FABRIC

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

Feasibility study on societal perspectives towards on road charging and set of current data regarding societal dimension

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LIST OF ABBREVIATIONS

ABBREVIATION	MEANING
ACC	Active Cruise Control
AC/DC	Alternating current/direct current
ARPANSA	Australian Radiation Protection And Nuclear Safety Agency (ARPANSA)
BEV	Battery electric vehicle
BM	Business models
CAPEX	Capital Expenditure
CEDR	Centre for effective dispute resolution
CH	Clearing House
CIO	Charging infrastructure operator
CO_2	Carbon Dioxide
DX.X.X	Deliverable X.X.X
DSO	Distribution System Operator
DSRC	Dedicated Short Range Communication
EM	Electro magnetic
EMC	Electromagnetic compatibility
EMF	Electromotive force
eq	equivalent
ER	Energy Retailers
ERG	External Reference Group
ERS	Electric Road System
EU	European Union
EV	Electric Vehicle
EVC	Electric Vehicle Customer

EVSE	Electric Vehicle Supply Equipment
EVSP	ERS Vehicle Service Provider
FABRIC	FeAsiBility analysis and development of on-Road chargIng solutions for future electric vehiCles
FEMP	Mobility Platform
GHG	Greenhouse gases
HDV	Heavy Duty Vehicle
I2I	Infrastructure to Infrastructure
IEC/DIN EN	International Electrotechnical Commitee /Deutsche Industrie Norm
ICE	internal combustion engine
ICEV	Internal combustion engine
ICT	Information and Communication Technology
ICNIRP	International Committee on Non-Ionizing Radiation Protection
IPT	Inductive Power Technology
ISA	Intelligent Speed Adaption
ITS	Intelligent Transport System
KPI	Key Performance Indicators
LCS	Lane Control Signal
LC	Life Cycle
LCA	Life Cycle assessment
LDV	Light Duty Vehicle
LDW	Lane Departure Warning
LTE	Long Term Evolution
kHz	Kilohertz
Km/h	Kilometre/hour

MRL	Market readiness level
ms	Milliseconds
MW	Megawatt
MX	Month X
NIST	National Institute of Standards and Technology
NO_X	Mono-nitrogen oxides
O_3	Ozone
OBU	On-board unit
OEM	Original Equipment Manufacturers
QoS	Quality of Service
PM	Particulate matter
POI	Points of Interest
PPP	Public-private partnership
PV	Photovoltaic
R&D	Research and Development
RO	Road operator
ROI	Return on Investment
RES	Renewable Energy Sources
SAE	Society of Automotive Engineers
SLA	Service Level Agreement
SME	Small and Medium Sized
SP	Sub-Project
SPM	Suspended Particulate matter
SuD	System under Design

SVD	Selective Vehicle Detection
SWOT	Strength, weakness, opportunity, threats
TCO	Total cost of ownership
PESTEL	Political, economic, social, technological, environmental, legal
TRL	Technology readiness level
TX.X.X	Task X.X.X
UC	Use Case
UK	United Kingdom
UML	Unified Modelling Language
µT	microTesla
UTMC	Urban Traffic Management and Control
V	Volt
V2G	Vehicle to Grid
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to any component
VAT	Value added tax
VMS	Variable Message sign
WP	Work Package
WPT	Wireless Power Transfer
WTW	Well-to Wheel

REVISION CHART AND HISTORY LOG

REV	DATE	REASON
1	26.4.2015	TOC and first draft of document
2	20.05.2015	Update chapter 4
3	25.05.2015	Restructuring of deliverable
4	29.05.2015	Updated scenarios, updated chapter 2
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6	05.06.2015	Improved chapter 8, rewritten chapter 3, added information on legal perspective in scenarios
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EXECUTIVE SUMMARY

FABRIC is working on implementing new and innovative concepts on Dynamically charging Electric Road Systems (DERS) aiming at supporting EU's target of reducing Greenhouse gases and other emissions affecting the society as a whole and the citizen in particular. Consequently, besides the technical realisation, FABRIC will address economic, environmental and societal aspects relevant to the transition from traditional, hybrid and electric vehicles to dynamically charged vehicles. These aspects will influence a successful uptake of the FABRIC solution or of any other ERS solution, and thus need to be considered at an early stage of the project. Previous work packages have focussed on establishing technical requirements, outlining the ICT infrastructure needed for the introduction of the FABRIC solution, establishing different user scenarios as well as on the technical development.

The main objective of this deliverable is to analyse the societal perspectives towards on-road charging and set of current data to provide a multi- dimensional framework, which will allow assessment from social, economic and environmental perspectives of solutions and combination of solutions addressed by SP2, 3 and 4.

However, as a successful uptake also depends on the conditions potential investors find in a market, the authors also look into the political and legislative aspects in various contexts. Based upon an analysis of the various studies, documents and project internal knowledge, the deliverable summarises the current state of the art, before it derives the key barriers and drivers for each of the aspects, technical, economic, societal, political, environmental and legislative at a general basis.

Given the early stage of this deliverable in the project, and the deeper analysis in SP5 that follows in later years, the main purpose is to provide sensible pathways and to provide a critical perspective to the potential technology push of ERS.

