charging in Sweden. 200 meters of test track was installed two years ago and has been tested during all types of weather. Another 150 meters will be installed this autumn and hopefully 2 km next year. www.elways.se
5. Building an alternative renewable power distribution system to the electrical grid using overhead dynamic charging of e-vehicles www.slideshare.net/bstarn/dynamic-charging-latest-developments-17234454
6. Source West - South West region of UK ICT4EVEU EU Commission project www.sourcewest.info
7. Involvement in pre-commercial innovation deployment by the National Swedish Road Administration, Road map work on deployment ERS (Electric Road Systems) and research funding
8. Funding a Pre-Commercial procurement in Sweden of on-road dynamic charging.
9. Victoria project (Málaga, Spain): www.endesa.com/es/saladeprensa/noticias/carga-autobus-electrico-induccion-dinamica

2.4.3 Geographical distribution

Overall, 65 of the 71 respondents were based in EU countries, with the following 12 countries represented (greatest number of respondents first):

France (15 respondents); Germany (14); UK, Italy and Sweden (6 each); Belgium (4); Spain, Czech Republic, Netherlands (3 each); Austria and Finland (2 each); Greece (1).

The remaining 6 respondents were from the USA (4), Canada and New Zealand (1 each).

In addition to experience from these 15 countries, respondents also mentioned other countries in which they have professional experience. These included China, South Korea, EU-wide and global experience. Experience in countries including France, the Netherlands, Italy, Germany, Sweden and the USA was also mentioned by respondents not currently based in those countries. Hence we can say that the sample is wide-ranging and provides a satisfactory geographical cross-section of respondents.

2.4.4 Role of respondents' organisation or company in EVs

We asked whether respondent's companies or organisations had any direct role regarding electric vehicles, i.e. whether they do any of the following (or plan to do so in the future):

- Provide EVs for staff or business use;
- Provide EVs for public use (car hire or car sharing scheme);
- Organise, plan or manage electric charging infrastructure;
- Support electric vehicle use (financially or organisationally).

The outcome is shown below. Significantly, over a third of respondents' organisations provide EVs for staff or business use, and a further 11% plan to do so in the future. Furthermore, 41% organise, plan or manage charging infrastructure and just over half support EV use in some way.

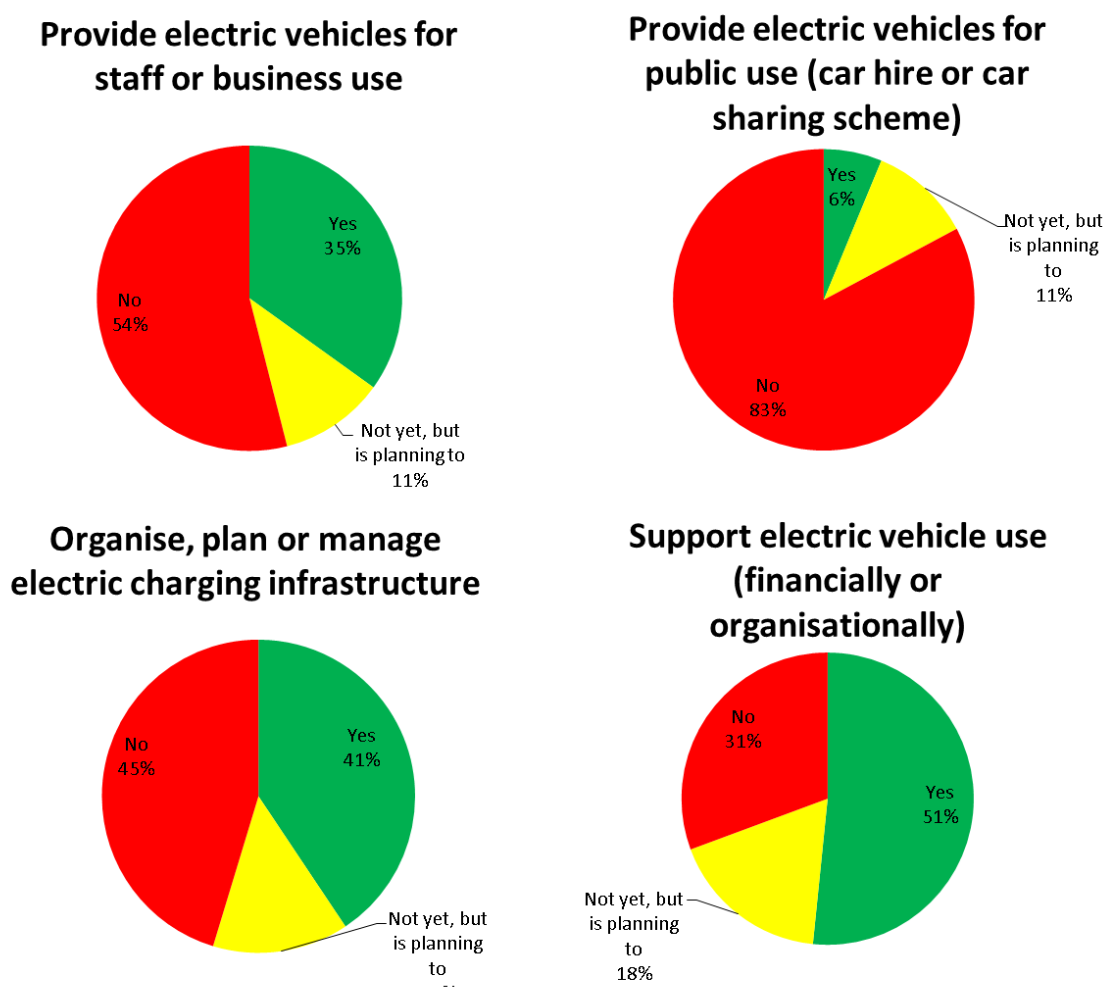

Figure 4: Respondents' organisation involvement in EVs

Eleven respondents clarified their answers by specifying relevant areas in which their organisations are involved. These are:

1. Providing software for planning and execution of trips;
2. Creating an e-mobility car policy for our own fleet;
3. Supplier of battery and electric powertrain;
4. Navigation for EVs;
5. Involved in R&D projects;
6. Consultancy, studies and internet publications;
7. Research and development of batteries and BMS;
8. Plug-in hybrid buses;
9. Supporting knowledge-base for government policies;

10. Research on charging infrastructures;
11. Solar Mobility: Recharge vehicles with the sun to minimise CO_2 emissions and grid impact.

2.5 Stakeholder Questionnaire responses: Direct experience with EVs and charging facilities

This section profiles the respondents in terms of their use of electric vehicles comparted to other vehicles, and also their experiences and opinions regarding public charging points for EVs.

2.5.1 Personal use of EVs and other vehicles

Regardless of the role of their company or organisation, respondents were asked about their personal experiences with EVs, i.e. what type(s) of vehicle they either own or regularly drive. Responses are shown below. Unsurprisingly, the vast majority (91%) either own or use petrol or diesel vehicles. However 48% have experience of driving FEVs (although only two of the respondents owned one). Only a quarter have experience with hybrid vehicles and even less in the case of vehicles using other fuels, e.g CNG.

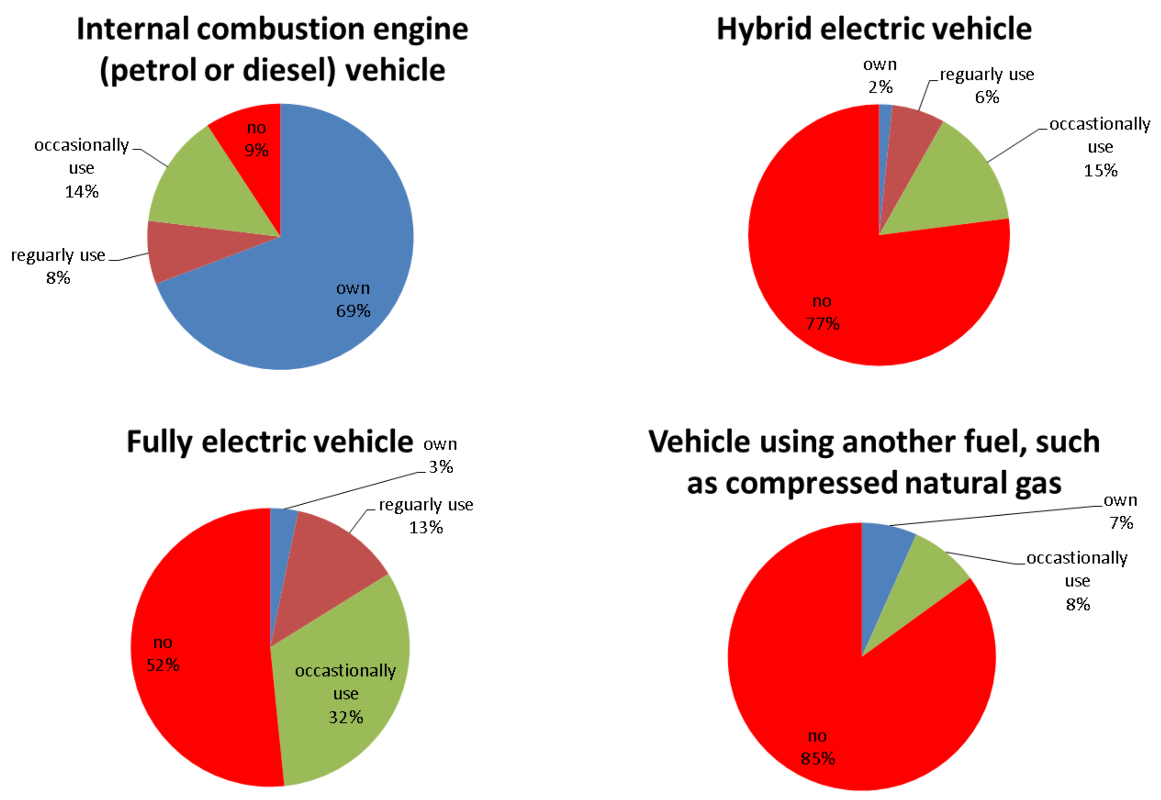

Figure 5: Respondents' ownership or use of EVs and other vehicle types

While most ICE cars are owned by their drivers, most users of FEVs, hybrids and other vehicles using alternative fuels do not own the vehicle.

2.5.2 Use of public EV charging points

Although almost half of respondents have driven FEVs at least occasionally, much fewer (27% of the 64 respondents who answered this question) have used public electric charging points. 15 respondents had used charging points in their own city or local area, and four of these 15 had also used points in other cities or countries. A further three had used charging points in other cities or countries (but not in their local area), bringing the total in this category to seven (see Figure 6).

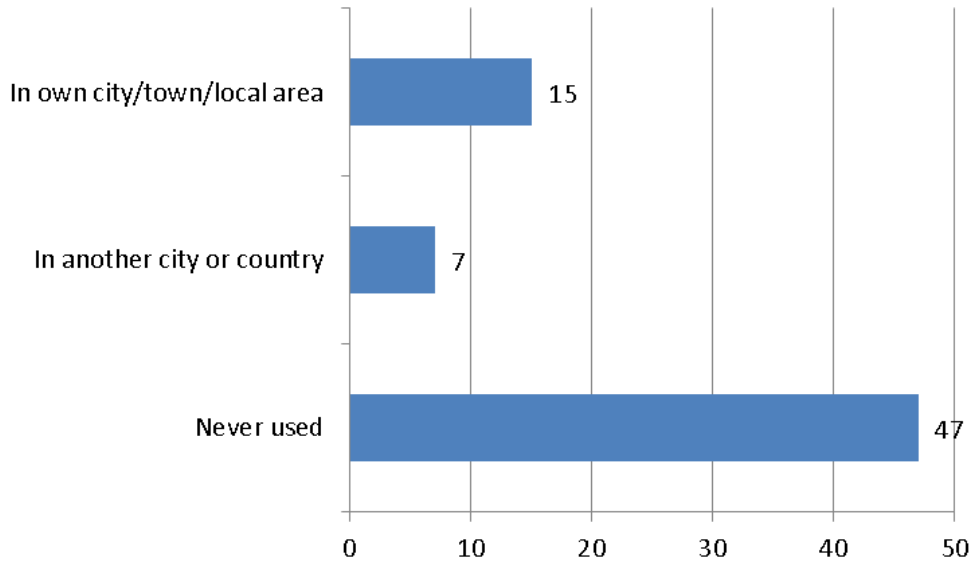

Figure 6: Respondents' use of EV charging points

Some respondents quoted the places (cities or countries) where they have used public charging facilities. These included Berlin, Stuttgart, Mannheim, Paris, Lyon, Chambéry, Barcelona, Rome, Madrid, London, Gothenburg, the Netherlands, Belgium, Luxembourg, Slovenia, Switzerland and Shanghai.

2.5.3 Respondent's experiences with public EV charging points

The questionnaire asked respondents' level of satisfaction (satisfied, neutral or dissatisfied) with the ease of use, charging duration, price and payment, and safety of public charging points for EVs that they have used. These were asked separately for public charging points in the respondent's own city or local area, and for points used in other cities or countries. The aim was to see if satisfaction was lower when a user uses facilities in a place away from their local area, particularly if in another country, as lack of interoperability might be an issue

(need for an account to access the service, etc), or also lack of information (knowledge of charging station locations and status, for example).

Figure 7 shows the results for respondents' own cities or local areas. Users were generally satisfied or neutral about most areas, but the charging duration, price and payment caused dissatisfaction in about a third of cases. No users were dissatisfied regarding safety.

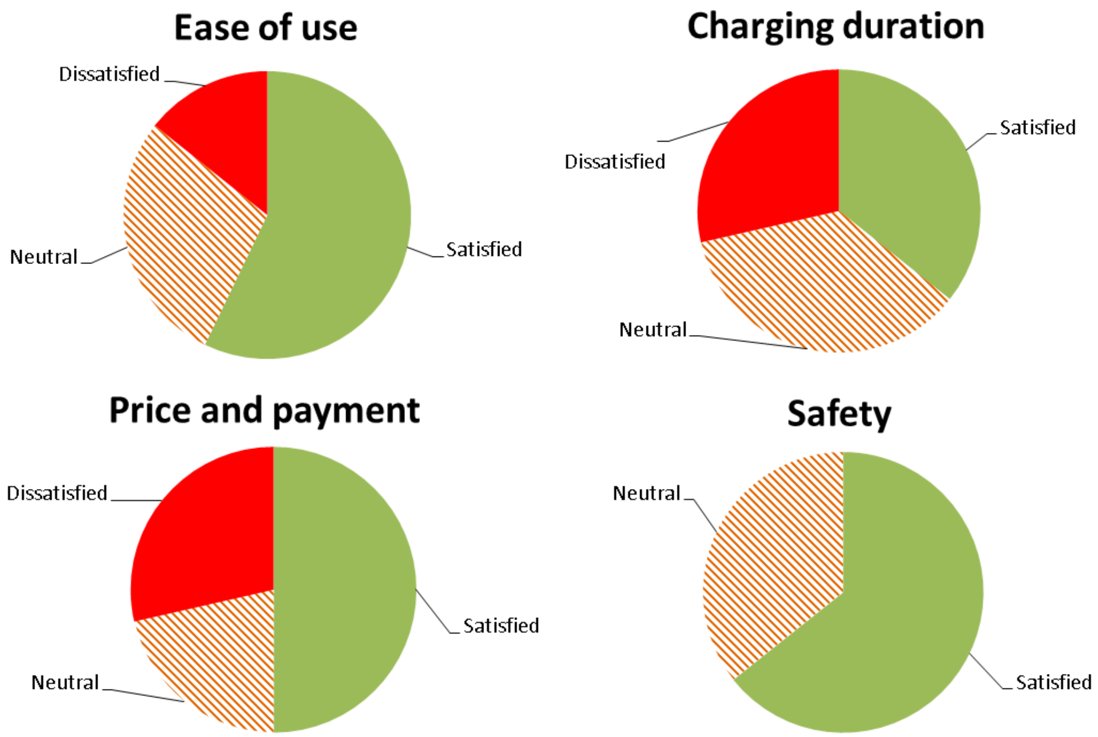

Figure 7: Respondent satisfaction in using public charging points in their local area

Regarding facilities in other cities or countries, only 13 respondents answered this question, so the results cannot be considered significant. Overall, there was a lower level of satisfaction for all the criteria, particularly ease of use and safety, but there was also a lower level of dissatisfaction, and consequently a much higher percentage of neutral responses.
One respondent indicated the lack of an antitheft device for charging cables in a charging point, a potential problem that would not arise with on-road charging. Lack of interoperability between different operators was mentioned only by one respondent.

2.6 Stakeholder Questionnaire responses: Responses to subjective questions

The following are the key responses to the questionnaire that have a potential impact or guidance on the FABRIC project, i.e. respondents' opinions on electro-mobility in general, on-road charging specifically and some issues regarding ICT and charging modes.

2.6.1 Opinions on electric vehicles and charging

A general policy question was asked: whether electrification of road transport should be a strategic priority. Two “yes” options were given: either that it should be a high priority (and consequently receive investment from public funding), or that is it is a priority but that public involvement should be more limited (for example, support for interoperability, providing parking/charging spaces and promoting integration with other transport modes, but not having the public sector directly operating systems or making major infrastructure investments). The third possible response was that it should not be made a political priority but be left entirely to the private sector to develop or not according to market conditions, and without state support. The question was asked for urban mobility as well as for interurban or rural mobility, partly because much EV use and infrastructure deployment is currently focused on cities, and also because one of the key advantages of a FABRIC-style on-road charging system is that it facilitates longer distance interurban use of EVs.