Based upon the previous work in FABRIC and a literature review, key barriers and drivers for uptake of DERS from a political, economic, social, technological, environmental and legal perspective have been identified and a corresponding assessment framework has been established. The objective is to provide a tool which supports a systematic assessment of the feasibility of dynamic on road charging. How each factor influence the feasibility is dependent on the boundaries and the conditions in a specific environment. Thus, in this first analysis, 10 different scenarios, comprising of different transport means (bus, taxi, cars, long and short-haul freight transports), as well as urban and highway scenarios, have been derived. For each of these scenarios, the authors have used the defined criteria from the FABRIC PESTEL assessment framework for a feasibility study. There are large uncertainties related to the factors itself, thus also the feasibility studies for each scenario contains large uncertainties. The main findings of this analysis showed that it seems likely to be feasible to apply dynamic on-road charging in four different scenarios, however comprising high risks:

- Metropolitan deployment of busses
- International freight corridors
- Long-haul national freight corridors
- Short-haul freight corridors

Consequently, from the 10 initial analysed scenarios, only one scenario involving passenger transport seems likely. That is the scenario for busses. For this scenario, there are already existing mature solutions for using other types of electrical charging. Main risks for this scenario is related to the incentives. The other three feasible scenarios are all related to freight transport. Two main reasons for the feasibility are the high likelihood of a positive return on investment for most stakeholders (depending to some extent on the incentives) and the environmental impact, since the new vehicles would replace diesel trucks. The vehicle used for comparison is however also, beside the large uncertainty in the potential users, one of the main reasons for a low feasibility of the light vehicles. For those, there are already existing EV solutions working so that there is low environmental improvement, and also the cost of the infrastructure cannot be covered by the fees that a user would be willing to pay.

For all scenarios, however, it can be stated that since ERS is still under development, that the lack of legislation as well as the lack of clear business models lead to a big variance in our prediction of feasibility. Therefore, other deliverables will develop and extend our first results further at a later stage in the project. The framework developed here will help both in terms of improving the conclusions as soon as more precise information is available and for being applied on new, not yet existing scenarios. However, the feasibility studies clearly show that scenarios for metropolitan busses and long haul freight transports are most suitable for ERS.

1 INTRODUCTION

One of the current goals of EU is to reduce the emissions of greenhouse gases by at least 40% below the 1990 level by 2030 [44]. Being one of the larger contributors, the transportation system plays an important role in achieving this goal. Consequently, large cutbacks in emissions of CO_2 and greenhouse gases are required. Optimisation of transport cannot contribute sufficiently, hence, new and innovative transport system like electric road systems (ERS), need to be put in place. ERSs may solve one of the big drawbacks of current Electric Vehicles (EV), namely range anxiety, once large scale implementation has been successful. However, before this can be achieved, several deployment challenges of the electrical road infrastructure need to be overcome as the uptake and implementation of DERS will have severe impact on current transport systems as well as on the society.

With large-scale systems like road transportation, it is per definition impossible to change overnight. Therefore the transition will be gradual, with many societal perceptions and culture playing a role [1]. In the current transportation system, the infrastructure is agnostic to the vehicles driving on it. By electrifying the roads to accommodate EV, the infrastructure is coupled to the type of vehicle that can be driven on it as well as to the electrical grid infrastructure required for supporting the Electrical Roads system (ERS). Multitudes of factors affect the design, deployment and usability of ERS within the transportation system. The factors affecting the ERS also depend of the type of charging solution being implemented. There are two main types of charging solutions: static charging – such that an electric vehicle can be charged when they are stationary – and dynamic charging, such that an electric vehicle can be charged while being driven on the road (See section 2.2). The main focus of FABRIC is on the less mature technology, the dynamic ERS including the V2X communication. Due to the fact that the maturity is quite low, several uncertainties are related to user acceptance, health risks, political and legislative guidelines as well as high investments risk. These issues are addressed as a part of the deliverable, which is a feasibility study analysing how barriers and drivers may influence the realisation of DERS in different scenarios.

The main objective of this deliverable is to analyse the societal perspectives towards on-road charging and set of current data to provide a multi-dimensional framework which will allow assessment from social, economic and environmental perspectives of solutions and combination of solutions addressed by SP2, 3 and 4.

However, as a successful uptake is also dependant on the conditions potential investors find in a market, the authors also look into the political and legislative aspects in various contexts. Based upon an analysis of the various studies, documents and project internal knowledge, the deliverable summarises the current state of the art, before it derives the key barriers and drivers for each of the aspects, technical, economic, societal, political, environmental and legislative at a general basis.

Given the early stage of this deliverable in the project, and the following deeper analysis in SP5 in later years, the main purpose is to provide sensible pathways and to provide a critical perspective to the potential technology push of DERS.

1.1 Contribution to FABRIC objectives

The FABRIC project addresses directly the technological feasibility, economic viability and socio-environmental aspects of dynamic on-road charging of electric vehicles. Previous work packages have focussed on establishing technical requirements, outlining the ICT infrastructure needed for the introduction of the FABRIC solution as well as on developing different user scenarios. The technical realisation is a pre-requisite for a successful prototypical implementation as well as a contribution to advances in state of the art from a research and development perspective.
However, even though the technical feasibility can be demonstrated within the lifetime and the scope of the project, this will not ensure long-term sustainability of project results with high deployment, since other factors like economical, societal acceptance and legislative rules play an important role for successful uptake of the prototypical solution. This deliverable develops a framework allowing systematic assessment of possible scenarios considering different perspectives. The framework identifies drivers and barriers within these perspectives. The relevance of the various barriers and drivers will vary for each specific scenario, but the framework will allow investigation of system level impacts of dynamic on-road charging as envisioned by FABRIC for different scenarios. The goal is to identify the overall feasibility of DERS for large-scale deployment in the transport system of Europe. That overall feasibility takes into account the technical and conceptual progress made during the project by the Sub Projects 2, 3 and 4 so far. The current document should therefore be read as an agenda-setting and nowhere near a final assessment of the concept of ERS for transportation in Europe. It does, however, provide insights into the likelihood of success of the concept, and specific challenges and strengths. The FABRIC project is not the only project looking into the potential of DERS. There are several other research activities and initiatives analysing different aspects of ERS. These have been analysed and used as relevant input to this deliverable (See Annex 1).