62% (36 out of the 58 respondents who answered this question) believe that electric vehicles have very visible public benefits in urban mobility (exhaust and noise emissions) that justify public investment. However for interurban or rural deployments, this figure drops to 40% (23 respondents out of 58). Nevertheless a clear majority (83%) still see electro-mobility outside urban areas as relevant, even if many of them consider that public support should be more limited. Support for measures to facilitate EV use outside cities is perhaps lower due to current lower penetration rates and lack of experience, but could rise if successful deployments take place and if viable business cases are developed to show that it can be developed without high levels of public spending.

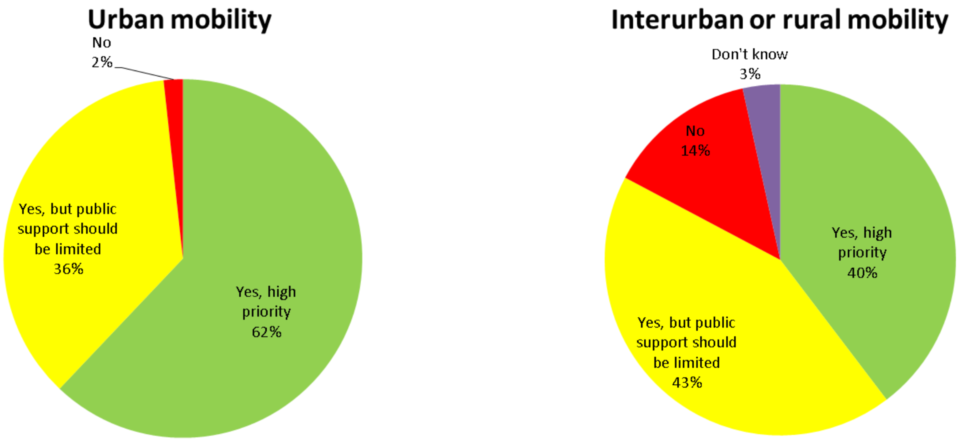

Figure 8: Respondent prioritisation of electro-mobility (urban and interurban)

By sector of employment, there appeared to be a greater than average level of enthusiasm for support for electro-mobility from people working in industry or business (including SMEs), whereas academics and researchers were much less likely to support prioritisation of electro-mobility (particularly at interurban level with only 3 out of 16 researchers

considering it a high priority). Support from respondents from public sector organisations was around the average, reflecting the overall distribution in Figure 8.

Main comments were:

- "EV infrastructure is sustainable in the urban centre but significant advances in battery technology are needed to transfer benefits to a rural setting, where investment is akin to subsidising bus services at present: Investment for a benefit for the few" (expert in electro-mobility and energy supply/distribution and ITS engineer from a regional or local public authority).
- "As 80% of car use is for proximity with less than 40 km/day, most and prior efforts have to be devoted to local infrastructure" (expert in electro-mobility and energy supply/distribution from a large energy company or DSO).
- "Pollution and CO_2 reduction should be a main priority in all sectors (energy, transport, finance, goods, food, etc) but unrightfully so, climate change doesn't seem to be a worry of significance to many" (expert in ITS and electro-mobility from a large company/industry supplying ITS).
- "For suburbs OK, but rural areas and interurban not appropriate" (ITS expert from small consultancy firm).
- "Synergies between guided electric transit (rail, trolleybuses) and electric cars should be considered" (expert in transport planning, ITS and electro-mobility from a consultant SME firm).
- "The development of cycling infrastructure in urban areas should be a higher priority than electric vehicles" (expert in electro-mobility and energy supply/distribution from research or academia).
- "An excellent mitigation tool for CO_2 emitting technologies" (expert in electro-mobility from a regional or local public authority).
- "Electric vehicles have very visible public benefits in urban mobility (exhaust and noise emissions) that justify public investment. These seem less relevant in interurban mobility. Considering the low market penetration in urban areas and for short trips (the overwhelming majority of all individual mobility trips), as well as the specific limitations of the technology, it seems premature to promote interurban eMobility now and may even be harmful with regard to the public's perception of the usefulness of eMobility" (expert in electro-mobility and energy supply/distribution from research or academia).

Respondents were then asked about the potential of on-road charging to change EV take-up in the longer term (in around 30 years' time). Compared to a situation where plug-in charging only exists, they were asked whether the take-up of electric vehicles is likely to increase a lot (over 40% more), to a medium extent (25-40%), to a small extent (10-25%) or not at all, for four scenarios:

- Stationary or static[1] on-road charging (in lay-bys or parking areas) in urban areas;

[1] The FABRIC project has differentiated between static and stationary charging: static is while the vehicle parked (it can have the motor turned off and the driver absent), while stationary is a short stop where the driver is normally present. However, to simplify the questionnaire, this differentiation was not used, so the term "stationary" in this chapter also implies the static charging mode.

- Dynamic on-road charging in traffic lanes in urban areas;
- Stationary or static on-road charging (in lay-bys or rest areas) on motorways (or other high quality major roads);
- Dynamic on-road charging in traffic lanes on motorways.

Compared with stationary charging, it is clear from the figure below that people see a much greater potential to increase the share of EVs in the case dynamic on-road charging (especially for longer distance travel), which would be a key benefit of FABRIC.

For stationary on-road charging, resultant increases in EV use were considered to be more likely in urban situations than for interurban: for stationary interurban charging more than half thought that it would lead to only a small increase (less than 25%) in EV use, or no increase at all.

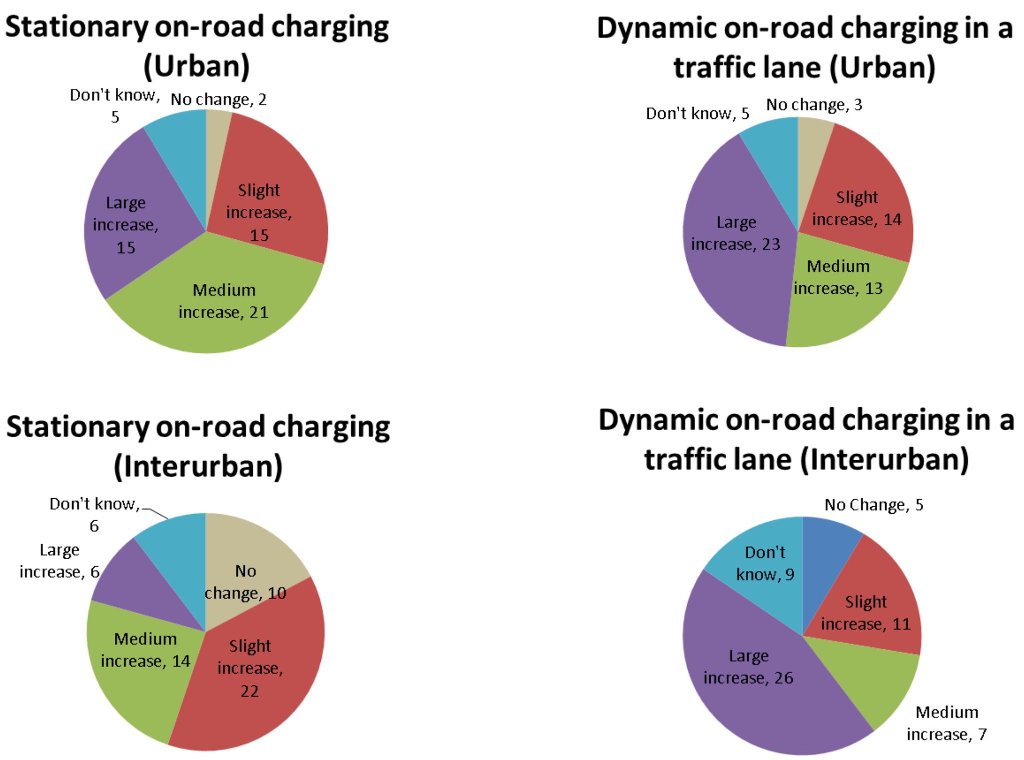

Figure 9: Views on increases in EV take-up with on-road charging in 30 years compared to a situation with plug-in only charging

Related free text comments were:

1. "What usability, efficiency and affordability would dynamic road surface charging offer?" (expert in electro-mobility from a large company involved in road infrastructure)
2. "Long range travelling and load carriers are the target of on-road charging" (expert in electro-mobility and energy supply/distribution from a large company involved in energy production or distribution).

3. "Hard to estimate, depends heavily on how the shift away from fossil fuel has progressed by then" (expert in ITS and electro-mobility from a large company manufacturing or supplying ITS equipment).
4. "For stationary charging points this (the level of potential) very much depends on the number of charging points. During resting phases, plugging in a socket might not be seen as a big inconvenience, much more a low number of opportunities for charging" (expert in ITS and electro-mobility from a large research/consulting company).
5. "Dynamic charging also includes overhead (catenary) charging" (expert in electro-mobility and energy supply/distribution from an SME research and advocacy company).
6. "This is impossible to answer. In reality, most private EV users tend to use home-charging anyway. Public Infrastructure is overrated in my view" (expert in electro-mobility from a national public authority).
7. "What about the costs and efficiency of such infrastructures?" (expert in electro-mobility and energy supply/distribution from a research or academic institute).
8. "Dynamic charging is a key technology for long range use of EVs" (expert in electro-mobility from a regional or local public authority).
9. "If in 30 years' time a plug-in-station-based infrastructure is well developed the contactless technology will have little to no impact in urban areas (I doubt that it is the act of plugging the car in that keeps consumers from buying it). For long trips (motorways) the impact will be limited if it is stationary (essentially the same as a fuel station), but it is not clear to me that people will switch to electric mobility for such long distance trips in great numbers, anyway" (expert in electro-mobility and energy supply/distribution from a research or academic institute).

Looking so far into the future is not easy and it falls to FABRIC to make a socio-economic and business case for on-road charging as well as a technical case; particularly considering that alternatives such as rapid plug-in charging are also likely to be more widespread, efficient and accepted in the future.

The questionnaire then asked about the potential for on-road charging in urban and interurban contexts for different usage types: private EV use, EV car sharing, freight or utility vehicles (trucks, vans, etc) and public transport (buses).

Responses are shown in Figures 10 and 11. In an urban context, people regard the prospects of electric buses most favourably, probably because it is relatively easier to achieve: routes are fixed and schedules are known, so the locations can more easily be determined and there is less risk of over- or under-use.

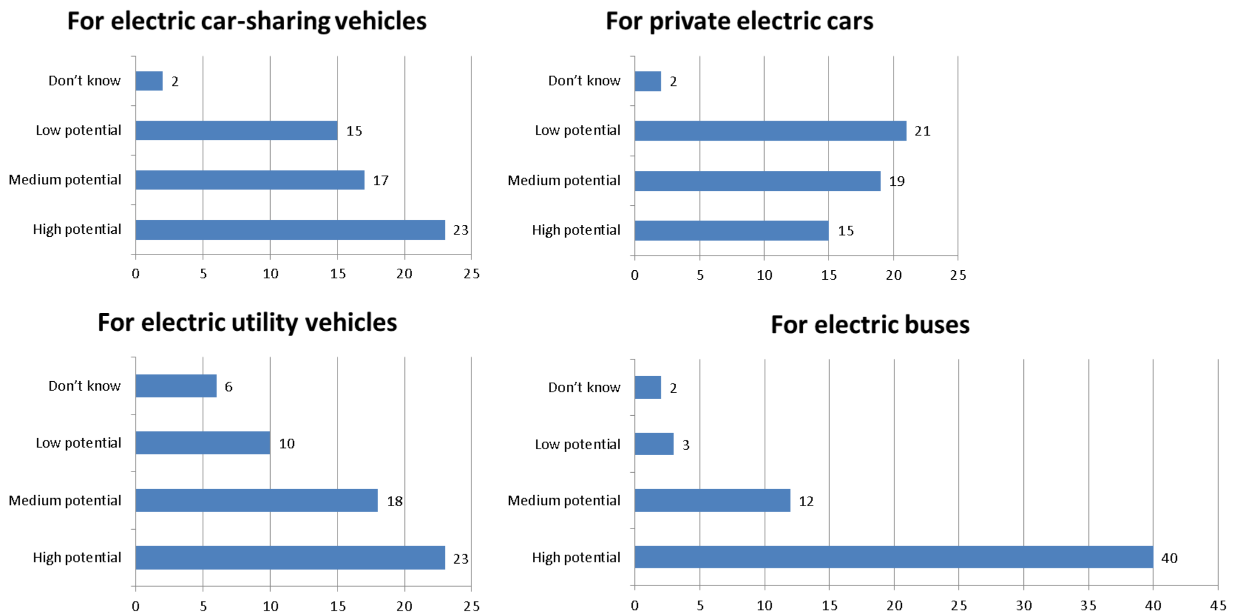

Figure 10: Potential of on-road charging for different vehicle types in urban areas

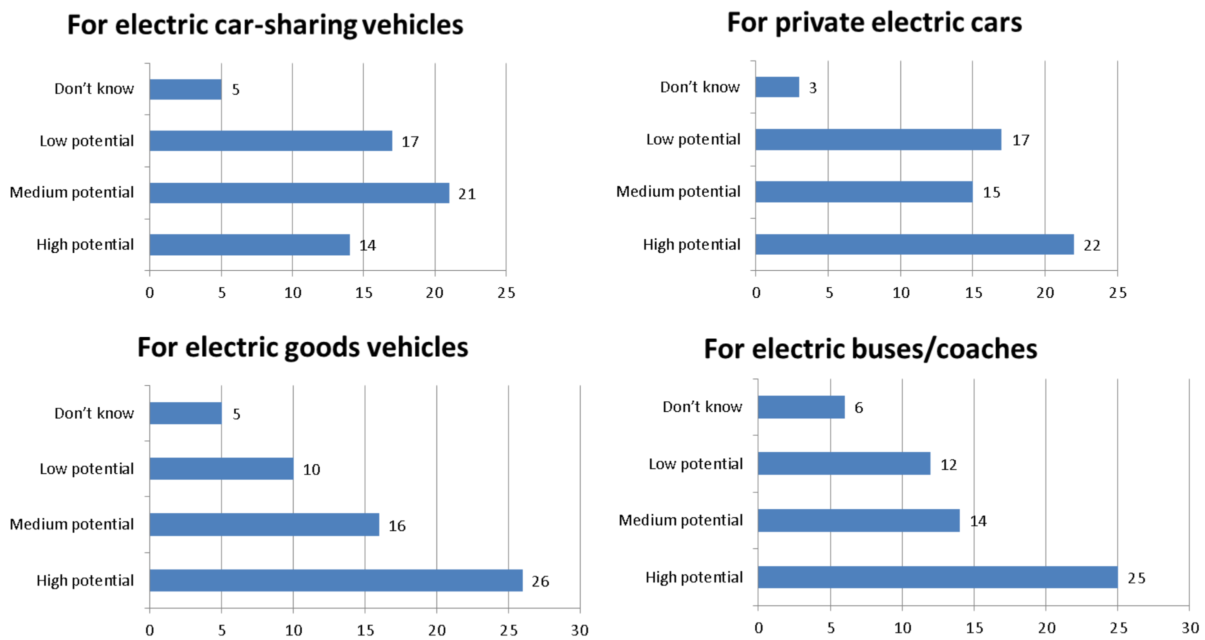

Figure 11: Potential of on-road charging for different vehicle types on major interurban routes

Comments received on ***urban*** charging modes were as follows:

1. "Intensively used vehicles, such as professional vehicles, are the main ones concerned" (expert in electro-mobility and energy supply/distribution from a large company involved in energy production or distribution).
2. "Buses with fixed routes: easy to implement" (expert in ITS and electro-mobility from a large company manufacturing or supplying ITS equipment).

3. “Professional entities are rather planning their trips (e.g. urban logistics) in a very detailed manner. Private users would like the freedom to "just hop in" without having to think about their routes in advance and hence gain a lot of flexibility which the drivers are used to with fuel cars today due to the comparatively short refuelling time” (expert in ITS and electro-mobility from a large company involved in research).
4. “Where applied to electric utility vehicles, the potential for on-road charging in urban areas depends on the type of vehicle (probably not suitable for snowploughs or telescopic work-platforms)” (ITS expert from research or academia).
5. “Many cities have deployed dynamic overhead charging infrastructure for buses” (expert in electro-mobility and energy supply/distribution from an SME research firm).
6. “For buses this could be done in a variety of ways, cf. Vienna buses charging on tramway wires” (Electro-mobility expert from a national public authority).
7. “Private cars are generally parked in private parking spaces for times long enough to allow traditional charging. For car sharing or public transportation, the potential depends on the rest times that allow for traditional recharging (e.g. buses in dense urban areas might be used during the night when bus traffic in smaller towns shuts down)” (expert in electro-mobility and energy supply/distribution from research or academia).
8. “For urban transport battery capacity is and will be sufficient” (expert in electro-mobility and energy supply/distribution from an energy distribution company, also with freight transport experience).

Comments received on i***nterurban*** charging modes (e.g. on motorways) were as follows:

1. “Main potential on interurban routes is seen with range extension without need for lengthy stops” (expert in ITS and electro-mobility from a large research/consulting company).
2. “I don't think that there will be long distance electric goods transport if other - equally clean - options are available which require a lot less infrastructure investment” (Electro-mobility expert from a national public authority)..
3. “Depending on the trip length, this kind of trips should be made by more efficient means (train/plane)” (expert in ITS and Intelligent Vehicles, involved in research and academia).
4. “I doubt that private car owners will switch to electric cars for long distance trips at all. However, ***if*** urban electric mobility develops further and significant public measures are taken to reduce combustion-engine traffic in cities (e.g. emission regulations), there might be a need for on-road charging for those vehicles that regularly make long distance trips and have to enter inner city traffic at the same time” (expert in electro-mobility and energy supply/distribution involved in research and academia).

5. "For interurban car transport battery capacity *is and will be sufficient*. For goods vehicles and coaches dynamic charging will be important, but must not necessarily be the inductive type. Other systems (e.g. overhead contact lines) might have less impact on road surface and higher efficiency" (expert in electro-mobility and energy supply/distribution from an energy distribution company, also with freight transport experience).