This systematic approach on the feasibility of ERS in various contexts early in the project will make all involved stakeholders aware of barriers, drivers and risks at an early stage and the application of the framework may help in reducing the risks related to ERS deployment.

1.2 Process and Methodology

This section outlines the process the authors have followed in developing the deliverable as well as describing the methodology the authors have used.

1.2.1 Process

This deliverable describes an initial feasibility study conducted at an early stage of the FABRIC project and is the first of several deliverables in SP5 dealing with different socio-economic aspects related to ERS. ERS still requires research and development activities before it is mature enough for market introduction. This implies that there are several uncertainties related to the technical solution and the feasibility of deployment. This deliverable is analysing the feasibility from technological, economic, societal, political, environmental as well as legal perspective in order to establish a systematic framework. The research approach was mixed-both using literature review and action based research

methods. The main body of the document consists of a so-called PESTEL analysis. This method systematically explores the areas of Political, Economic, Social, Technological, Environmental and Legal aspects to identify the key issues that can advance or stagnate the deployment and commercialisation of a technology.

The starting points of this feasibility study are the technical SPs deliverables on ICT infrastructure, technical requirements and user scenarios. These form the basis since they outline the FABRIC solution. These contains some valuable information regarding the use of economic instruments to stimulate growth of EVs, however not so much information related to economic impacts of introduction of DERS on the society as a whole [45, 60], thus in order to carry out a holistic feasibility study, it is necessary to look more into economical, societal and political aspects on societal scale. As stated in the introduction, in the field of EV using static charging, or wired charging technological mature solutions exist and are in operation, even though the deployment in different markets varies very much, but there have been several previous studies carried out on ERS. The authors therefore carried out a literature review. Due to the nature of our perspective, the literature review was not only limited to scientific publications, but also comprising project information, legal and political information as well as economic analysis. Most of these are only looking at static charging solutions and not at DERS and therefore need careful examination. Based upon the findings of the literature review, drivers and barriers as well as main risks for each of the six perspectives where identified. However, the transport system is complex, the barriers and drivers are interconnected, and the relevance of each factor depends on deployment context. Thus, based on the user scenarios developed in D4.3.1, 10 different scenarios where developed for which the authors carried out a scenario analysis for each of the PESTEL perspectives. Finally, taking the large uncertainties into account the authors reached a first feasibility conclusion on large scale DERS deployment.

1.2.2 PESTEL analysis

The factors affecting large scale deployment of ERS can be analysed on different dimensions. In this document, the authors work with 3 axes, as depicted in Figure 1.

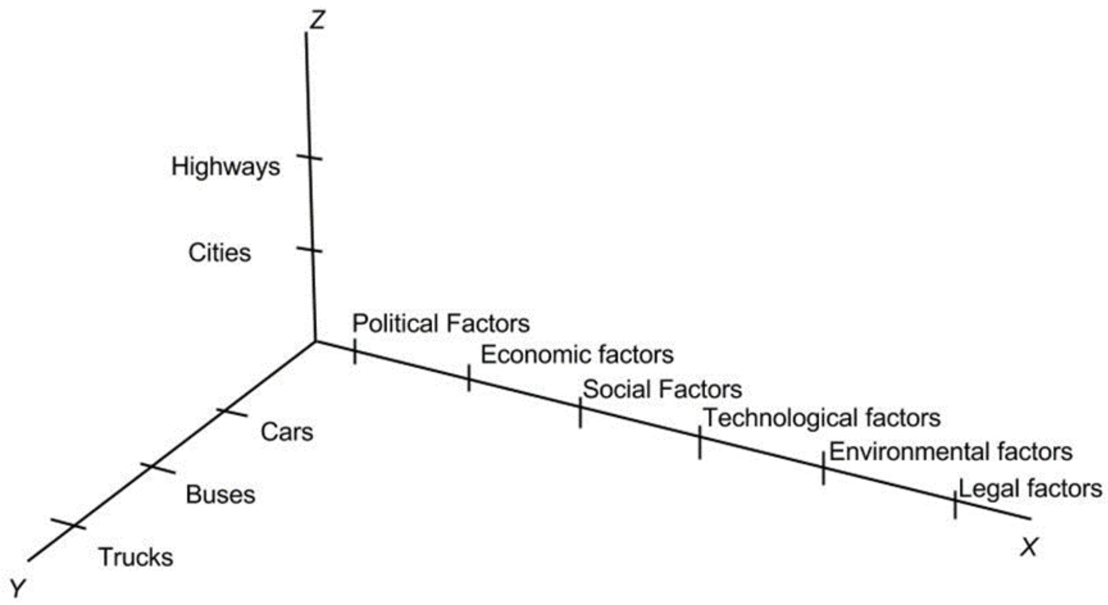

Figure 1: Feasibility analysis framework

The X axis represents the PESTEL dimension, which consists of Political, Economic, Social, Technological, Environmental and Legal factors affecting the feasibility of on road charging. The Y and Z dimensions represent the scale and the type of vehicles impacting the feasibility. The authors also collect data in this 3 dimensional structure and conduct PESTEL analysis for each type of vehicle on each type of deployment.

Political factors

Design and deployment of ERS involves a large number of stakeholders, also including a set of stakeholders who are not involved in the current transport systems like actors from the energy sectors. These actors will all be affected in different ways and seek to influence any political decision making process. Policies makers will therefore meet different, sometimes competing interests.