Lastly, the potential of ***stationary or static*** on-route charging was asked, for the following three situations:

- Stationary rapid charging (not plug-in) for cars in car parks in towns and cities: 31 respondents out of 55 (56%) saw this as having high potential, 21 as having medium potential and just 3 seeing it as having low potential.
- Stationary rapid charging (not plug-in) for cars at motorway rest areas: this was rates slightly lower with 17 respondents out of 55 (31%) seeing it as having high potential, 24 as having medium potential and 14 as having low potential.
- Stationary rapid charging (not plug-in) for buses at bus stops or bus stations in urban areas: over half of respondents to this question (29 out of 53) saw this as having high potential, 14 medium potential and 10 low potential.

While stationary or static charging are not the main focuses of FABRIC, they constitute two of the FABRIC charging modes, so questions on these are relevant in terms of comparing views on the potential of dynamic charging to that of static or stationary charging by WPT. Overall there is not a great difference between support for dynamic charging and support for stationary or static charging; the main differences relate to the types of vehicle and user, with a much greater level of support for WPT charging for fleet vehicles (public transport or freight) than for private cars. Although the potential for WPT for private cars or car-sharing EVs is lower, it is still seen as having either high or medium potential by over 60% of respondents.

The above represents only a simple snapshot of opinions: clearly the costs, likely usage, possible business cases, etc. for these different implementation scenarios are not known by the questionnaire respondents and will be part of future work-packages in FABRIC. However this first snapshot could provide a useful indicator to guide work on the feasibility analysis in SP5, in particular by allowing us to collect several different opinions which can guide hypotheses or scenarios, or help identify additional issues to consider.

2.6.2 Opinions on organisation, ICT and road infrastructure aspects for on-road charging

A question on organisational aspects concerned who should inform the users of the location and status of on-road charging facilities. There appears to be no real consensus on this, with very similar numbers (between 35 and 43 respondents in each case) agreeing that it could be the road authority, a third party (e.g. on-board navigation system) or the operator of the charging system. Note that respondents could choose more than one answer. Provision of

information by the system operator is the preferred option in the figure below, but only by a small margin.

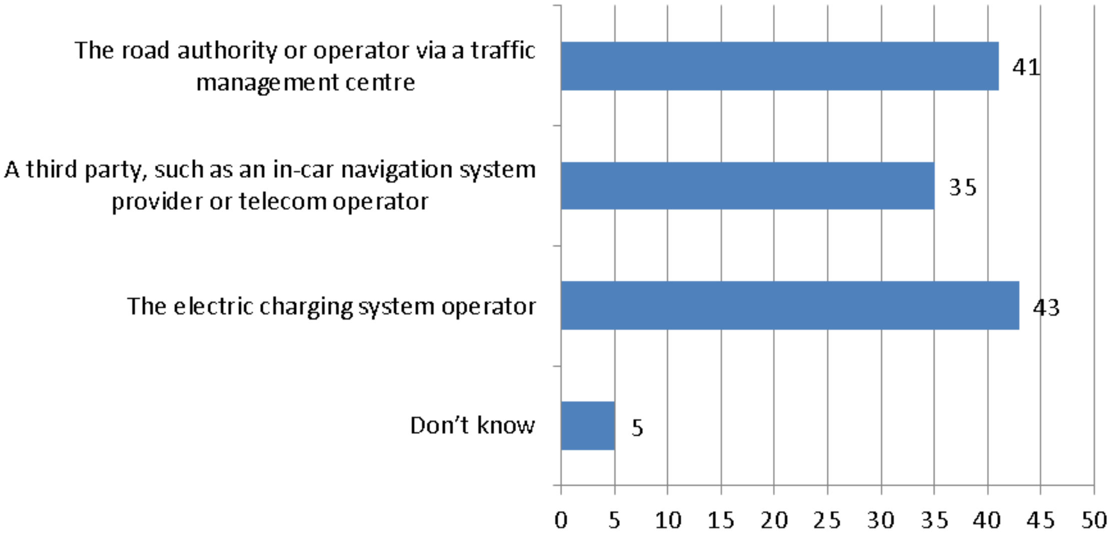

Figure 12: Who should provide information on EV charging facilities?

Related comments were as follows:

1. "Interoperability between operators on that purpose is required" (expert in electro-mobility and energy supply/distribution from a large company involved in energy production or distribution).
2. "The information should be treated as open data taken up by any interested party in the value chain" (expert in ITS and electro-mobility from a large company involved in research).
3. "Mostly will be provided by drive through restaurants, banks etc." (expert in electro-mobility and energy supply/distribution from an SME involved in research and advocacy).
4. "This is a question of data availability. If charging infrastructure is online it can feed into a lot of providers' information systems" (expert in electro-mobility from a national public authority).
5. "Stationary on-road charging will very likely be much more costly than the development of traditional charging infrastructure, certainly less energy-efficient. It's acceptance in the public sphere will likely be difficult and subject to comprehensive regulation (induction of strong electro-magnetic fields or open conducting materials). The difference to traditional charging for electric vehicle owners will likely be marginal (namely the effort of plugging the car into a charging station)" (expert in electro-mobility and energy supply/distribution from research or academia).

6. “It must be privatised to ensure continuous innovation” (expert in electro-mobility and energy supply/distribution from a large company involved in energy distribution).

Variable Message Signs (VMS) constitute a well-established ITS application for real-time driver information in urban areas and on motorways/major roads. While there is a trend towards in-vehicle information which could make VMS redundant in the medium-term, their advantage lies in providing the same message to everyone, whereas in-vehicle information might depend on the provider, user settings, etc. We asked about the relevance of VMS in providing information on on-road charging facilities (location, status, etc), perhaps in a similar way to urban parking guidance VMS systems (showing numbers of free spaces in nearby car parks).

Three quarters of respondents (42 out of 55 who answered this question) agreed that the availability of dynamic charging facilities should be shown on VMS in urban areas. Only 6 disagreed and 7 were undecided.

Another issue which is relevant to the physical set-up of WPT charging lanes and hence the supporting ICT infrastructure is whether they be provided on ordinary traffic lanes that are freely accessible by any vehicle (including non-EVs), or whether they be provided in lanes reserved for charging EVs only (with access possible controlled or enforced in some way, by traffic signals/signs or by physical measures such as barriers). The former option is more efficient in terms of use of road space, particularly in urban areas where dedicating an entire lane to charging EVs only may be impossible to justify in terms of the traffic that would use it. The latter option however makes the charging easier to regulate and could perhaps overcome potential safety issues related to non-users coming into contact with the charging infrastructure.

The views of the 55 respondents who answered this question are shown in Figure 13. Just over half of the respondents (29 out of 55) favoured an open system. 23 favoured some sort of access control. People with at least some experience or expertise in transport planning or ITS were more likely to opt for an open system (62% in favour) compared to people without experience in these sectors (e.g. energy experts outside the transport sector). As transport planners and engineers would be expected to have a more informed opinion on road configurations, it could be argued that an open system is preferable from a traffic and transport point of view, although it could present more difficulties for energy supply/WPT.

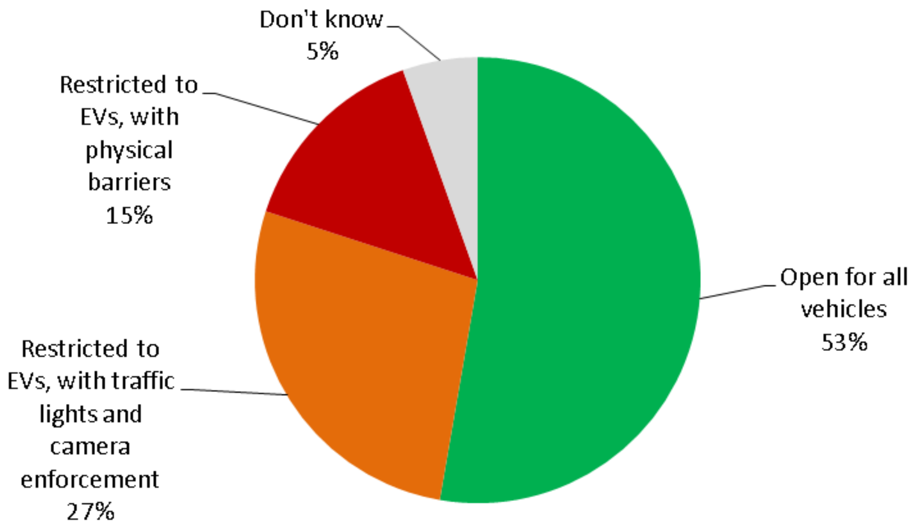

Figure 13: Views on access to dynamic charging lanes in urban areas

Comments on this question showed awareness of the advantages (encouragement of EVs) and disadvantages (efficient use of road space, cost, giving preference to EVs generating hostile opinions towards electro-mobility) of reserving lanes for EV charging:

1. "In limited space, it is best not to exclude any type of traffic, and the dynamic charging service is seamlessly combinable with other types of traffic" (expert in ITS and electro-mobility from a large company involved in ICT/ITS supply).
2. "Restricted at first to foster take up of electric vehicles, later open to all" (expert in ITS and electro-mobility from a large company involved research).
3. "Restriction as an advantage for pollution free vehicles" (expert in transport planning, intelligent vehicles and electro-mobility from an SME consultant).
4. "The investment costs will be prohibitive. Maybe there will be some special - restricted - applications like the heavy goods electric vehicle transport from airport to harbour in Los Angeles (?) but broadly available dynamic charging lanes will be too expensive for cash-stripped cities" (expert in electro-mobility from a national public authority).
5. "There might be other low-emission vehicles also (presumably sharing an EV lane)" (researcher from a large vehicle manufacturer).
6. "You would not want to create a negative sentiment against EVs (through having a reserved lane)" (expert in electro-mobility from a regional or local public authority).
7. "I am not generally opposed to electric-car-only lanes as a public policy measure to promote urban eMobility, however, enforcement measures should certainly not exceed those of bus lanes" (expert in electro-mobility and energy supply/distribution from research or academia).

8. “Ideally it would be in a segregated lane, but given limited road-space this is unrealistic” (expert in transport planning or operations from a regional or local public transport operator).

Related to this issue is a question on potential safety concerns of on-road charging, especially risks in cases where a dynamic inductive charging lane is accessible by all users, including pedestrians, cyclists, people walking dogs, etc, as would be the case on a city street.

Figure 14 shows the responses to this question. 23 out of 55 respondents considered the risks to be low and 15 considered them to be medium. Six respondents considered the risks to be sufficiently high to require segregation and controlled access to any charging lane.

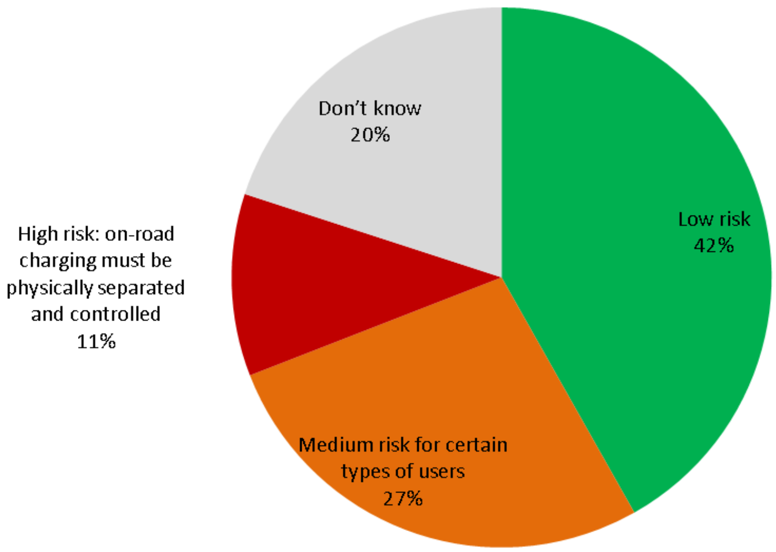

Figure 14: Views on risks posed by open-access on-road dynamic charging facilities

The relatively high numbers of “don’t knows” illustrates that this is an area where more clarification is needed: not only evidence but communication to the public. This is also borne out by the comments, as follows:

1. “This risk has to be pared anyway, otherwise it is not a solution” (expert in electro-mobility and energy supply/distribution from a large company involved in energy production or distribution).
2. “I don’t know what it is, so we don't know whether it is safe. Does one get x-rayed/microwaved/magnetised when one crosses such a road? Communication about this is of key importance” (expert in ITS and electro-mobility from a large company involved in ICT/ITS supply).

3. “Further in depth study on the effects of electromagnetic radiation needed” (expert in ITS and electro-mobility from a large company involved research).
4. “Low risk possible but depends on the technology” (transport planning, ITS and electro-mobility expert from an SME consultancy).
5. “Overhead dynamic charging is significantly safer than induction charging and also works in winter” (expert in electro-mobility and energy supply/distribution from research SME).
6. “While no direct risk should result from the operation of inductive charging in normal conditions if norms like those by the ICNIRP are respected, comprehensive risk analysis seems necessary with regard to malfunctions, pace-maker patients, unusually close contacts to the charging pads (accidents, pedestrians tripping), object interactions (bicycles, metallic objects on the street), etc. Also, it is not clear if guidelines for general public exposure should apply if inductive charging becomes omnipresent in urban areas” (expert in electro-mobility and energy supply/distribution from a research or academic institute).
7. “The chargers should recognise the inductive vehicle to start the process, and stop if any other vehicle or pedestrian or non-inductive receiver is on the zone” (expert in energy supply/distribution from a research or academic institute)..

Moving to interurban applications, respondents were asked about the potential positioning of on-road WPT infrastructure on motorways: which lane(s) should be used? Results are shown in Figure 15.The nearside lane is the most popular choice, which seems logical as speeds are lower. On the other hand, heavier traffic on this lane (more goods vehicles) could make it more congestion and also cause more wear and tear on the infrastructure. Using the hard shoulder might be an option where this is wide enough for traffic to use, however it is also the lane that is most likely to see people on foot, in the event of breakdowns or accidents, so there could be a safety issue with this.

Several comments strongly questioned how realistic or worthwhile it is to install this type of facility on a motorway.

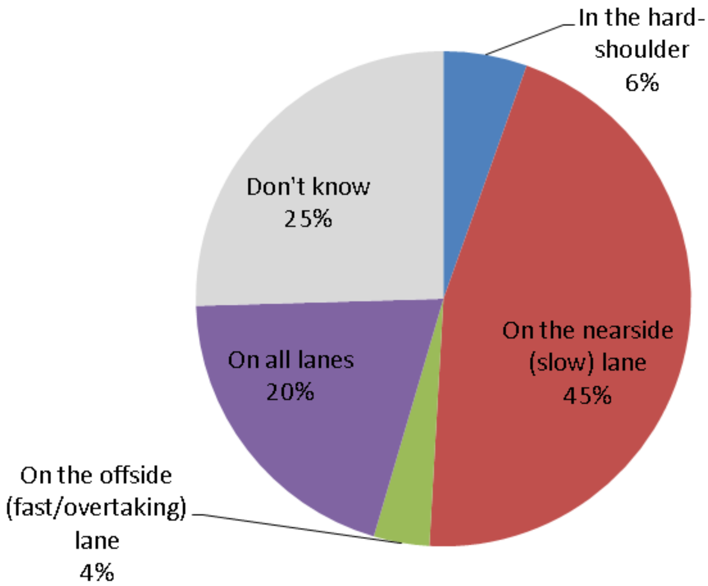

Figure 15: Potential location of charging lanes on motorways

Comments received were:

1. "It depends on the characteristics and ability of the system" (expert in electro-mobility and energy supply/distribution from a large company involved in energy production or distribution).
2. "Counts for Germany only, as no speed limit and e-vehicles are usually slow(er)" (ITS and electro-mobility expert from a large consulting or research company, who selected "on the nearside [slow] lane).
3. "But preferably use conductive charging which is much cheaper" (expert in energy supply/distribution from a research SME).
4. "Most dynamic charging will be at private commercial facilities like drive through restaurants" (expert in electro-mobility and energy supply/distribution from research SME).
5. "I don't think that is a realistic option. For long-distance transport emphasis should be placed on clean vehicles requiring less expensive infrastructure investments like LNG trucks, CNG, H2..." (expert in electro-mobility from a national public authority).
6. "This seems so costly that it makes no sense" (expert in ITS and intelligent vehicles from a research or academic institution).
7. "Laugh at the investment and usage costs!" (expert in intelligent vehicles from a research or academic institution).
8. "The lane should be located on the nearside lane, or on a separate lane. Charging at lower speed probably also makes sense with regard to the coupling and the physical extent of the system at limited energy transmission rates. The emergency lane should be kept free for emergencies" (expert in electro-mobility and energy supply/distribution from a research or academic institution).

9. “Ideally all lanes, but not sure that it matters too much. If the facility is there, then EV drivers will use the appropriate lane” (expert in transport planning or operations from a regional or local public transport operator).

Similarly to the question of physical separation of lanes in urban areas, we asked whether this should be done on motorways. 43 out of 55 considered that there should be no physical separation of WPT lanes and other lanes on a motorway. 5 respondents were in favour of separation (one of whom stated that ideally it should be separated but not if it significantly constrains deployment), and 7 did not know.

Finally, regarding the physical impacts of the integration of an inductive system in the road, respondents were asked about their views on the risks of faster deterioration of the road surface and the risks of interference with roadside equipment. Responses (Figure 16) were not decisive, with quite a high proportion of “maybes” and “don’t knows”.