The influences of all stakeholders along with the current political climate also affect the ERS. The literature on such socio-technical transitions describes dynamics of large-scale (and often long-term) structural changes as a process of the co-evolution of technological designs alongside organizational and institutional designs. The term ‘‘regime’’ is used to describe the existing set of technologies, organizations, and institutions (i.e., the formal and informal rules of the game) that dominate socio-technical systems [2]. The analysis of such groups of stakeholders in terms of solutions proposed for Y and Z dimension (in Figure 1) is an important aspect of feasibility at the societal scale.

Economic factors

Economic factors include economic growth, interest rates, exchange rates and the inflation rate. These factors have major impact on how businesses operate and make decisions. New economic incentives for

the EV owners, manufacturers and operators could have a major impact on acceptance and growth of the ERS.

Social factors

The safety concerns of ERS on society over long term are an important factor. Other social factors such as demography of the population and their receptiveness towards a new technology should inform the design process of ERS over longer term such that most needs of the different social groups are met by ERS. This also helps in widespread adaptation of ERS.

Technological factors

The technological aspects such as R&D activities, automation, technology incentives and the rate of technological change can determine barriers to entry, minimum efficient production level and influence outsourcing decisions. Furthermore, technological shifts can affect costs, quality, and lead to innovation. In this feasibility study the authors assume that all technological barriers can be overcome (at any cost), since this lays the premises for introducing ERS in the first place.

Environmental factors

Ecological and environmental aspects such as weather, landscape, and climate change, which may especially affect industries such as tourism, farming, and insurance. Furthermore, growing awareness of the potential impacts of climate change is affecting how companies operate and the products they offer, both creating new markets and diminishing or destroying existing ones. The ecological advantages of dynamic charging in terms of pollutants, emissions compared to conventional vehicles might be advantageous to introduction of ERS.

Legal factors

Legal factors include discrimination law, consumer law, antitrust law, employment law, and health and safety law. These factors can affect how a company operates, its costs, and the demand for its products. Regulatory factors include acts of parliament and associated regulations, international and national standards, local government by-laws, and mechanisms to monitor and ensure compliance with these.

1.3 Deliverable structure

This deliverable comprises nine chapters. Chapter 1 introduces the topic and puts the document in the FABRIC context. Chapters 2 to 7 comprise a detailed description of the key drivers, barriers and risks for each of the six perspectives in the PESTEL analysis, leading to the definition of our PESTEL framework. Since the different factors are dependent on deployment context, Chapter 8 defines different scenarios for which the authors apply the PESTEL framework and conduct the feasibility study. Chapter 9 discusses the main opportunities and threats before concluding the study and outline future work.

The document is accompanied by D5.2.2 that contains a set of data regarding the societal aspects of ERS. D5.2.2. can be perceived as the appendix to D5.2.1. For the sake of readability, the authors choose to include a lot of the data of D5.2.2 also in D5.2.1

2 TECHNOLOGICAL FACTORS

This chapter summarises the main findings in various other FABRIC deliverables, specifically D221 and D231 have been heavily re-used and summarised The objective is to shortly outline the different technologies, the main drivers and barriers for implementation. The technological feasibility lays the foundation for the introduction of dynamic on road charging. Thus, in the analysis the authors do assume that all technical barriers may be overcome within a certain period.

2.1 Relative position against competing technologies

This section gives a brief overview of different charging technologies and solutions.

2.1.1 Conductive charging

Conductive static charging is widely implemented as a technique for providing power to the electric vehicle battery. The battery is charged through a conducting cable. The use of this physical device ensures a higher transmission performance than using electro-magnetic power transmission. However, the drawback is that the user has to connect manually and plug-in the cable from the vehicle to the charging station and the power grid. Several conductive charging systems are available, depending on the power transmission (AC/DC), the power level (from slow to fast and super-fast charging) and the connectors. In addition, there is no standard for this cable; consequently, it varies for each vehicle and for each country. A standardised cable might boost conductive charging for EV, since it would reduce the costs, increase the usability and ensure a higher utilisation of infrastructure. The average capacity of a battery of EV gives an approximate driving range of 250 km in an urban scenario. This depends also on factors like weather conditions, power usage etc. There are currently four static charging modes available for charging electric vehicles. The conductive charging system itself for EV is defined in the IEC/DIN EN 61851 standard [17]. Plugs, socket outlets as well as vehicle inlets and vehicle connectors are likewise normatively stipulated in the IEC/DIN EN 62196 standard for the charging of electric vehicles [17]. Due to the lack of an IEC standard for the cable, cable manufacturers need to design a standard that is set in a national operator regulation.

Conductive charging for dynamic charging scenarios can be implemented either through overhead wires or through profiles in the pavement. Overhead wires are highly mature technology since there are a large number of cities with trolley busses; however the typical pick-up to connect to the wires is rather clumsy and fails regularly. It is therefore widely considered as in need for technological upgrades. Siemens currently offers a new system with a pantograph pick-up that is marketed towards the electric truck market. Conductive technologies in the pavement have been tested in many places in lab/pilot area setups, like Volvo operating a lane for testing the concept for their truck in Hällered for a project with Trafikvärket and Vattenfall [62], but they are also involved in similar project with Alstom [63]. Also the British government invest in similar projects [62]. However, the Swedish company Elways together with road construction company NCC [62, 58, 59] and especially the Koreans [58, 59] seems to be further in commercial development. Both the modern overhead wire and in-pavement system include automatic placement and management of the pickup device to be able to connect while driving.

2.1.2 Inductive charging

Inductive charging technology enables the battery to be wirelessly charged with no need to plug-in the vehicle. Wireless power transmission is nothing new, but due to low efficiency, its use was for a very long time limited to power transmission for robotic vehicles and cranes, etc.
The wireless system relies on the well-known principle of electromagnetic induction [19, 20]. A magnetic field generated by an alternating current in a primary coil induces a current in a nearby secondary coil. Efficiency improvements have recently been made for short air gaps and low power transfer. The design for the coil shape is optimized to minimise energy losses and to guarantee high power transfer performance even if the coils are misaligned. However, the magnetic field has to be controlled so that it stays within a safe limit [20, 21]. Improved efficiency might lead to a breakthrough for this technology as charging method.