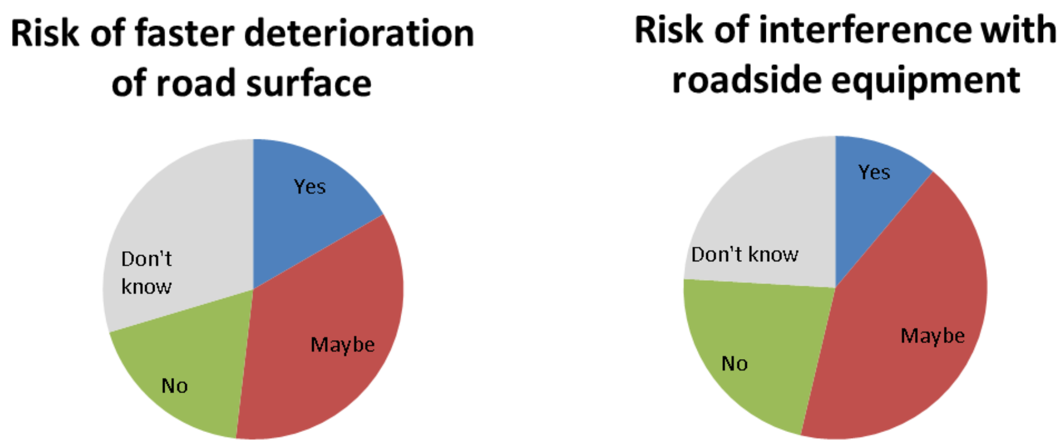

Figure 16: Risks relating to charging lanes in the road surface

Comments regarding the road surface mentioned that the risk of deterioration is dependent on surface material and one questioned how it would work in wet/slippery conditions (and consequent safety issues).

Comments regarding roadside equipment included one that interference with inductive loops is likely

Two comments favours conductive charging lanes (e.g. overhead wires), as cheaper and more practical (especially in snowy conditions in winter), as well as easier to maintain. Of course this implies limitation to trucks and buses.

2.6.3 Opinions on grid aspects

The likely impact on the electricity grid and the need for safeguards to guarantee secure operation of the grid were asked. Responses are in the following figure:

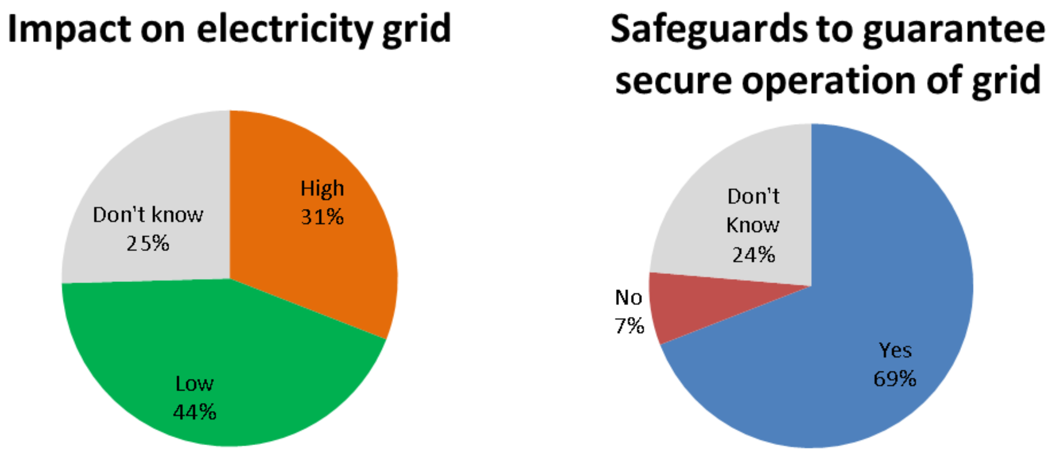

Figure 17: Views on the impact of WPT charging on the grid and safeguards needed

Regarding ***impact on the grid***, comments included:

1. "Highly dependent on number of vehicles, power transferred, availability of buffer storage, local renewable energy supply, etc. The more centralised energy supply is, the greater the impact" (expert in electro-mobility and energy supply/distribution from a consultant SME).
2. "Similar to electric trains or trams" (expert in electro-mobility and energy supply/distribution from a large company involved in energy production or distribution).
3. "Significant but well manageable because it is predictable" (expert in ITS and electro-mobility from a large company involved in ICT/ITS supply).
4. "Highly volatile impact as charging volume depends on traffic volume, might pose a risk to the electric grid and incur high costs to satisfactorily implement sufficient power supply" (ITS and electro-mobility expert from a large consulting or research company).
5. "Low if made in conjunction with solar panels added along motorways" (expert in electro-mobility from a large manufacturing company).
6. "At least on the distribution level it will have high impact locally" (expert in energy supply/distribution from a research SME).
7. "Depends on the technology, performance, system, grid stability, etc" (3 similar comments from different respondents).
8. "Depends on penetration" (ITS expert from a research or academic institution).
9. "Dynamic charging should use only renewable energy" (expert in electro-mobility and energy supply/distribution from research SME).

10. "Might be substantial if deployed and used on a large scale in rural areas" (expert in electro-mobility and energy supply/distribution from a research or academic institution).

Comments on the ***need for safeguards*** (which ones, who should do what) were as follows:

11. "Grid operator, as is currently the case with overload situations" (expert in electro-mobility and energy supply/distribution from a consultant SME).
12. "Grid operators and standardisation bodies (IEC...)" (expert in electro-mobility and energy supply/distribution from a large company involved in energy production or distribution).
13. "On all thinkable levels, safeguards are required. I have no doubt this will be regulated as the technology develops" (expert in ITS and electro-mobility from a large company involved in ICT/ITS supply).
14. "All parties should be involved (n-tier concept)" (expert in electro-mobility from a large company involved in infrastructure management).
15. "Electricity supplier based on information from (or in conjunction with) the road operator" (4 similar comments from different respondents).
16. "No special safeguards other than normal grid operation necessary" (transport planning, ITS and electro-mobility expert from an SME consultant).
17. "The question of operator is a very relevant one in a lot of issues related to electric mobility, there is no easy answer to that" (expert in electro-mobility from a national public authority).
18. "Primarily the road authority/operator should be responsible" (2 comments from different respondents) "but solutions will have to be worked out in accordance with the governing structure of each country".
19. "On a large scale, EV charging will become part of the predictable load profile. The need for additional particular measures (apart from existing grid security measures) seems speculative, in particular with regard to the more general changes in the electricity grid in the near future" (expert in electro-mobility and energy supply/distribution from a research or academic institution).

Also regarding energy and grid aspects, the question was asked: "***What implications do you see on the electricity grid*** if on-road charging is deployed on a large scale? (imagine in 30 years' time)": This allowed a free text answer and responses were as follows:

1. "More night-time freight transport, balancing the load over the 24h cycle and reducing congestion in the day time" (expert in electro-mobility from a large company involved in infrastructure management).
2. "Depending on uptake the need to provide more kW using sustainable energy sources will be required" (ITS expert from a regional or local authority).

3. "A highly centralised grid would make extensive deployment of on-road charging very infrastructure intensive - Possibilities for the use of renewable energy with buffer storage solutions near roads to avoid this - Equipment of roads also makes outfitting roads with electricity transmission systems at the same time a possibility (superconducting transmissions lines, etc.) - More research needed in the areas of smart grids / transport systems in this context. Automated or semi-automated freight movement maybe, especially if roads need to be upgraded for inductive charging anyway. - Possibility of organising freight movement for most energy effective time (mid-day for solar, or during windy periods) for freight that is not time dependant - Possibility to upgrade motorways to make them more friendly to residents (silent tarmac, sound barriers, etc.) as well as reduction in noise due to electric drive and necessary aerodynamic improvements (to make HGV s more efficient)" (expert in electro-mobility and energy supply/distribution from a consultant SME).
4. "Bring energy line close to the road by a special line" (expert in electro-mobility and energy supply/distribution from a research or academic institution).
5. "Positive, as EV batteries can balance the grid" (transport planning and ITS expert in a large company carrying out research).
6. "Power load variability and possible harmonics pollution have to be studied; but not much different than electric train and trams" (expert in electro-mobility and energy supply/distribution from a large company involved in energy production or distribution).
7. "Limited smart grid (V2G) functionality no controlled charging possible in off-peak times" (expert in electro-mobility and energy supply/distribution from a large manufacturing company).
8. "A well manageable and predictable load. Question is, do vehicles have capacitors and are those also part of that grid and are they also connected on a management layer? So stationary vehicles can support peak demand. Question also is, to what extend have we migrated to wind and solar? What about nuclear-fusion tech?" (expert in ITS and electro-mobility from a large company involved in ICT/ITS supply).
9. "Cars should balance when and how much they load during driving" (electro-mobility expert from a large company providing ITS and managing infrastructure).
10. "The grid must be designed to cover peaks at locations where they only occur at specific times (e.g. morning/evening peaks)" (expert in ITS and electro-mobility from a large research company).
11. "Depends on use of solar power to power road-charging" (expert in electro-mobility from a large company).
12. "The electricity grid will need some reinforcements especially locally. Generation should change towards non fossil to a large extent" (expert in energy supply/distribution from a research SME).

13. "Stabilisation of the transmission network in respect to smart grids" (researcher with experience in transport planning and electro-mobility).
14. "High maintenance costs, difficulties for construction works" (ITS expert from an SME consultant).
15. "May cause more peak/off peak differences" (expert in transport planning, intelligent vehicles and electro-mobility from an SME research company).
16. "Day/night regimes should be in balance - re-charging should be enabled from vehicles (or other devices) to the grid back" (ITS expert from a research or academic institution).
17. "Very little impact if dynamic charging is used as a competitor to electrical grid where eVehicle is used to transport energy as well as people and goods" (expert in electro-mobility and energy supply/distribution from an SME research company).
18. "I don't think this will happen but the electricity grid requires major investments anyway to cope with the challenges of becoming a smart grid" (expert in electro-mobility from a national public authority).
19. "a) Fuel consumption for vehicles will be reduced; b) This same fuel ***will*** be used elsewhere, probably on grid usage, which might end up as a high effect; c) But smart grid is taking care of this already --> explains the low effect choice" (Intelligent vehicle expert from a research or academic institution).
20. "The major problem comes from the supply of the energy, with risks of lack of energy! / A higher need for allocated power from the grid / Additional power plants will be needed / More power transmission cables needed" (similar comments from various respondents).
21. "Increase of peaks power on the grid High standby consumption" (expert in electro-mobility and energy supply/distribution from a research or academic institution).
22. "Risk of electrocution of people ,or disruption of public grid electricity" (expert in energy supply/distribution from a research or academic institution).
23. "Will in some areas create a bigger need for smart grid solutions. A new type of structure for utilities will emerge and payment solutions will have to be developed that work seamlessly between operators/utilities" (expert in electro-mobility from a regional or local public authority).
24. "In urban areas, overall load might increase significantly. Depending on the implementation (stationary, dynamic) the load profile might be smoothened (traffic peaks in addition to evening and noon peaks). If deployed in rural areas, the impact might be more profound, since it might make new infrastructure investment necessary (overloading of rural distribution networks especially if consumption peaks are pronounced)" (expert in electro-mobility and energy supply/distribution from a research or academic institution).

25. “High cost for grid reinforcement, can be avoided by local storage and local energy production” (expert in electro-mobility and energy supply/distribution from a research or academic institution).
26. “Cars will be used as a load-leveller to reduce spinning reserve and improve grid efficiency” (expert in electro-mobility and energy supply/distribution from a large energy distributing company).
27. “It will be necessary to include RES and Storage systems to generate the energy needed” (expert in energy supply/distribution from a research or academic institution).

2.6.4 Opinions on business models

A final question was asked about business models, with four models proposed with which respondents could fully agree, mostly agree, give a neutral opinion, mostly disagree or fully disagree. Respondents were free to agree with several business models (perhaps according to different local circumstances) so were not asked to select the best or rank them.

The four options were:

- Development and operation by private companies, with all development financed with usage charges (“Private model”);
- Development and operation by public authorities, as part of a policy to increase electric vehicle use (and with charges covering electricity supply costs but not infrastructure development and maintenance) (“Public model”);
- Urban public transport operators or authorities developing a system for buses, which can be made available to other users at marginal cost (“Public transport led model”);
- Development and operation by toll road operators (in countries where they exist) with users managing payment via their toll tag (electronic fee collection) account (“Toll road operator led model”).

Responses are shown in Figure 18. The third model above (“public transport led model”) had the greatest level of agreement, with 33 respondents either fully or mostly agreeing and only 7 fully or mostly disagreeing. The second option above (“public model”) had the second greatest number of people agreeing (30 fully or mostly) but also the greatest level of disagreement (16 fully or mostly disagreeing).

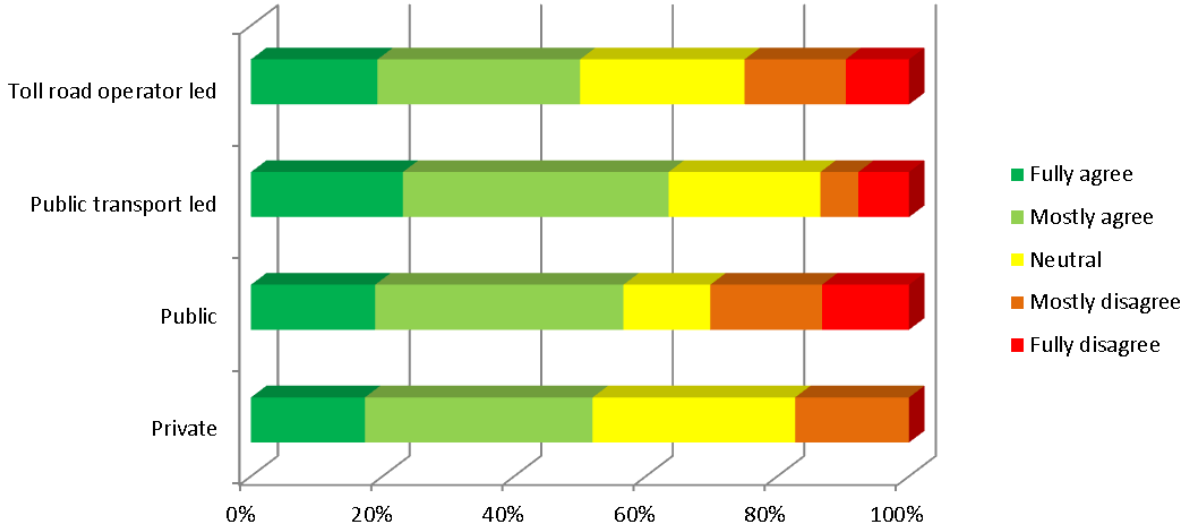

Figure 18: Views on potential business models

One comment argued that on-road charging should not be combined with toll roads as we are thinking 30 years ahead, so building a dependency on another service could complicate matters. Another suggested a viral business model where SMEs deploy dynamic charging to compete with the electrical grid. Two comments suggested Public-Private Partnerships (PPPs), one of them specifying that it would depend on the degree of development, phase, type of operation, and maturity of the business model to handle risks.

2.7 User needs

From comments from the survey, as well as internal discussions, reference to FABRIC Deliverable D43.1 and eCoFEV Deliverable 200.1, the following describes the expected needs of FABRIC users and other involved stakeholders, structured by the user groups listed in Chapter 2.1.

2.7.1 Drivers

These are the main direct users of FABRIC: passenger car drivers and commercial vehicle (van, truck, bus) drivers: these users directly interact with the pre- and on-trip in-vehicle systems and applications that interact with external systems (roadside or back-office). Users may be private motorists or professional drivers using a vehicle that is not owned by them or registered in their name, and using a corporate account.

Key requirements:

1. Ability to set up and manage an account which gives access to on-road charging across different operators in different locations (including cancelling accounts, moving to a different account provider or moving an account to a different vehicle).

2. To be informed of the location and real-time status of charging infrastructure, including their price structures.
3. To be able to plan a trip using different charging infrastructures.
4. To have a single point of contact for account, payment, help, technical questions, etc.
5. Booking infrastructure, taking into account that they may not know the precise time they will arrive at the charging lane or the amount of power they will require. Hence, short notice booking (a few minutes in advance or even immediate use without booking if the system is available and has spare un-booked capacity) should be possible, as should the ability to modify or cancel bookings easily.
6. Real-time information via HMI regarding Wireless Power Transfer (WPT) when in use (charging status, efficiency and price).
7. Real-time guidance via HMI for driving while WPT is taking place (speed and trajectory), with power cut-off and appropriate notification where efficiency drops below an acceptable level or if the driver deviates from the required trajectory.
8. Easy fitment of any systems (electricity meters, HMI, etc) into their vehicle.
9. Common "look and feel" for systems in different locations and inside different vehicles.
10. High reliability of systems (in-vehicle and infrastructure).
11. Security/privacy of account information (personal details, usage and billing).

2.7.2 Vehicle owners

The vehicle owner is taken to be the person in whose name the vehicle is legally registered. This could be the driver but also a leasing company or a company operating a fleet of vehicles (public transport, taxis, freight and delivery companies, car hire companies, etc). Depending on the payment scheme that will be used in the various installations of FABRIC, the owner may be the one that will be billed for the power transferred to the vehicle regardless of who drives it. Needs are essentially the same as for the drivers (above) with the addition of the following:

1. Ability to set up and manage corporate accounts covering several vehicles;
2. In the event of an account for several vehicles, ability to identify which vehicle has used which facilities and the power transfer involved (in case the cost is passed on directly to final clients, for example rental vehicles).

2.7.3 Transport planners

The transport planner is the actor that directly interacts with the pre-trip planning application and in some cases also on-trip and post-trip applications. The interaction is similar or the same as with the driver and vehicle user, however this is larger scale planning that may involve vehicle fleets or public transportation vehicles. In particular, requirement number 3 for drivers (To be able to plan a trip using different charging infrastructures), is relevant, with the ability to plan for a fleet of vehicles.

2.7.4 Road and other infrastructure operators

Road operators and authorities directly interact with the applications defined in the FABRIC transport management & control applications. In addition road contractors that build and maintain the FABRIC systems need to adjust their operations to ensure that the system as a whole remains functional. Their needs include agreements with the FABRIC operator regarding location and maintenance of charging facilities. They also have responsibility for signage and safety, hence commonly understandable signs, symbols and lane markings to denote on-road charging are needed. As operators of other ITS equipment, they may also have a role in managing or operating EV detection and use of charging facilities.

Other infrastructure operators include car parks, freight terminals, bus stations, etc – all potential locations of stationary or static rapid charging by WPT, and therefore have responsibilities and needs similar to road operators.

2.7.5 Toll collectors

In this context, toll may mean a price paid to use road infrastructure (e.g. motorway tolls, urban road charging, etc), but also the price paid to use charging facilities, or other facilities such as car parks. Depending on business models, a FABRIC system could in some cases be bundled with existing tolling systems, for example the holder of a toll tag valid on certain roads may also use it to pay for EV charging. The needs are therefore principally interoperability related and the ability to provide multi-service accounts to clients. In some countries, toll tag providers exist that are independent of any infrastructure operator (they are third party service providers), so such organisations may wish to add EV charging payment to their portfolio for the convenience of their clients. Communication is therefore required with the FABRIC operator for usage and billing data.

2.7.6 Distribution System Operators (DSO)

The DSO, or grid operator, is responsible for the electricity provision and regulating supply according to needs. Their key needs are:

1. Access to the charging infrastructure for maintenance.
2. Appropriate infrastructure maintenance by the road authority/operator.
3. A load balancing algorithm to allow numerous vehicles to charge at once, possibly at speed.
4. High quality communication/data transmission with the energy supplier and the FABRIC operator.

2.7.7 Energy suppliers/retailers

Energy suppliers or retailers buy energy at the electricity market and sell it via the grid (DSO). Their needs include:

1. High quality communication/data transmission with the energy supplier and the FABRIC operator.
2. Accurate metering of energy transfer.
3. In the case where the metering is on the vehicle, there is a need to calculate and add an appropriate margin to cover energy loss between the road and the vehicle, which will differ according to the vehicle type, speed, trajectory, etc.

2.7.8 Billing service operators

The billing service operators include banks, clearing houses and potentially the FABRIC operator itself (if it provides accounts to clients). It will also include toll collectors. Its needs are to provide accounts, billing and related customer service either to final clients, or be a back office with the FABRIC operator being the interface with the client (depending on the business model adopted). Accurate data transfer from the FABRIC operator (ultimately data from the energy supplier) is needed regarding energy used per vehicle, along with data such as vehicle identification, time and location of charging. Other needs are the requirement to transfer accounts (to different clients, bank accounts or vehicles), operate multi-vehicle accounts, deal with international transactions, set up mechanisms in case of non-payment or fraud, etc.

2.7.9 FABRIC operator

The operator of an on-road charging system is responsible for the functioning of the system, interfacing with direct users, payment providers and other stakeholders. The operator may be the same as the road/infrastructure operator or authority, or may be an energy supplier or third party operator.

Key requirements are:

1. Cost-effective installation, operation and maintenance of the system;
2. Ensure the safety of users and non-users (including to reduce the likelihood of claims against the operator resulting from incidents/accidents);
3. Liaison with road operator/local authority (in cases where the system operator is not the road operator or local authority), particularly regarding agreements on access, maintenance, policing, user information, traffic management, etc;
4. Operation of an interoperable payment system or agreement with a payment system provider;
5. Ensure interoperability both in terms of vehicles which can use the system and with systems in other areas, via adherence to relevant standards and protocols.

2.7.10 Map service providers

These are third party information providers, including data for mobile navigation systems as well as home or office use. They will need accurate information on the locations and types of charging facilities. Several charging station maps exist for plug-in charging, either comprehensive national maps or European/worldwide ones relying on data from charging system providers (and therefore often not comprehensive). Most rely on background mapping from providers such as Google Maps. A future need may be a recognised symbol agreed and used by different mapping providers to denote dynamic charging facilities or stationary WPT facilities. The FABRIC operator should liaise with all relevant map providers to ensure mapping is accurate and up to date. Additionally, in-vehicle and back office software providers will wish to incorporate this information.

2.7.11 Car manufacturers/OEMs

Car manufacturers developing and selling EVs that accept WPT need to have common power transfer and vehicle identification protocols in order to provide suitable vehicles. Common standards for in-vehicle HMI are also an issue, as is type approval of any new system to ensure it is legal for road use.

2.7.12 Technology providers and suppliers

These may be OEM suppliers, ICT suppliers for roadside or back-office systems, etc. Their main needs therefore concern standardisation and interoperability. Industry de-facto standards are a necessary first step to avoid the roll-out of non-compatible schemes.

2.7.13 Service providers

Needs for map service providers are already given above. Other service providers include providers of traffic and weather information, which is increasingly incorporated into mapping. Broadcasters are another group. All therefore need up to date information on charging facilities to integrate into their services. Memoranda of Understanding or Data Sharing Agreements with the FABRIC operator will be needed.

Other service providers are those providing on-trip services such as motorway service centres or drive-through fast food outlets, which are potential locations for fast stationary WPT charging facilities, and therefore have needs similar to those of road operators.

2.7.14 Standardisation bodies

Going beyond de-facto industry standards, there will be a need for national and European standardisation bodies to become involved, in particular with respect to smart grid aspects

and WPT technology. They do not have needs in terms of FABRIC, but are potential catalysts towards interoperable solutions.

2.7.15 Local, regional and city authorities

In most cases these are the local road operators, so needs are as in that category above in cases where FABRIC infrastructure is situated on their roads. They will also be responsible for signage and traffic management, so should take account of charging facilities even when they are on adjacent roads (e.g. national roads or motorways, or at off-road facilities). Local authorities also have a policy role and will often be keen to promote electro-mobility. They therefore have a communicative role with the public. Furthermore, they are often responsible for meeting environmental targets such as emissions, as well as promoting integrated multimodal transport, so will see EVs as an important contributor to those goals. Integration could be facilitated by promoting electric car sharing schemes or by providing charging facilities at railway stations to promote multimodal journeys.

2.7.16 National governments

National governments set the overall regulatory environment so need to ensure nothing proposed in FABRIC poses any legal obstacle, or propose alternatives where this is the case. They may also be national road operators (see above). Enforcement may be necessary, particularly in cases where the on-road charging infrastructure is accessible to any vehicle, and legal frameworks may be needed for this in the same way as camera enforcement for other traffic offences. National vehicle registration databases will be needed for EV identification, so access to these from approved operators will need to be granted.

2.7.17 Construction industry

The construction industry is essentially concerned with the implementation and maintenance of WPT facilities, so their needs essentially amount to the provision of clear standards and specifications.

2.7.18 Other road users (non-users of FABRIC)

This group comprises vehicles that do not use the FABRIC systems: unequipped cars (ICE or other non-electric vehicles) but also equipped vehicles passing over the charging infrastructure but which do not wish to use it. Other non-users include two-wheeled vehicles, pedestrians, animals, etc.

Key requirements are:

1. Safety: particularly in the case of an “open” system (i.e. where access is not physically restricted to users) such as in an urban area, pedestrians, cyclists, dogs, etc may come into contact with the charging zone, e.g. when crossing the road, possibly in

close proximity to an EV that is in the process of receiving energy from the road. Such road users should not be affected by the WPT. Situations to consider include people with metallic footwear or walking aids, horses with metallic hooves, or accidents where a person or animal might be hit by a vehicle and possibly end up on the road underneath a vehicle while the WPT is operating;

2. Severance effects or visual impact of charging infrastructure: for example if a charging lane in an urban area is physically segregated from other lanes (e.g. for safety reasons above), the presence of barriers, fences and other equipment may spoil the streetscape visually and restrict the movements of other vehicles, cycles and pedestrians (ability to cross the road, access buildings or driveways on the other side, etc);
3. Fair and efficient allocation of road space: similar to other types of reserved lanes (such as bus lanes), taking a lane of a public road and allocating it to certain types of users only can be controversial particularly if the reserved vehicles make up a small proportion of overall traffic and the lane stands empty much of the time while adjacent lanes are congested.

2.7.19 Sales agents for cars and commercial vehicles

As these are usually the interface between the EV purchaser and the final user, their knowledge of on-road charging and the capabilities of different vehicles to benefit from it is important in the effort to persuade people of the benefits of EVs compared to ICE vehicles. Therefore their need is accurate information from both the OEMs and the FABRIC operator, in order to assist their marketing and customer liaison efforts.

3. SUB-SYSTEMS AND MODULES

3.1 Introduction and Charging Modes

The basis of the FABRIC ICT scenario for wireless power transfer for charging electric vehicles (EVs) is the definition of a general service platform to enable the integration of EVs with different power transfer technologies, different infrastructure systems cooperating with each other through the development of EV telematics services and charging management services based on real time information.

The cooperation among EVs and independent EV-related infrastructures is achieved through information collection from independent infrastructure systems and provides data aggregation functionalities to enable high quality EV services for EV users. The overall system includes sub systems integrated in the EV, at the roadside, at the charging infrastructure and at the backend to realise EV assistance services before and during a trip and charging.

Different sub systems need to be defined for the FABRIC ICT architecture together with different modules and components for the applications.

The key physical sub-system in FABRIC is the Charing Infrastructure itself (CI), also known in other electro-mobility projects and related standards as Electric Vehicle Supply Equipment (EVSE). Three charging modes have been defined in FABRIC: static, stationary and dynamic. Although the main focus of the project is on dynamic charging, the other two modes can be seen as simpler derivatives of this solution, which may be more appropriate for certain circumstances (e.g. when vehicles need to stop anyway) and would typically require fewer charging pads (e.g. one per vehicle in the case of static/stationary use, compared to several over a certain distance for dynamic use).

The three charging modes are fully described in Deliverable D24.1 (ICT functional architecture and specifications), however the following is a brief summary:

- Charging mode 1: Static Charging

Power is transferred to the vehicle while the vehicle is immobile for a long period of time (>5 minutes) and without the necessity for the driver to be in the vehicle. This predominantly refers to charging of vehicles while they are parked, thus is similar to conventional plug-in charging except that no handling of a connector is necessary to couple the vehicle to the charger. Examples include cars parked in a garage or car park, buses parked at a bus terminus or station, or freight vehicles while loading or unloading at an off-road location.

- Charging mode 2: Stationary en-route charging

Power is transferred to the vehicle while the vehicle is stationary for a short amount of time (< 5 minutes) but is en-route and therefore would typically have a driver on-board and probably have the motor switched on. The vehicle would stop in a location that would be suitably equipped but might not be a dedicated stopping / parking spot, but rather on a road (or a very short term roadside location like a bus stop layby). Power transfer would only be activated when the vehicle is stationary. Charging would commence automatically after the

driver's confirmation from within the vehicle. Examples include vehicles stopping at junctions, traffic lights, toll stations, etc; taxis queuing in a taxi rank, buses stopping at bus stops, or delivery vehicles making short on-street stops to load or unload.

- Charging mode 3: Dynamic charging

Power is transferred to the vehicle when the vehicle is in motion at constant or variable speed. The electric power / energy flow is variable depending on the conditions. The power transfer level could be responsive in real time to vehicle power demand or the condition of the electric grid / distribution system, within the constraints of the system capability or other fixed parameters. Examples include urban applications (lower speed, e.g. 50km/h or less), and highway/motorway applications (high speed, up to 130km/h or applicable speed limit).

3.2 Definition

In addition to the Charging Infrastructure (CI), the identified FABRIC sub-systems comprise the Charging Infrastructure Operator (CIO), the EV On-Board Unit (EV OBU), Road Side Unit (RSU), Distribution System Operator (DSO), Energy Retailer (ER), FABRIC Electric-Mobility platform (FEMP), EV backend (EVB), the Road Operator (RO) and a Clearing House (CH). These sub systems (described further below) interact with each other and with different EV related infrastructure systems.

The functional requirements need to be linked to the requirements to ICT applications and interfaces specified. This feeds into WP23 (Technical Benchmarking). A first step is to identify sub-systems, which are high level groups of physical systems, and the modules they contain. The proposed sub-systems for FABRIC are shown as the main boxes in Figure 19 and the bullet points in each box are the modules within each sub-system.

The FABRIC overall ICT scenario should take into account different subsystems, modules, communication capabilities, information exchange, interactions and adopted technology.

The proposed ICT scenario needs and architecture that should be flexible and modular, being able to accommodate different infrastructure systems, satisfying local requirements at the implementation site and enable additional services, facilitating the operation of the system. For this purpose, standardised interfaces will be identified and used wherever applicable.

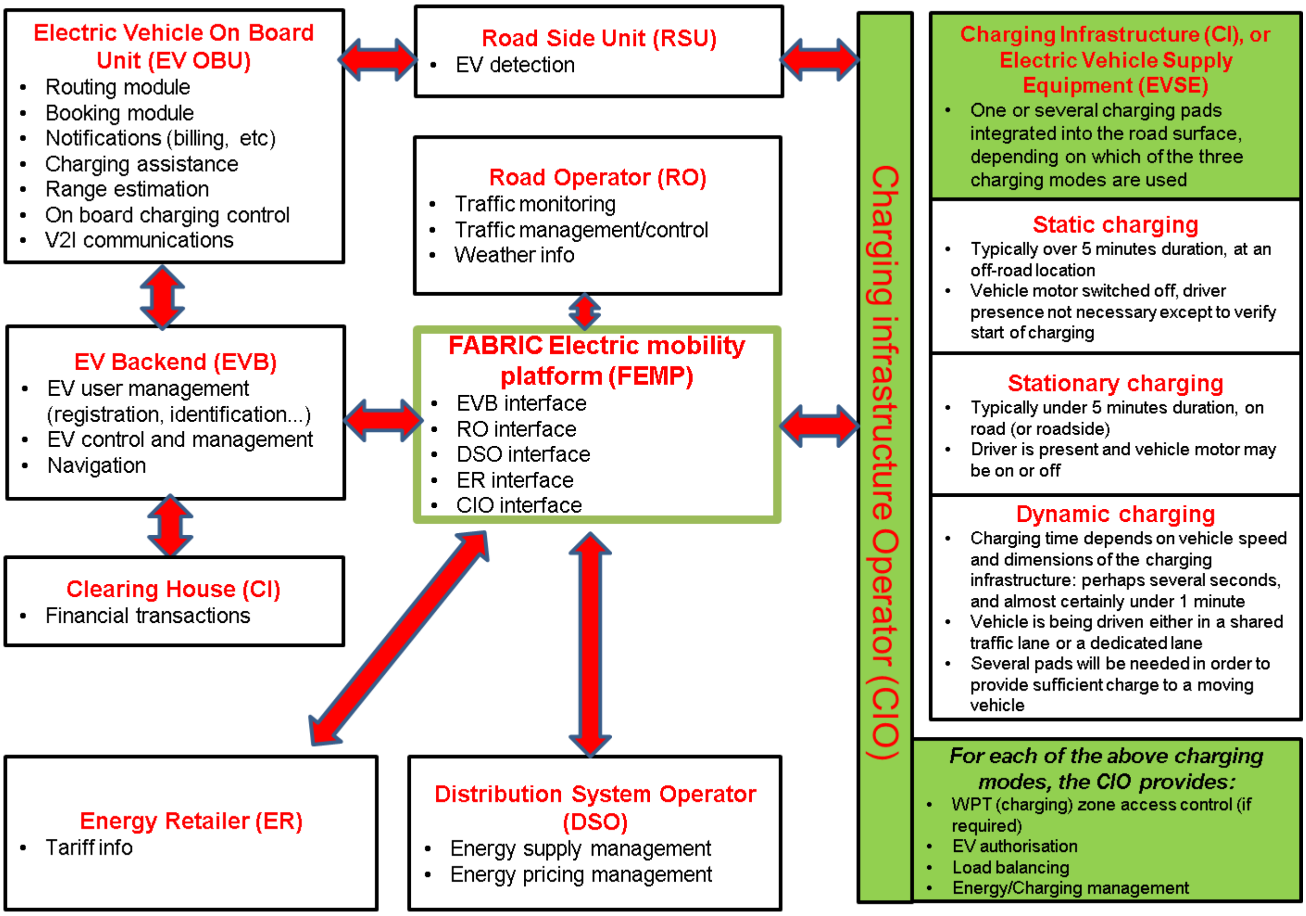

Figure 19: FABRIC high level sub-systems

3.3 Identification of main FABRIC sub-systems

Considering only the high level architectural design, the main FABRIC sub-systems are:

- **On Board Unit (OBU)**: OBU is integrated into the EV. It includes communication hardware (e.g. Wi-Fi, UMTS, G5…), application unit hardware, vehicle gateway to interface with EV electronic system, at least one HMI device and the in vehicle charging system.
- **EV Backend (EVB)**: Electric vehicles from different vehicle manufacturers have their own protocol, communication technology and services; in the FABRIC scenario different OEMs are foreseen therefore the EV OEM backend is the interface with the FABRIC platform.
- **FABRIC Electric-Mobility Platform (FEMP)**: This represents the FABRIC backend system; it includes at least a middleware platform for infrastructure data collection and potentially data aggregation functionalities, and one service provider platform that provides EV services to customers. Additionally and according to the business strategy, other backend systems may be included such as an ID provider that manages the ID and contract information of customers.