2.1.3 Comparison of static and dynamic charging systems

The inductive power transfer technology has merits for static charging (when the vehicle is parked), stationary charging (when the vehicle is stopped for a short period of time, for example, at a bus stop), and dynamic charging (when the vehicle is moving along a dedicated lane equipped with an IPT system). In the case of static chargers, the product has a high maturity level and initiatives for standardisation are launched. There are several examples of stationary charging systems in operation for commercial buses like an example of Bombardier Primove bus project (inductive fast charging system) or the EDDA bus project also on fast charging.[56, 57]
Dynamic charging is a concept, however, still in its infancy. Besides the challenges related to the technology itself, there are from a technical point of view also challenges related to efficiency. Also safety issues and high infrastructure costs hinder implementation. However, if these challenges are overcome, overnight charging would be partly or completely eliminated through continuously charging on the road. A compact network of dynamic chargers installed on the roads would also reduce the range anxiety and increase the reliability of EVs. Furthermore, dynamic charging would open up for a reduction of the size of the battery pack, reducing the related high costs, since the batteries would only need to supply power when the IPT system is not available.
The differences of the charging systems are described below.

2.1.3.1 Static charging

In this mode vehicles are predominantly charged while parked. This mode is analogous in its principle to conventional plug-in charging, which also can be seen as static mode. The vehicle is parked in a dedicated space where charging commences either automatically with a driver confirmation from within the vehicle or, manually by driver starting the charging process through some sort of off-board user interface. In any case, no handling of a connector is required. Typically, no driver or passenger would be present on board during charging (other than to confirm the charging process). This is the most typical way of charging with thousands of installations in operation. The charging duration typically lasts for several hours, however recent advances reduced the charging time to 30 minutes.[65, 66]
Typical application scenarios:

- Car parking in a garage or car park.

- Bus parking at a bus terminus or station.
- Freight vehicles while loading or unloading.

2.1.3.2 Stationary charging

Stationary charging refers to charging vehicles while they are stationary for a short period of time but en-route to another location. In theory, this would also be possible with some cases by conventional plug-in charging. In reality, however, this might neither be practical nor safe and thus considered to be a mode unique to on-road charging solutions (either inductive or conductive). The vehicle stops at a location being suitably equipped, but not a dedicated stopping / parking spot. Typically, this would be on a road, and power transfer would only be activated when the vehicle is stationary. Charging commences automatically with the driver confirmation from within the vehicle. Mostly, the driver and passengers would be present on board the vehicle during charging.

The charging lasts between seconds to minutes. High power is transferred from the infrastructure to the EV. There are several stationary charging systems in operation [56, 57], focused mainly on partially recharging buses during their short stops at the bus stops. PRIMOVE by Bombardier in Braunschweig and Berlin bus (inductive fast charging system) [58, 68] are examples of the same. Main advantages are that the size of the batteries is smaller and the charging is faster.

Typical application scenarios:

- Taxis queuing in a taxi rank.
- Bus stopping at bus stops.
- Vehicles stopping at junctions, traffic lights, tolls, rail level crossings, etc.

2.1.3.3 Dynamic charging

This mode refers to power transfer between the charging infrastructure and the vehicle while the vehicle is moving. The electric power flow is variable depending on the conditions, including also possible phases with power flowing from the on-board energy storage and the grid to the on-board traction system.

The vehicle might travel at a variable speed while power transfer level would be real-time responsive to vehicle power demand or the condition of the electric grid/distribution system, within the constraints of the system capability or other fixed parameters. Charging commences automatically with driver-confirmation from within the vehicle as soon as the vehicle enters a charging zone on the road. The driver is on-board during charging.

Vehicle speed variation might result in increased power demand, which again causes increased power transfer level, subject to power supply availability and other affecting parameters such as price, charging solution capability, demand from other nearby vehicles, etc.

Currently there are only a few solutions commercially available for stationary charging, namely a conductive overhead solution by Siemens known as eHighway [68]. There is also a Korean example of dynamic wireless charging. Dongwon OLEV and KAIST have recently commercialised a dynamic online wireless charging EV bus – in the Korean city Sejong, where 24 km of lane offer dynamic charging [58, 59]

The advantages may be identified in battery size reduction and increment of the EV range and comfort.
Typical application scenarios might be the following ones:

- Highways (multiple lanes).
- Urban roads with dedicated charging lanes.

2.2 Barriers

This section describes the main barriers from a technological perspective and is mainly based on D2.3.1 [1] and D3.3.2 [60]

2.2.1 Integration of on-road electrical power transfer solutions with existing road infrastructure.

Currently five different on-road power transfer solution installations are investigated:

1. Wireless systems buried in the road.
2. Wireless systems flush with the road.
3. Wireless systems on the road.
4. Conductive systems flush with the road.
5. Overhead line systems.

The physical requirements are first considered. These included size, weight, components (materials), strength, and robustness (heat resistance, fire resistance). The size has implications on structure of the road (for buried systems), while for conductive systems clearance needs to be considered. The road is a harsh environment, so road maintenance costs are a substantial factor. Thus, any equipment installed in or on the road must not influence the longevity of the road or increase maintenance requirements. For integration of the power transfer system to current road infrastructure the following has to be taken into account:

- The system must not affect the non-electric vehicles or the non-charging vehicles travelling on the road (especially their electronic components).
- The system must not affect the driving abilities of the drivers for any type of vehicles.
- The system must not affect the health of the passengers of the vehicles for any type of vehicles.
- The system must not affect the health of the pedestrians nearby.