- **Charging infrastructure (CI)**: This includes EV supply equipment at road side for Wireless Power Transfer (WPT) to EVs.
- **Charging Infrastructure Operator (CIO)**: This is CI backend comprising the infrastructure management and operator interface. Therefore it includes communication hardware (e.g. Wi-Fi, UMTS, etc.), application tool, energy provision equipment for power transfer. The backend operator is in charge of managing, operating and monitoring all functionalities. It also provides services to assist the EV charging process such as authentication, authorisation, accounting, monitoring of power transfer, etc.
- **Road Side Unit (RSU)**: An RSU includes communication hardware (e.g. Wi-Fi, UMTS, etc.), and potentially gateways to interface with road side infrastructure or with WPT infrastructure. It main purpose is to enable communication between EV and charging control infrastructure.
- **Distribution System Operator (DSO)**: This concerns the provision of energy and its pricing, managed by the DSO, which interfaces with the FEMP and the CIO.
- **Energy Retailer (ER)**: Supplies the power via the DSO, using the CI. Also interfaces with the FEMP regarding energy pricing/payment.
- **Road Operator (RO)**: Its role is to provide traffic and weather information to the FEMP. In a scenario where the RO also operates the CI, this would be merged with the CIO and would also perform access control and enforcement functions (if needed, i.e. in a closed access system).

Each identified sub system will have communication capabilities based upon different technologies according to requirements, to enable the functionalities of the FABRIC ICT modules.

3.4 Identification of Modules for the main ICT functions

The first module to be considered is the registration and subscription management tool to the FABRIC platform that allows drivers and EVs to access FABRIC modules:

- Registration and subscription

Among the modules within the FABRIC platform, a very important one will be the trip planning and dynamic routing during the trip. The objective is to help the traveller to plan a trip, to respect the planned itinerary, and to adapt it in case of needs during the trip. According to this consideration, the following modules will be developed:

- Trip planning and assistance
- Charging facilities booking
- Dynamic routing
- Re-routing in case of unexpected charging needs.

Within the FABRIC EVB sub-system, the following modules will be developed:

- EV usage monitoring (registration, etc)
- EV control and management.

Another important aspect is related to global energy management for the electric grid, the energy provisioning and management at the charging infrastructure. The energy provider provides energy to charging facilities and interacts with the charging facility to operate the energy provision as required by the EV. The amount of energy provided to the EV shall be calculated and costed (pricing from the ER and DSO), with billing information received by the Clearing House (CH). Banking and payment facilities are not considered in the scope of FABRIC demonstrator.

According to this consideration, the following high level functionality groups will be developed:

- Access to charging facilities
- Charging monitoring and control
- Charging assistance to driver
- Billing and payment tools.

4. FUNCTIONAL REQUIREMENTS OF FABRIC

4.1 Introduction and approach

The FABRIC platform will manage relevant information from EVs, from charging infrastructure systems and the energy provider(s); it will perform data aggregation functionalities on collected data. Furthermore it will manage the tool to identity and manage access rights for EV users.

The EV On-Board Unit (OBU) will receive information from the platform to realise navigation applications. The Roadside Unit (RSU) located near the charging infrastructure will allow the provision of local information to EV users and the communication between the charging equipment and the EV.

In this chapter, the FABRIC functional structure and the key functional requirements is described. All modules and functions will provide services by connecting the FABRIC platform (FEMP) system to other back-ends, such as the Charging Infrastructure Operator (CIO) backend, EV backend, and DSO, allowing gathering and processing of large amount of data from multiple infrastructure systems and from EVs. Based on this, high level requirements are defined for each functionality, and linked to the relevant sub-system(s).

The approach to this task has been to produce a list of functionalities grouped into coherent categories, for example user accounts, dynamic routing, the charging process, etc.

This has been done for a projected future system concept in the year 2030 or beyond, so does not define which functions will be met during the FABRIC project lifetime. However it provides a basis upon which to make those decisions, with each function being defined either as:

- High (= always essential),

- Medium (= important or normally essential, unless its omission can be justified), and
- Low (= not essential but could improve the performance or user experience; an aspect which is "nice to have").

Whether a functionality is required, recommended or optional might depend on the circumstance, e.g. if the charging facility is in an urban or interurban situation, whether it is open for all traffic or has restricted access, etc. The level of requirement is considered in terms of a long-term future scenario (year 2030+) and then again in terms of what is possible or reasonable within the timescale of FABRIC to develop and demonstrate a working system.

The requirements may be different according to the charging mode (static, stationary or dynamic, as described in Chapter 3.1) or the geography/ configuration of the charging infrastructure (urban streets, interurban roads, motorways, limited or open access, etc).

The level of physical separation of the infrastructure from the rest of the road (including access by non-users, including pedestrians and other non-vehicular traffic) depends on the circumstances and type of infrastructure installed, and in particular safety considerations.

The levels of requirement (whether required, optional, etc) will be validated in the next stage with key stakeholders and revised where necessary.

As preliminary high level architecture, the overall FABRIC system shall consider if modules and functions will be operating within the vehicle or at backend or infrastructure level: on board or off board. In the following figure a simplified concept of the system is presented:

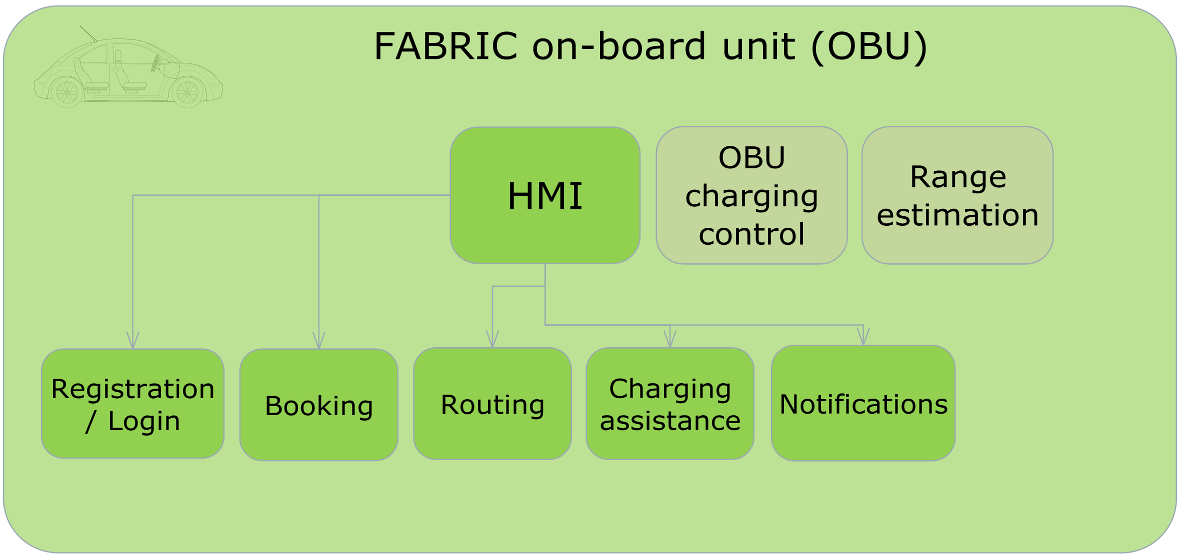

Figure 20: FABRIC OBU preliminary functional architecture

The FABRIC EV OBU comprises:

- The charging hardware which includes the secondary coils needed for inductive charging and the charging control electronics.
- An application device for tools like range estimation, booking, routing

- HMI device/tool for driver interaction and messages notification

The off-board FABRIC Electric Mobility Platform (FEMP) comprises several interfaces to different backend of external actors:

- The DSO interface.
- The energy retailer interface
- The road operator interface
- The charging infrastructure interface
- The clearing house interface.

The FEMP is therefore a core module that will function as the central management system and it will coordinate the actions of all peripheral modules.

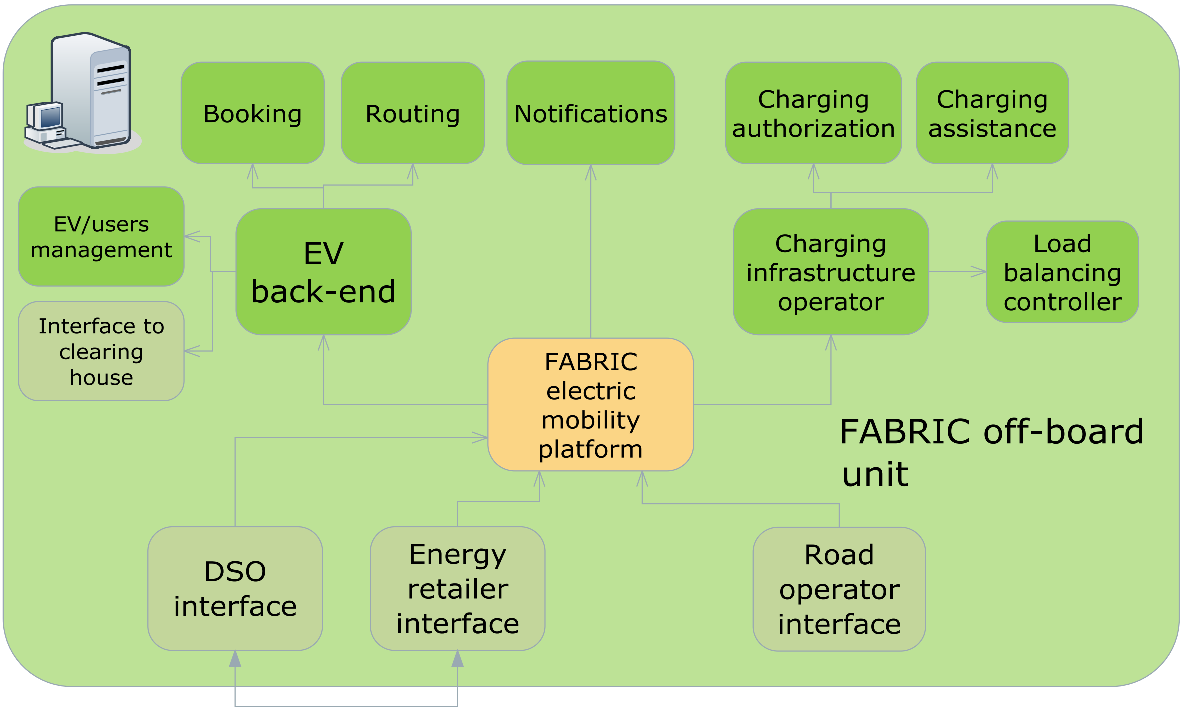

Figure 21: FABRIC off-board unit preliminary functional architecture

All identified functions may be therefore developed on different sub systems to perform the service. Therefore in the following paragraphs it will be reported where the requirement is intended to be developed.

4.2 Function Class A: User accounts, booking and billing

This group of functions lies in the FABRIC Electric-mobility platform (FEMP), the OBU and OEM Backend sub-systems. The individual functions are listed in the following tables.

Table 1: Functional requirement A1: User Account Creation and Maintenance

Requirement ID:	A1 - ACCOUNT
Name of requirement:	User Account creation and maintenance
Goal	An interoperable account should be available to users to facilitate post-trip billing for electricity from different service providers
Description	A service provider (FABRIC operator, financial organisation, existing toll service provider, electricity company, etc) provides a simple registration process linked to a vehicle and to credit or debit card. Corporate accounts should also be available. Statements (weekly, monthly, etc) and different payment options should be offered. A helpdesk should also be offered, both online and by telephone. Users should have the possibility to change the vehicle or credit card on their account.
Created by	ERTICO
Priority	High
Related use cases (if any) from FABRIC D43.1	#1.1: Driver-owner registration; #1.3: User account management.
Validation criteria (tests, indicators, performance bounds)	Different account providers available, with interoperable services (similar to some toll tag providers now).
Acceptance criteria	Client satisfaction.
Relationship with other requirements	Needed for A2 – lane booking, A4 – billing. Related also to A5 – Clearing house
Risk analysis	Possible reluctance of some market operators to provide a service interoperable with different charging points (e.g. in several countries). Local operators may provide accounts for their own services only.
Related FABRIC sub-systems	Handled by the FABRIC Electric-Mobility Platform (FEMP).

Table 2: Functional requirement A2: FABRIC Lane Booking

Requirement ID:	A2 – BOOKING
Name of requirement:	FABRIC Charging Infrastructure Booking
Goal	Users should be able to book a lane (or stationary charging spot), including up to immediately before use.
Description	Booking is required to allow the WPT system to recognise booked vehicles with valid accounts and thereby provide the power transfer. Without booking, the grid could become overloaded with multiple users. However a "last minute" booking could be available where the driver makes a charging request via the OBU immediately before charging; the provider can therefore accept or refuse such as request depending on load on the grid and other bookings already made. Bookings may be made at home (e.g. via Internet) or, perhaps more usually, on trip, as the user may not be able to plan in advance his charging needs and may require emergency charging. The system shall provide information for booking to the FABRIC booking module once a route is selected by the

	user.
Created by	UniGe, ERTICO
Priority	High
Related use cases (if any) from FABRIC D43.1	#1.2: Logging in to FABRIC interface (end users); #1.6 : Emergency charging; #6.1: Dynamic route and booking management
Validation criteria (tests, indicators, performance bounds)	Rapidity of handling bookings, especially those a minute or less before actual use. Reliability of handling booking from OBUs in other areas or countries (interoperability).
Acceptance criteria	Client satisfaction.
Relationship with other requirements	A1, A3 and A4.
Risk analysis	Risk of rapidity of booking and linking booking to EV identification. Risk of complicated procedure for drivers with a registration for another service provider (e.g. abroad), when they should be able to make the booking using one or two touches to an OBU (while driving).
Related FABRIC sub-systems	Handled by the EV OBU, and transmitted via the EVB to the FEMP

Table 3: Functional requirement A3: Changes to Booking

Requirement ID:	A3 – BOOKINGCHANGE
Name of requirement:	Changes to FABRIC Charging Infrastructure Booking
Goal	Users should be able to unbook a lane or re-specify their time of arrival at the lane. Flexibility for the user and to optimise infrastructure use
Description	Many users, particularly those who have booked some time in advance (e.g. more than an hour or two ahead) will not be able to accurately predict the time they will arrive at the charging lane, and some may change their itinerary or decide that they have sufficient charge already for their trip and therefore do not require charging. Hence there should be the option to change or cancel a booking, preferably with no penalty.
Created by	ERTICO and UniGe
Priority	High
Related use cases (if any) from FABRIC D43.1	#1.2: Logging in to FABRIC interface (end users); #1.6 : Emergency charging; #6.1: Dynamic route and booking management
Validation criteria (tests, indicators, performance bounds)	Rapidity of handling changes to bookings, especially those a minute or less before actual use. Reliability of handling booking from OBUs in other areas or countries (interoperability).
Acceptance criteria	Update the booking server information. Client satisfaction.
Relationship with other requirements	A1, A2 and A4.
Risk analysis	Risk of rapidity of changes to booking and linking booking to EV identification. Risk that if penalties are imposed on changing bookings, people will be dissuaded from using the system altogether.
Related FABRIC sub-systems	Handled by the EV OBU, and transmitted via the EV Backend (EVB) to the FABRIC Electric-Mobility Platform (FEMP).

Table 4: Functional requirement A4: Billing

Requirement ID:	A4 – BILL
Name of requirement:	Billing
Goal	Users should receive regular itemised bills detailing the charging infrastructure used and the amount of power received. In case of on-board metering (see Chapter 4, Function D: WPT), billing may need to include a factor to take into account power supplied by the road but lost due to inefficiencies. These might be different according to each vehicle type, if average efficiency of each can be determined.
Description	The aim should be that users receive a single bill for all the EV charging they have used, regardless of the operator. They therefore have a relationship with only one service provider, who acts as an intermediary to the different charging providers.
Created by	ERTICO
Priority	High
Related use cases (if any) from FABRIC D43.1	#1.3: User account management
Validation criteria (tests, indicators, performance bounds)	Accuracy of billing (depending on accuracy of metering and EV detection).
Acceptance criteria	Client satisfaction.
Relationship with other requirements	A1, A2, A3 and A5.
Risk analysis	Risk of non-interoperable billing. As a fall-back (less desirable but still workable solution), drivers may be billed separately for the use of charging infrastructure under different operators.
Related FABRIC sub-systems	Handled by the FEMP, also involving the EV OBU, EVB and a clearing house.

Table 5: Functional requirement A5: Clearing House

Requirement ID:	A5 – CLEAR
Name of requirement:	Clearing House
Goal	A clearing house operation is needed between FABRIC operators and account operators
Description	The clearing house should ideally be on a European scale, or at least a network of national ones.
Created by	ERTICO
Priority	Medium
Related use cases (if any) from FABRIC D43.1	#1.1: Driver-owner registration; #1.3: User account management
Validation criteria (tests, indicators, performance bounds)	"Out of area" (interoperable) billing possible, including internationally, similar to credit card use or mobile phone roaming
Acceptance criteria	Client satisfaction.
Relationship with other requirements	A1, A2, A3 and A4.
Risk analysis	Risk of no clearing house being set up if there are not enough different operators to warrant one (otherwise bilateral agreements might be preferred).
Related FABRIC sub-systems	Handled by the EVB

4.3 Function Class B: Dynamic routing for EVs

This group of functions considers guidance of drivers towards the nearest appropriate charging areas, as well as more general route planning.