Regarding the performance of charging systems, these must not adversely affect the traffic condition. Hence, systems need to work at prevailing traffic speeds, and should not change traffic behaviour to induce congestion. Safety concerns dictate that systems need to be remotely controllable. Further, the installation should not affect the skid resistance of roads.
Installation and maintenance are key requirements for road operators. Several EU countries have a wide range of regulation covering the installation and maintenance of roads and road-side infrastructure. These are designed to ensure sufficient quality and safety standards of the road and include structural integrity, surface regularity, safety (from a road texture perspective), ride quality, drainage, time frames for installation and maintenance practice. The installation of novel in-road, over-road and roadside equipment will need to meet all these requirements, and where necessary new practices need to be generated.

2.2.1.1 Infrastructure design, planning and construction

Local transport authorities and the guidance from the central government are required to design and plan DERS. The local authorities, at present are ill-prepared for incorporating on-road charging in local transport networks. The solution providers also need to be in compliance of the physical design constraints, especially if the proposed solution is in urban areas. The road operator and local authorities must define the constraints and the solution providers must develop their systems to operate within specified limits [60]. The solutions for DERS should be in compliance with infrastructure planning and construction tools [60]. Currently, the main tools of road planning do not incorporate on-road charging. The knowledge of design, planning and construction of DERS is not as evolved as the knowledge of road construction. There are processes to be developed and possibly new institutions/bodies to be formed to oversee these new processes. There is also lack of estimation of cost of infrastructure for the new system [61]. The lack of tools and the lack of incorporation of on-road charging option into the plans of the local authorities could be a significant barrier to the development of DERS.

2.2.1.2 Infrastructure location

The number of users of DERS is related to the location of installation of DERS. In order to get the maximum usage of DERS, it should be located in areas of constant use, and in areas which can accommodate significant length of electrification of roads. It is a circular dependency. The most beneficial scenarios for installation have been discussed in chapter 8. It is also important to consider locations which are not inconvenient for vehicles, or for installations. These requirements have not been considered yet [61] but should be considered as part of urban deployment plan. This could be a significant barrier to expansion and adaption of DERS.

2.2.1.3 Operations

The solutions should consider the impacts of the new infrastructure on other vehicles on the road. The effect of the new system on driving ability is completely unknown [61] and needs much investigation. Major work is needed to control exposure to EMF without reducing the rate of power transfer. The effects of installations on traffic flows should be considered. The installations could also affect the existing traffic management infrastructure, such as sensors. Further investigation and planning is needed, along with stakeholders such as local governments and transport authorities to ensure good planning and development of DERS. The present lack of such preparations could be significant barrier to development of DERS.

2.2.2 Vehicle requirements

IEC and SAE are developing standards specifically designed to address dynamic or wireless power transfer methods, such as IEC 61980 and SAE J2954.

The efficiency is strongly affected by the power transfer frequency and thus the frequency has to be high enough to efficiently provide power, but not interfere with other systems. It also needs to be safe for humans. This leads to a trade-off between efficiency and safety. For safety reasons the frequency range of the power transfer systems should be between 10-150 kHz

The typical voltage range for a car is, dependent on the battery pack, normally 150-400 V, for HDV it can be higher. The size of the secondary coils is defined in IEC 61980, according to the standards the dimensions of the secondary.

The battery packs should be sized to ensure that the range is sufficient to minimise the range anxiety but the total battery weight should not affects the size and the performance of the vehicle. The current state of art indicates that the average range of an electric vehicle is between 150-200 km.

Interoperability issues of providing power for both cars and HDV, high power secondary coils are that too large and heavy to be integrated into car or LGV could be barriers for development of DERS.

2.2.3 ICT

ICT products and services that could be used or be relevant for the design and implementations of the FABRIC system's scenarios of use are analysed [1]

2.2.3.1 Booking and Billing

Existing booking and billing approaches are designed to meet the requirements of static charging, i.e. long charging periods and no time constraint EV identification and authorization which can last several seconds. Dynamic charging has, due to the charging on the fly and while moving, other requirements and thus there are some gaps:

- Speed of identification and authorization for dynamic charging needs to be faster. Depending on EV speed while charging the identification/authorization be within a range of (3-5 ms) milliseconds per charging pad. The whole contact duration of the EV with the charging pad for 120km/h is less than 30ms.
- The need of booking solutions for stationary and dynamic charging should be investigated. In case booking is required, a mechanism that can take into account delays in reaching the charging infrastructure is required, since the EV is moving prior to the charging booking. Since the charging duration is very short, the delay may easily exceed the actual charging duration so current booking methods may be irrelevant.
- The use of different systems for the identification of the EV for the dynamic charging should be possible. Billing process is likely to be different for two reasons: First, the EV is on the move and there is no physical contact of the user with the EVSE (to use a credit card for example). Second, the billing process needs to take into account the difference between the transmitted energy and the energy that is actually received by the EV. For static plug-in charging the losses are negligent, for dynamic wireless charging the losses can be more than 20%.

2.2.3.2 Challenges related to measuring and billing of wireless power transfer

For plugged-in solutions, the energy sent to the EV is easily measured and there are no loses. This does not hold for dynamic charging having significant losses. It needs to be decided if billing is for the transmitted or received energy or based upon average energy consumption. One could also let the market decide. This would imply that different energy retailers would enter in competition and bill the drivers differently depending on the energy price and their

marketing strategy. Billing the user may also depend on driving style inside the charging lane. In this case, drivers exceeding the maximum driving speed inside the charging line could be billed more, since the energy loss also increases. Measuring the energy is also a topic of research within FABRIC project. The energy can be measured at the charging infrastructure and at the EV. The measuring method will also affect the billing.