Table 6: Functional requirement B1: Itinerary Choice

Requirement ID:	B1 - ITIN
Name of requirement:	Itinerary choosing
Goal	To let the user choose an itinerary
Description	The user should be able to choose an itinerary to destination: the user may ask to have a free itinerary or he may specify himself a certain number of infrastructures he wants to use
Created by	UniGe
Priority	Medium
Related use cases (if any) from FABRIC D43.1	#1.4: Planning of a trip; #1.5 Guidance to a charging facility; #4.1: Integration of FABRIC with UTMC
Validation criteria (tests, indicators, performance bounds)	Function availability
Acceptance criteria	Provide the itinerary to the user
Relationship with other requirements	A2, A3, B2, B4
Risk analysis	The user may be unable to reach his destination without real-time guidance including charging facilities. However it is classed as medium as FABRIC can operate without it; however at less convenience to the end user.
Related FABRIC sub-systems	Handled by the EV OBU and EVB

Table 7: Functional requirement B2: Locating Infrastructure

Requirement ID:	B2 - LOCATE
Name of requirement:	Locating infrastructure
Goal	To let the user charge his car while driving
Description	The system shall be able to locate charging infrastructures along the route and inform the driver while he is driving (via an appropriate HMI)
Created by	UniGe
Priority	High
Related use cases (if any) from FABRIC D43.1	#1.5: Guidance to a charging facility; #6.1: Dynamic route and booking management
Validation criteria (tests, indicators, performance bounds)	function availability
Acceptance criteria	Display charging locations to the user
Relationship with other requirements	B1
Risk analysis	The battery charge may become too low to let the user drive to a specific place
Related FABRIC sub-systems	Handled by the EV OBU and EVB

Table 8: Functional requirement B3: Availability of Charging Infrastructure

Requirement ID:	B3 - AVAIL
Name of requirement:	Availability of charging infrastructure
Goal	To let the user be confident that he can charge his vehicle
Description	The system shall pre-check the availability of charging infrastructure prior to providing the driver with a route
Created by	UniGe
Priority	Low
Related use cases (if any) from FABRIC D43.1	#1.5: Guidance to a charging facility; #6.1: Dynamic route and booking management
Validation criteria (tests, indicators, performance bounds)	function availability
Acceptance criteria	Provide the driver with the availability of the charging infrastructure
Relationship with other requirements	A2, A3, B1
Risk analysis	The user can not charge his battery at the charging infrastructure
Related FABRIC sub-systems	Handled by the FEMP

Table 9: Functional requirement B4: Route Calculation

Requirement ID:	B4 - CALC
Name of requirement:	Route calculation
Goal	To assist the driver in reaching his destination efficiently and to help avoid running out of charge
Description	The system shall always compute routes that allow the vehicle to arrive at destination with at least 15% of remaining charge
Created by	UniGe
Priority	Medium
Related use cases (if any) from FABRIC D43.1	#1.7: Guidance to destination
Validation criteria (tests, indicators, performance bounds)	Function availability
Acceptance criteria	Provide the desired route if possible or alert the user if he cannot reach the destination with the remaining charge
Relationship with other requirements	B1
Risk analysis	The user may not reach its destination. Classed as medium as FABRIC can operate without it, but with less user-friendliness towards drivers.
Related FABRIC sub-systems	Handled by the EV OBU and EVB

Table 10: Functional requirement B5: Targeting Charging Level

Requirement ID:	B5 - TARGET
Name of requirement:	Targeting charge level
Goal	Allow the user to visit more than one destination
Description	The user should be able to set a target charge level range to be achieved by the arrival at destination (e.g. 20-30%)
Created by	UniGe
Priority	Medium
Related use cases (if any) from	#1.4: Planning of a trip; #1.5: Guidance to a charging facility;

FABRIC D43.1	#1.6: Emergency charging; #4.3/4.4: Charging or road infrastructure availability status updating
Validation criteria (tests, indicators, performance bounds)	Function availability
Acceptance criteria	For a defined destination, inform the user if the target charge level can be respected or not.
Relationship with other requirements	A2, A3, B1
Risk analysis	The driver may have to charge his vehicle on road
Related FABRIC sub-systems	Handled by the EV OBU and FEMP

Table 11: Functional requirement B6: Choice of Charging Location

Requirement ID:	B6 - LOCATIONCHOICE
Name of requirement:	Charging location choice
Goal	Let the user charge his vehicle according to its technical specifications and his budget
Description	The user shall be able to choose what charging place he prefers to use.
Created by	UniGe
Priority	High
Related use cases (if any) from FABRIC D43.1	#1.4 Planning of a trip; #1.5 Guidance to a charging facility
Validation criteria (tests, indicators, performance bounds)	Function availability
Acceptance criteria	Provide the charging stations with relevant details
Relationship with other requirements	B1, B3, B4
Risk analysis	The user may be unable to charge his car.
Related FABRIC sub-systems	Handled by the FEMP

Table 12: Functional requirement B7: Saving Preferences

Requirement ID:	B7 - SAVEPREF
Name of requirement:	Saving preferences
Goal	Reduce the user interaction with the system
Description	The system shall be able to save the preferences of the user (if the user wants to), in terms of preferred charging infrastructure and types. This is potentially valuable for those who regularly use the same charging location for similar amounts of charge.
Created by	UniGe
Priority	Low
Related use cases (if any) from FABRIC D43.1	#1.3: User account management; #1.4: Planning of a trip
Validation criteria (tests, indicators, performance bounds)	Function availability
Acceptance criteria	Provide the user with the saved preferences
Relationship with other requirements	A2, B6
Risk analysis	The user will spend much time to choose charging locations
Related FABRIC sub-systems	Handled by the FEMP

Table 13: Functional requirement B8: Trip Timing

Requirement ID:	B8 - TIMING
Name of requirement:	Trip Timing
Goal	To let the user use the lane when he reaches it
Description	The system (onboard) shall check if vehicle is on time according to the existing route: The onboard system/driver shall be alerted in case unexpected high traffic situation can cause delay The onboard system/driver shall be alerted by Fabric if a pre booked infrastructure is not available The system shall update the booking module on-route in case of delays and alerts driver The system shall provide alternative routing if the pre-booked infrastructure is not available (maybe because of delays and/or over-request)
Created by	UniGe
Priority	Medium
Related use cases (if any) from FABRIC D43.1	#1.4: Planning of a trip; #6.1: Dynamic route and booking management
Validation criteria (tests, indicators, performance bounds)	Function availability, user acceptance
Acceptance criteria	Provide all needed info to the driver
Relationship with other requirements	A2, A3
Risk analysis	The vehicle may run out of charge
Related FABRIC sub-systems	Handled by the FEMP

Table 14: Functional requirement B9: Low Charge Warning

Requirement ID:	B9 - LCW
Name of requirement:	Low Charge warning
Goal	Let the user reach his destinations and increase battery life time
Description	The system shall warn the user if the vehicle's autonomy is too low and provide directions to one or more closest charging infrastructure
Created by	UniGe
Priority	High
Related use cases (if any) from FABRIC D43.1	#1.6: Emergency charging; #1.7: Guidance to destination
Validation criteria (tests, indicators, performance bounds)	Function availability
Acceptance criteria	Warn the user immediately if the charge is low
Relationship with other requirements	A2, A3, B2, B4, B10
Risk analysis	The vehicle is out of service.
Related FABRIC sub-systems	Handled by the EV OBU

Table 15: Functional requirement B10: Closest Infrastructure Routing

Requirement ID:	B10: CLOSINF
Name of requirement:	Closest Infrastructure Routing
Goal	Give the user options to charge his car
Description	The system shall always provide an option to tell the route to the 3 closest charging infrastructures
Created by	UniGe
Priority	High
Related use cases (if any) from FABRIC D43.1	#1.6: Emergency charging; #1.7: Guidance to destination
Validation criteria (tests, indicators, performance bounds)	Function availability
Acceptance criteria	Provide the option to the user
Relationship with other requirements	A2, A3, B2, B4, B9
Risk analysis	Decrease user satisfaction
Related FABRIC sub-systems	Handled by the EVB

4.4 Function Class C: Vehicle identification, charging lane access control and management/enforcement

This group of functions considers the access of the vehicle to the charging infrastructure (whether it is physically segregated or not), including the identification of vehicles (whether pre-booked or not), management of booking/access (according to available charging capacity and road conditions) and, where appropriate, enforcement to prevent unauthorised access or use. The following tables describe the requirements of the functions.

Table 16: Functional requirement C1: EV Identification

Requirement ID:	C1: EVID
Name of requirement:	Identification of EVs
Goal	The charging infrastructure needs to recognise pre-booked or other authorised vehicles in order to activate the charging process.
Description	Identification of pre-booked EVs, using either Direct Short-Range Communication (DSRC) or Automatic Number Plate Recognition (ANPR) .
Created by	ERTICO
Priority	High
Related use cases (if any) from FABRIC D43.1	#4.2: EV identification
Validation criteria (tests, indicators, performance bounds)	100% availability (unless charge lane is out of service). The EV should be able to transmit a signal to broadcast that it is in stationary (or opportunistic) charging mode so that charging is initiated automatically when the EV is above a charging pad.
Acceptance criteria	Able to recognise pre-reserved vehicles (essential). Able to recognise and accept non-reserved vehicles that are equipped for dynamic charging (optional, depending on whether reserving is essential or not).
Relationship with other requirements	B2, B3, C2

Risk analysis	Risks of late booking not being processed in time. Risk if vehicle arrives earlier or later than booked time: margin of acceptance to be defined.
Related FABRIC sub-systems	Handled by the RSU and the EV OBU.

Table 17: Functional requirement C2: Charing Lane Access Control

Requirement ID:	C2: CLAC
Name of requirement:	Charging infrastructure access control
Goal	Either access to the lane needs to be controlled/restricted, or else users should receive warning/advice of the presence of charging infrastructure
Description	Controlled infrastructure may need to have access regulated by barriers or lights. Open infrastructure is not affected by this requirement.
Created by	ERTICO
Priority	Low (only relevant in cases where non-charging vehicles are banned from the charging lane).
Related use cases (if any) from FABRIC D43.1	#4.2: EV identification
Validation criteria (tests, indicators, performance bounds)	All authorised and pre-booked vehicles are able to charge. Others are not.
Acceptance criteria	100% accuracy
Relationship with other requirements	B2, B3, C1
Risk analysis	Unauthorised use of lane by other vehicles, congestion meaning that booked EVs cannot access it.
Related FABRIC sub-systems	Handled by the RSU

Table 18: Functional requirement C3: Emergency Control of Charging Lane

Requirement ID:	C3: EMERCTRL
Name of requirement:	Emergency Control of Charging Lane
Goal	Road operator or police need to be able to take control of the charging lane (restrict or ban access) in cases of emergency
Description	The lane should be able to be closed at very short notice. Conversely, it could be opened to all traffic at short notice to relieve another lane or road, but have the charging system de-activated.
Created by	ERTICO
Priority	High
Related use cases (if any) from FABRIC D43.1	#4.1: Integration of FABRIC with UTMC
Validation criteria (tests, indicators, performance bounds)	Function availability
Acceptance criteria	Acceptance by police or road operator.
Relationship with other requirements	C2
Risk analysis	Safety or congestion risks if not met.
Related FABRIC sub-systems	Handled by the FEMP

4.5 Function Class D: Wireless Power Transfer

This covers the billing of the vehicle owner or account holder (which may be an individual or a company) for the electricity used, payment methods, interoperability considerations between different sites, etc.

The metering of the WPT could be either in-vehicle or off-vehicle. In-vehicle would sound more logical at first sight, given that household electricity is monitored by meters placed in the house. It also allows the user to see and monitor his consumption and would be simpler both technically and organisationally.

However there is significant power loss between the road and the vehicle, which can vary considerably according to driving style (speed, trajectory) and vehicle type. This variation is therefore far greater than for household electricity or for plug-in vehicles, hence using a standard percentage mark-up on the price charged to the user to cover this loss would result in unfair treatment of the more efficient drivers. This would imply that to achieve fair pricing and to encourage users to drive according to recommendations to maximise the efficiency of power transfer, the metering should be measured from the infrastructure side. This presents the challenge of ensuring that power provided is billed to the correct vehicle (especially in cases where multiple vehicles are able to use the charging infrastructure at the same time); or alternatively limiting the system to one that can only admit a vehicle for charging after the preceding vehicle has left the system. There would also be a need to inform the driver about the level of charging efficiency and costs of charging, perhaps with advice to change behaviour (e.g. to slow down) in cases where efficiency is poor. This could either be during the charging phase (requiring a specific HMI and risking driver distraction) or by providing post-trip advice (when it would be too late for the driver to modify his driving and may cause user dissatisfaction when receiving an unexpectedly high bill for a low amount of energy transfer after the charging has taken place).

The following tables describe the requirements.

Table 19: Functional requirement D1: Smart Metering of Energy Transfer

Requirement ID:	D1: SMARTMETER
Name of requirement:	Metering of Energy Transfer
Goal	Accurate metering of energy used. Smart meters must be installed in the charging infrastructure in order to enable the collection of demand data by the DSO and ER.
Description	May be energy transferred from the road (in which case off-vehicle metering would be required), or energy received by the vehicle (on-board metering). In the latter case, account needs to be taken in the billing of energy loss. The DSO management system should be able to access metering data either through a direct connection to FABRIC's smart meters or through a gateway such as FABRIC's DSO interface that connects to the charging operator who aggregates the smart meters' data.
Created by	ICCS/ERTICO
Priority	High
Related use cases (if any) from	#1.8/1.9/1.10: Assisted Charging

FABRIC D43.1	
Validation criteria (tests, indicators, performance bounds)	Efficiency and accuracy, Information exchange tests
Acceptance criteria	Accuracy level to be set according to the level of confidence of the metering and charging mode used. The DSO can receive the metering information.
Relationship with other requirements	B4, D2, F2
Risk analysis	The higher the speeds and traffic densities, the more difficult it is to meter energy use accurately.
Related FABRIC sub-systems	Handled by the EV OBU or EVB, together with the DSO.

Table 20: Functional requirement D2: Energy Cut-Off

Requirement ID:	D2: CUTOFF
Name of requirement:	Energy Cut-Off function
Goal	When energy transfer drops below a certain level of efficiency (due to driving behaviour or technical factors), the charging supply is interrupted and the driver informed of this.
Description	Controlled infrastructure may need to have access regulated by barriers or lights. Open infrastructure is not affected by this requirement.
Created by	ERTICO
Priority	High
Related use cases (if any) from FABRIC D43.1	#1.8/1.9/1.10: Assisted Charging
Validation criteria (tests, indicators, performance bounds)	Threshold to be defined.
Acceptance criteria	Threshold to be defined.
Relationship with other requirements	B2, B3, C1
Risk analysis	Failure to cut off will incur significant energy wastage (e.g. if WPT efficiency is lower than 50%).
Related FABRIC sub-systems	Handled by the EV OBU or EVB

4.6 Function Class E: Driving assistance while charging

The following table describes the requirements for driver assistance.

Table 21: Functional requirement E1: Driver Assistance while Charging

Requirement ID:	E1 - ASSIST
Name of requirement:	Driver assistance while charging
Goal	During charge while driving, information on lane approaching and charging process shall be provided to driver
Description	Along the all charge while driving procedure in a lane, the driver shall monitor all the charging phases and shall be able to immediately stop the procedure. The driver shall be aware of the charge level and pricing. Requires an on board HMI connected to the FABRIC OBU; real-time notification capability is required.
Created by	CRF

Priority	High
Related use cases (if any) from FABRIC D43.1	#1.8 Assisted charging - static #1.9 Assisted charging - stationary #1.10 Assisted charging - dynamic
Validation criteria (tests, indicators, performance bounds)	Function availability, user friendliness
Acceptance criteria	The acceptance criteria is to provide all needed info to driver without causing driver distraction
Relationship with other requirements	B1, B2, B3, B4
Risk analysis	If this requirement is not met, the driver may not accept the dynamic charging technology
Related FABRIC sub-systems	Handled by EV OBU

4.7 Function Class F: Energy supply and grid management

This group of functions relates to the functions of the Distribution System Operator (DSO).