2.2.3.3 User data privacy and system security

Systems such as FABRIC will mainly face the same threats as all other ITS systems. The user identity, the EV location and sensitive data such as billing and personal information have to be stored, handled and transmitted securely throughout the system. In addition, system availability and data reliability is required in order to prevent attacks aimed at the infrastructure, which could also compromise the grid security. Attacks that are specific to the FABRIC system could be identity-theft in order to avoid payment or charging someone else, OBU hacking to provide false information, malicious attacks aiming at reducing the system efficiency. Thus, all security risks need to be solved prior to large-scale implementation.

ICT has a huge role in operations and delivery, as well as economic aspects of DERS. Slow communications could also affect the traffic flow on the charging lane adversely. It has been identified that there is a gap in the ICT, although it is not severe [60].

2.2.4 Distance to market

Regarding the distance to market, the authors have assessed the Technology Readiness Level (TRL) and Market Readiness Level (MRL) available connected and wireless technologies.
Static wireless charging is a technologically mature solution and is comprehensively tested. The products are ready for the market. Major vehicle manufacturers and OEMs are expected to provide wireless charging stations and EVs within one or two years.
Stationary wireless charging is also technologically mature solution, extensively tested for buses. The EVs and infrastructure products are already on the market.
The maturity of dynamic charging technology is low and still in R&D phase, except for one solution [45]. There are tests carried out in lab environment and some tests on regular roads. However, commercialization is expected to take more time due to the significant investments required to transform normal roads to electric roads [62], due to the higher investments needed for the road construction as well as for the maintenance and also higher complexity of this task increases [69]

2.2.5 Interoperability

2.2.5.1 Communication

It is essential that the vehicle to grid communication channel is standardised so that interoperability can be ensured. Furthermore, also the back office and billing interfaces require interoperability, so that the users can be correctly identified and billed for their usage of the charging equipment and to ensure that charging operations comply with grid constraints.

2.2.5.2 Safety

Safety issues related with the electromagnetic field are mainly related to coil geometries and shielding. First, it is required that the electromagnetic field does not affect any persons neither inside nor outside the vehicle. An example: if primary coils are too large, the field may extend beyond the vehicle (lateral or longitudinal). In this case, it is preferable that the secondary coil (on the vehicle) is larger than the primary coil so that the primary coil is always covered by the vehicle.

2.2.5.3 Charging efficiency

There is no information on charging efficiencies available. This is at one hand due to the complex task to estimate the efficiency of one system operating with another; on the other hand, the available data are insufficient for the establishment of any qualitative or quantitative metrics of efficiency for any given combination.

The interoperability of systems will influence the efficiency of the systems since they might not work at their optimum. Several parameters influence the efficiency:

- Communication: will have a severe negative impact if it is not working properly, i.e. might be no power transfer at all.
- Coil geometry: The highest efficiency is only achieved when primary and secondary coils have identical geometry. This parameter has a high relevance for efficiency, but less critical for interoperability, i.e. the system could still transfer power.
- Lateral misalignment tolerance: In general, lateral misalignment reduces efficiency. The tolerance is directly related to the coil geometry. As a rule of thumb, a misalignment of 30% of the coil width can be tolerated (assuming equal primary and secondary coil width). If not identical, additional tolerance is gained, losing in default maximum efficiency. This only holds for inductive circuits, which are inherently tolerate some misalignment.
- Air gap: Frequency variation can compensate air gaps, since all systems work with resonant topologies. Consequently, frequency variation will move the system out of resonance and less power will be transferred. In this case, a reduction in transferrable power does not always mean less efficiency; in fact it might also increase slightly.
- Vehicle velocity: Vehicle velocity is mainly limited by the speed of the implemented control and the ramp-up capability of the system. If the vehicle moves faster than specified, less power will be transferred. However, it does not necessarily mean that power transfer efficiency is lower. The system is just not able to react fast enough in order to supply nominal power.
- Operational frequency: Frequency is directly related to resonance. The inductive circuit is optimized for a certain frequency, thus only small variations are possible without losing performance. However, if the system moves away from resonance, the primary circuit demands less power. For any resonant power transfer, standardisation of the operating frequency is crucial. It is also important that the architecture of the system is understood by both the primary and secondary ends. For example, if the secondary operates in a constant current mode, power control will have to happen at the primary side, while if the secondary operates in a constant voltage mode it can perform its own power control.

- Achievable secondary coil voltage: Assuming that voltage deviations are small, the impact on overall system efficiency is small. Nevertheless, if voltages are not compatible, this system will not transfer any power.
- Power rating: In general, system efficiency is optimised for nominal power conditions. If power transfer must be reduced, part load conditions typically increase losses and reduce efficiency. The reduction of cable losses due to reduced power can be neglected here, as its contribution is much less than that of power electronic elements.

2.2.6 Competing technology position

The table compares the advantages and disadvantages of ERS, wireless static charging and normal EV system.

Table 1 gives an overview of how different technologies are deployed in wireless and dynamic charging as well as for plug-in. As described previously, the wireless static and the plug-in are already on the market, whereas dynamic charging is not so mature. Thus, the introduction of wireless dynamic charging have to be so much better in different ways that potentials users and operators are willing to invest. Looking at the different advantages and disadvantages is can be concluded, that if just looking at batteries and range, the wireless dynamic is preferable, since there is no range limitation, lighter batteries and lower costs. However, main barriers for this technology seem to be that it is difficult to have a gradual growth (always a challenge for immature technologies) and high investments. That the wireless charging is immature is the source of several risks related to further technology development and deployment. Furthermore, also the high need for standardisation is a main drawback, which will make it harder for this solution to compete with the already existing once.