Table 22: Functional requirement F1: FABRIC smart grid communications

Requirement ID:	F1 – SMARTGRID
Name of requirement:	FABRIC smart grid communications
Goal	Exchange of information between the DSO/energy retailer and the FABRIC Electric Mobility Platform (FEMP) enhances reliable operation of the grid.
Description	The FEMP must embed an interface for communications in order to exchange data with the DSO/energy retailer
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	#2.1 EV charging supply management – high level #3.1 Energy supply tariff modulation
Validation criteria (tests, indicators, performance bounds)	Information exchange tests of the FABRIC system with simulated or existent grid DSO systems
Acceptance criteria	The system can exchange information such as supply limits, nominal power line ratings etc with existing or simulated grid DSO systems
Relationship with other requirements	
Risk analysis	Gateway interfaces between major actors of future smart grid reference architectures have been identified as essential elements that ensure system interoperability. If this requirement is not met, then the FEMP may not be compatible with future DSO/energy retailer grid management systems. Additionally, lack of communication with other smart grid actors results in disabling among others, the following smart grid operations; 1) grid stability,2) high level charging infrastructure supply management and 3) demand side management.
Related FABRIC sub-systems	Handled by the DSO

Table 23: Functional requirement F2: Energy tariff information

Requirement ID:	F2 – TARIFF
Name of requirement:	Energy tariff information
Goal	To receive energy pricing information from the energy retailer (or the DSO) for billing purposes. A secondary goal for the future is the indirect demand side management which enables grid load balancing and cost efficiency by dynamically manipulating the EV charging price.
Description	Energy tariff information will be provided to the system by the appropriate external actor (energy retailer or DSO) via the corresponding FABRIC interface.
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	#3.1: Energy supply tariff modulation
Validation criteria (tests, indicators, performance bounds)	Energy tariff dissemination tests
Acceptance criteria	Energy tariff is displayed on the EV OBU
Relationship with other requirements	
Risk analysis	If this requirement is not met then the FEMP may not be compatible with future energy retailer management systems that may require the support of dynamic tariffs in order to deploy DSM and thus enable the efficient management of energy supply.
Related FABRIC sub-systems	Handled by the DSO

Table 24: Functional requirement F3: FABRIC to DSO low latency communications

Requirement ID:	F3 – LOLATENT
Name of requirement:	Low latency communications between the FEMP and the DSO system
Goal	Low latency communications between the DSO and the FEMP are essential in order to enable the reliable operation of the dynamic wireless charging system
Description	Low latency protocols and mechanisms must be employed in the communication channel between the DSO and the FEMP in order to enhance the reliability of the system
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	#2.1: EV Charging supply management – high level
Validation criteria (tests, indicators, performance bounds)	Communications latency tests
Acceptance criteria	The overall latency in communications is below a predefined latency indicator. This indicator is defined according to reliability and safety criteria.
Relationship with other requirements	F2
Risk analysis	If this requirement is not met, the system will not comply to constraints that must be satisfied, especially during grid-related emergencies that require low latency switching operations. (fault detection, isolation, and restoration)
Related FABRIC sub-systems	Handled by the DSO

Table 25: Functional requirement F4: Standardised object data model

Requirement ID:	F4 – OBJDATA
Name of requirement:	Standardised object data model
Goal	The use of a standardized object data model will enable the integration of the FEMP with standard based DSO and energy retailer systems
Description	A standardised object data model must be used in order to exchange grid information.
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	#2.1 EV charging supply management – high level #3.1 Energy supply tariff modulation
Validation criteria (tests, indicators, performance bounds)	Standard conformance tests
Acceptance criteria	The system satisfies a suite of conformance tests that certify compliance to standards
Relationship with other requirements	F2
Risk analysis	If this requirement is not met then the FEMP may not be interoperable with standardized DSO and energy retailer management systems as defined in the smart gird reference architecture: http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/xpert_group1_reference_architecture.pdf
Related FABRIC sub-systems	Handled by the DSO

Table 26: Functional requirement F5: FABRIC to DSO/energy retailer secure

Requirement ID:	F5 – DSOCONNECT
Name of requirement:	Secure connection between the DSO/energy retailer and the FEMP
Goal	A secure connection must be made between the DSO/energy retailer and the FEMP in order to enable grid reliability and security
Description	The information exchange between the DSO and FEMP must ensure: reliability, confidentiality, integrity, authenticity, availability, non-repudiation
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	#2.1 EV charging supply management – high level #3.1 Energy supply tariff modulation
Validation criteria (tests, indicators, performance bounds)	Robustness to security attacks
Acceptance criteria	The system demonstrates reliability, confidentiality, integrity, authenticity, availability, non-repudiation under security attacks
Relationship with other requirements	F2
Risk analysis	Risk of vulnerability to cyber attacks that could be deployed in multiple forms such as, malicious software and firmware installation or hardware compromise. Such attacks could lead to grid service disruption, denial of service, customer privacy violation.
Related FABRIC sub-systems	Handled by the DSO

Table 27: Functional requirement F6: FABRIC demand information availability

Requirement ID:	F6: DEMAND
Name of requirement:	FABRIC demand information availability
Goal	The FEMP must be able to provide information regarding the overall demand due to charging, in order to enable demand monitoring by the DSO
Description	The FEMP must collect information regarding demand in order to provide aggregated demand information to the DSO management system on request.
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	
Validation criteria (tests, indicators, performance bounds)	Information exchange tests
Acceptance criteria	Successful reception of demand information by the DSO management system.
Relationship with other requirements	F2
Risk analysis	The overall load profile due EV charging can reveal essential information regarding the typical day, month and year cycles of demand. If this requirement is not met, information that could be useful in forecasting future demand patterns will not be available for the DSO.
Related FABRIC sub-systems	Handled by the DSO

Table 28: Functional requirement F7: Local Grid Power Capacity Interface

Requirement ID:	F7 – LGPC
Name of requirement:	Local Grid Power Capacity Interface
Goal	FABRIC to DSO communications must accommodate an interface that enables the exchange of information regarding the local grid's forecasted power capacity. This information can be used by FABRIC in order to generate charging profiles that make the best use of available power supply capacity
Description	FABRIC's DSO interface must support the exchange of information related to the local grid's forecasted power capacity. Such information will enable the generation of charging profiles that make the best use of power supply. This interface should be based on standardized communication technologies and information models in order to ensure interoperability with existing and future DSO systems.
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	#2.1
Validation criteria (tests, indicators, performance bounds)	Information exchange tests
Acceptance criteria	The FABRIC system can correctly receive nominal the forecasted day ahead supply from a real or simulated DSO system.
Relationship with other requirements	F1, F2
Risk analysis	Risk of designing a system that cannot be integrated in an automated grid environment.
Related FABRIC sub-systems	Handled by the DSO

Table 29: Functional requirement F8: FABRIC to DSO/energy retailer interface maintenance

Requirement ID:	F8: RETAILERINT
Name of requirement:	FABRIC to DSO/energy retailer interface maintenance
Goal	The FEMP must operate even when ICT maintenance is ongoing.
Description	The FEMP must operate continuously, therefore backup reserves must be dispatched when ICT maintenance is performed
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	#2.1 EV charging supply management – high level #3.1 Energy supply tariff modulation
Validation criteria (tests, indicators, performance bounds)	FABRIC management system uptime
Acceptance criteria	The overall uptime is not affected by maintenance
Relationship with other requirements	F1, F2
Risk analysis	Many grid level services and applications (dynamic tariff rates, high level supply and demand management, distribution system operations such as fault Detection, isolation, and restoration) require real time exchange of information. If this requirement is not met due to service disruptions the overall grid reliability could be threatened.
Related FABRIC sub-systems	Handled by the DSO

Table 30: Functional requirement F9: Communications Logging

Requirement ID:	F9 – LOGGING
Name of requirement:	Communications logging
Goal	Communication between the DSO/energy retailer and the FEMP must be logged to ensure non-repudiation.
Description	The FABRIC management system must log communication events with DSO.
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	#2.1: EV charging supply management – high level
Validation criteria (tests, indicators, performance bounds)	Logging tests
Acceptance criteria	Log files reflect the communication events of the log file tests.
Relationship with other requirements	F1
Risk analysis	Risk of not tracking historical events that could serve as evidence or debugging data
Related FABRIC sub-systems	Handled by the DSO

Table 31: Functional requirement F10: Time synchronisation

Requirement ID:	F10: TIMESYNC
Name of requirement:	Time synchronization
Goal	Time in both the DSO and FEMP must be synchronised in order to ensure data consistency
Description	The FABRIC management system and the DSO must synchronise time on the basis of a network time protocol, or GPS or another common time reference
Created by	ICCS
Priority	High
Related use cases (if any) from FABRIC D43.1	#2.1: EV charging supply management – high level
Validation criteria (tests, indicators, performance bounds)	Timing offset
Acceptance criteria	The timing offset between the DSO and the FEMP is below a threshold that will be defined according to reliability criteria
Relationship with other requirements	F1
Risk analysis	Time synchronization is an essential aspect of data consistency among the DSO, energy supplier, the FEMP. If this requirement is not met, time shifts between grid operations such as actuation of switches or monitoring of data could occur, and thus lead to non-reliable operation of the grid system.
Related FABRIC sub-systems	Handled by the DSO

5. CONCLUSIONS

This deliverable brings together the output of WP22 of FABRIC "User needs and requirements", including some preliminary findings that were also reported in D43.1 "FABRIC Final Use Cases". The output is twofold: firstly the initial user consultation and user needs, and secondly a high level description of the FABRIC sub-systems/modules and the system's functional requirements. The functionalities do not have a one-to-one correspondence to the sub-systems, as many involve input from different systems.

This work will feed into next tasks in SP2, in particular WP23 on technical benchmarking and WP24 on system specifications. Elements may also be used in other SPs, notably key results from the survey contributing to SP3 on charging solutions and SP5 on assessment.

The questionnaire responses provided a wide array of free text comments, with all relevant or useful ones listed in this deliverable. Many of these expressed either supported the concept of on-road charging, or were sceptical about certain aspects (costs, business case, safety). Responses provided views on where electro-mobility could be most successful and types of deployment that might be less useful, as well as possible barriers and opportunities. These could help with building scenarios and hypotheses in SP5.

Next steps in SP2 will involve determining which functionalities listed here are to be addressed in the prototypes to be built and tested within the project.

6. REFERENCES

1. eCoFEV Deliverable 200.1 – Use cases and requirements for an efficient cooperative platform, eCoFEV FP7 project, 2014
2. eCoFEV Deliverable 200.2 – Overall architecture and functional design for e-mobility cooperative infrastructures, eCoFEV FP7 project, 2013
3. FABRIC Deliverable 42.1 – Assessment of the technical feasibility of ICT and charging solutions, FABRIC FP7 project, 2014
4. FABRIC Deliverable 43.1 – FABRIC final use cases, FABRIC FP7 project, 2014

ANNEX I QUESTIONNAIRE TEXT

The following is a text version of the questionnaire. The version sent to respondents was online in html format using the SurveyMonkey tool (www.surveymonkey.com).

Factual questions (respondent profile, knowledge, experience)

1. In what type of organisation do you work?
(one choice only)

- □ Public authority or agency, regional or local level (city, county, province, etc)
- □ Public authority or agency, national level (or autonomous region/devolved government)
- □ EU or international institution or agency
- □ Large company (50 employees or more)
- □ Small or medium enterprise (SME), or self-employed (fewer than 50 employees)
- □ Research or academic institution
- □ Association (for industry, users, trade union, campaign group, etc)
- □ Other (specify): ________________________

2. What is/are your main function(s)?

- □ Public policy/administration
- □ Funding/financing
- □ Road infrastructure management/operation
- □ Passenger transport (public transport or taxi operator)
- □ Freight transport (logistics, distribution)
- □ Energy production or distribution
- □ Vehicle manufacturer
- □ ICT / ITS manufacturer/supplier
- □ Other manufacturer/supplier
- □ Researcher or academic
- □ Advocacy, campaigning, lobbying or politics
- □ Consultant or specialist services
- □ Other (specify) : ________________________

3. In which country are you currently based? ____________

If a significant part of your current or past professional experience is in a different country to the one above, please state which country (or countries): ________________

4. What is your level of expertise/experience in the following?

I have little or no I have some This is a key

	experience / it is not part of my work	experience, or the topic is related to my professional activity	area of my experience and/or is a key area of my current work
Transport planning or operations	❑	❑	❑
Intelligent Transport Systems (ICT infrastructure)	❑	❑	❑
Intelligent vehicles	❑	❑	❑
Electro-mobility	❑	❑	❑
Energy supply or distribution	❑	❑	❑

5. Does your company or organisation do any of the following?

	Yes	Not at present but planned in the future
Provide electric vehicles for staff or business use	❑	❑
Provide electric vehicles for public use (car hire or car sharing scheme)	❑	❑
Organise, plan or manage electric charging infrastructure	❑	❑
Support electric vehicle use (financially or organisationally)	❑	❑

Any other activities relating to electric vehicle use: please describe: ___________

6. Do you personally own or drive any of the following vehicles?

	Own (or have recently owned)	Do not own, but I drive one regularly*	Do not own, but I drive one occasionally*
Internal combustion engine (petrol or diesel) vehicle	❑	❑	❑
Hybrid electric vehicle	❑	❑	❑
Fully electric vehicle	❑	❑	❑
Vehicle using another fuel, such as compressed natural gas	❑	❑	❑

* - may be a company or fleet car, hire car, or commercial vehicle (truck, bus, van, etc). “Regularly” = at least once a month. “Occasionally” = less than once a month, including if you have only driven one only once.

7. Have you personally used a public electric vehicle charging point?

a) In your own city or local area: ❑
b) In other cities or countries: ❑
c) No, never used one: ❑

8. How satisfied are you with the following regarding public charging points in your city or local area? (only for respondents who answered positively to question 7a)

	Satisfied	Neutral	Dissatisfied
Ease of use:	❑	❑	❑
Price and payment:	❑	❑	❑

Charging duration:	❑	❑	❑
Safety	❑	❑	❑

Comments: ______________

9. How satisfied are you with the following regarding public charging points you have used in other cities or countries? (only for respondents who answered positively to question 7b)

	Satisfied	Neutral	Dissatisfied
Ease of use:	❑	❑	❑
Price and payment:	❑	❑	❑
Charging duration:	❑	❑	❑
Safety	❑	❑	❑

Comments: ______________

Opinions on electric vehicle charging

10. Do you consider that the electrification of road transport (replacement over time of petrol and diesel road cars, buses and goods vehicles with electric vehicles) should be a strategic priority?

	For urban mobility	For interurban or rural mobility
Yes, high priority which should receive public investment	❑	❑
Yes I support it, but public support should be limited (for example facilitation such as support for interoperability, providing parking/charging spaces and promoting integration with other transport modes, but not operating systems or providing major investment)	❑	❑
No, electro-mobility should be allowed to evolve or not according to the market, and not receive public support	❑	❑

Comments (if you wish to explain your response above): _____________________

11. The FABRIC project concerns dynamic on-road charging, where vehicles are charged from the road surface without any contact or need to plug into a socket. It could be done while moving (dynamic charging) or during short stops (stationary charging).
To what extent do you think provision of the following types of inductive electric charging would increase the take-up of electric vehicles, on a scale from 1 (no increase in electro-mobility) to 5 (high increase, for example double the current rate of growth):

	In urban areas	On motorways or expressways
Stationary on-road charging (in lay-bys or rest areas)	❑	❑
Dynamic on-road charging in a traffic lane	❑	❑

Comments:
____

12. How do you see the potential of dynamic on-road charging in **urban areas**?

	For electric car-sharing vehicles	For private electric cars	For electric utility vehicles (city logistics)	For electric buses (public transport)
High potential:	❑	❑	❑	❑
Medium potential:	❑	❑	❑	❑
Low potential:	❑	❑	❑	❑
Don't know:	❑	❑	❑	❑

Comments: ________________________________

13. How do you see the potential of dynamic on-road charging on major **interurban routes** (motorways)?

	For electric car-sharing vehicles	For private electric cars	For electric goods vehicles	For electric coaches (public transport or tourism)
High potential:	❑	❑	❑	❑
Medium potential:	❑	❑	❑	❑
Low potential:	❑	❑	❑	❑
Don't know:	❑	❑	❑	❑

Comments: ________________________________

14. How do you see the potential of stationary on-road charging?

	For cars, at parking spaces in towns/cities.	For cars, at motorway rest areas or petrol stations	For buses, at bus stops/ bus stations in towns/cities.
High potential:	❑	❑	❑
Medium potential:	❑	❑	❑
Low potential:	❑	❑	❑
Don't know:	❑	❑	❑

Comments: ________________________________

15. Should information on the location and availability of dynamic charging facilities be provided by: *(several responses are possible)*

The road authority or operator via a traffic management centre ❑
The electric charging system operator ❑
A third party, such as an in-car navigation system provider or telecom operator ❑
Don't know ❑
Comments: ________________________________

16. Should the availability of dynamic charging facilities be shown on Variable Message Signs (similar to dynamic car park information signs) in urban areas? (as well as via in-car systems)

Yes ❑
No ❑
Don't know ❑
Comments: ________________________________

17. If a dynamic on-road charging lane is deployed in an urban area, should access to it be:

Open for all vehicles (the charging is only activated when a registered and booked electric vehicle is using it) ❑
Restricted to electric vehicles only, with traffic lights and camera enforcement ❑
Restricted to electric vehicles only, with physical barriers or bollards to control access ❑

Comments: ______________________________

18. How do you see the safety risk in cases where a dynamic inductive charging lane is accessible by pedestrians, cyclists, animals, etc? (consider urban areas, also hard shoulders of motorways or rest areas where people on foot can be present):

Low risk: dynamic charging technology does not present an increased risk of electrocution or other harmful effects ❑
Medium risk for certain types of users ❑
High risk: any on-road charging lane or zone must be physically separated and controlled (like railways) in order that people or animals cannot access it ❑
Don’t know ❑
Comments: ______________________________

19. If a dynamic inductive charging lane is deployed on a motorway, should it be located:

In the hard-shoulder (emergency lane) ❑
On the nearside lane (slowest lane, next to the hard shoulder) ❑
On the offside lane (fastest overtaking lane, next to the central reservation) ❑
On all lanes ❑
Don’t know ❑

20. Should a motorway electric charging lane be physically separated from the other lanes?

Yes ❑ No ❑ Don’t know ❑
Comments: ______________________________

21. How do you see the physical impacts of the integration of an inductive system in the road?

	Yes	Maybe	No	Don’t know
Risk of faster deterioration of the pavement structure, resulting in increase of cost of maintenance:	❑	❑	❑	❑
Risk of interference with roadside equipment	❑	❑	❑	❑

22. What impact do you believe on-road charging will have on the electricity grid?

High ❑ Low ❑ Don’t know ❑
Comments: ______________

23. What implications do you see on the electricity grid if on-road charging is deployed on a large scale? (imagine in 30 years time)

____

24. Should there be safeguards to guarantee the secure operation of the grid?

Yes ❑ No ❑ Don't know ❑
If yes, who should handle the safety measures? (electricity supplier, road authority, etc):
____

25. To what extent do you agree with the following business models for on-road charging infrastructure (how to pay for it / who operates it)?

Possible responses: Fully agree, mostly agree, neutral, mostly disagree, fully disagree, don't know.

Development and operation by private companies, with all development financed with usage charges
Development and operation by public authorities, as part of a policy to increase electric vehicle use (and with charges covering electricity supply costs but not infrastructure development and maintenance)
Urban public transport operators or authorities developing a system for buses, which can be made available to other users at marginal cost
Development and operation by toll road operators (in countries where they exist) with users managing payment via their toll tag (electronic fee collection) account
Comments: __________________________

Further information

26. If you or your organisation are involved in a current or recent project or deployment of on-road electric charging (not plug-in charging), please state the project, its location(s) and the web page (if one is available).

27. If you wish to be on FABRIC's mailing list to receive occasional news from the project and be informed of events, please enter your email address here. ____________

You can unsubscribe at any time. Your email will not be passed to third parties.
Your responses to this questionnaire will be treated anonymously. If you provide your email for further information above, these will **not** be linked to your responses to the questionnaire.