Table 1: Competing technologies comparison

Technology	Wireless dynamic charging	Wireless static charging	Plug-in EV
Battery	Smaller battery, lower costs	Bigger, heavy and expensive battery	Bigger, heavy and expensive battery
Range	No limitation of driving mileage within regions equipped with power transfer systems	Limited by the range from charging station	Limited by the range from charging station
Cost reduction electricity	Potentially with smart scheduling	Potentially with smart metering	Potentially with smart metering
Long term usage	Technology buy-in	Technology buy-in	Robust solution
Gradual growth potential	Low, massive investments required per stretch.	High, provision of parking spots, etc with coils	High
Capital intensiveness	High	Medium	Low
Need for standardisation	High	Medium	Low
Multi-level governance dependency	High	Low	Low
Solution for all vehicles	Yes	Yes	No, special charging points required for heavy-duty vehicles

2.3 Drivers

This section looks at technology's contributions that support an uptake of dynamic on-road charging. In this deliverable, a technological factor is considered to be a driver for DERS, if advances this technology leads to a higher probability for market take up, reducing the distance to the market or contribute to a reduction of social, legal, environmental or economic barrier. The main idea of this section is to point out specific technical opportunities that may add value to a potential user, that he will be willing to either invest in this technology or to use it as a consumer. Finally, the last part of this chapter describe the current gaps. These will have to be overcome for a successful deployment.

2.3.1 Strengths of the technology

The traffic distribution in a specific mobility network in a country needs to be investigated. As an example, in the US only 1% of the roadway coverage are interstate highways, i.e. small infrastructure, but they count 22% of all travelled distance. In addition, a recent study shows that with roadway electrification, the cost of an EV can be essentially the same as an ICE vehicle [22]. Analysis of this scenario indicates that due to the high oil prices (6 times higher than electricity), it will be possible to increase the price of the electricity for infrastructure

users. This would help in financing the infrastructure costs (not covered in the model presented in [22]). It would also eliminate the problem of EV range anxiety since the EV will be charged while travelling through the road infrastructure. The efficiency can remain high if the magnetic field is turned on only when a vehicle is passing.

Three-phase IPT systems have shown very good performance compared to conventional IPT systems in roadways. Conventional single-phase IPT tracks will always have a magnetic field cancellation null along the lateral direction. However, the null is removed when the three phases are combined at high frequencies to generate a rotating magnetic field and provide a smooth power distribution along the track cables.

If the track cable is laid the same direction as vehicle movement, it is not possible to scale the track width without increasing the track current; hence conduction and standing losses are high. Consequently, the design of the three-phase track layout has to be in the horizontal direction, so that the horizontal tolerance can be extended indefinitely by increasing the cable length. Hence, this decouples the design requirements of high track currents to provide the lateral alignment.

2.3.2 ICT

2.3.2.1 Dynamic routing

According to [1**Error! Reference source not found.**] the state of the art navigation system of electric vehicle fulfil the FABRIC needs in terms of trip planning and routing calculation, low charge level warning, routing to charging infrastructure.

Current V2X Vehicular Communication Systems comprising vehicles and roadside units are used for information exchange, providing safety warnings, collision avoidance, traffic status, and congestion reduction etc. to stakeholders. Vehicular networks enhance applications like congestion reduction and route navigation by enabling real time data processing. Added value services based on V2X communication will be provided in two ways in FABRIC: Firstly, traffic management can be applied to road segments prior to charging lanes in order to reduce traffic congestion, real-time accident reporting as well as reports on traffic and charging lane availability, which may allow efficient re-routing to other charging lanes or fixed charging infrastructure. The second service area is related to real time dynamic charging management by prioritizing the vehicles according to their needs and other criteria including real time negotiation of charging lane usage between vehicles with different priority index. This negotiation can be carried out either between vehicles or via a control centre (V2I communication). In both cases, V2V communication is necessary to warn other vehicles about the potential changes in the charging lane queue.

2.3.2.2 Vehicle identification, charging lane access control and management/enforcement

Variable Message Sign (VMS) can be adapted for providing guidance and control for on-road charging systems, providing information on the next facility and its status, or to direct EV users who want to charge to an alternative on-road facility in case a charging zone is not available. Lane Control Signal (LCS) may be adopted and used to indicate the charging lane and possibly reserve its use for EVs only (or certain classes of other vehicles only, e. g. public transport) in the case of only one charging lane on a multi-lane road or motorway. LCS may also be used to

set a specific speed limit for the charging lane, lower than the speed for the other lanes of the road.

The relevance of such systems depends on the prevalence of on-road charging areas and their use: VMS messages only being relevant to a very small proportion of road users risk ignorance, since specific symbols or messages on VMS for EV charging hardly exist and are not harmonised. However, this could be achieved through discussions in CEDR working groups. As stated in [1] existing systems are fully capable of fulfilling FABRIC functions Locating infrastructure (B2), Closest infrastructure routing (B10), Charging lane access control (C2) and Emergency Control of Charging Lane (C3). Applications such as VMS and LCS are fully ready and deployable. Only decisions on symbols to use and strategies for signing need to be made.

2.3.2.3 Driving assistance while charging

Adaptive cruise control (ACC), Intelligent Speed Adaptation (ISA) and Lane Departure Warning (LDW) are safety applications that are potentially valuable for a dynamic on-road charging system. ACC can be used to keep two dynamically charging electrical vehicles at distance ensuring power transfer to properly function for each vehicle. Given the stricter requirements for dynamic charging trajectories, major advances compared to state-of-the-art approaches regarding adaptations and improvements are necessary.

A given WPT installation is expected to be less efficient (or have less time to provide the necessary power) at higher speeds, so a maximum or recommended driving speed should be set according to the road type and the configuration/performance of the charging infrastructure. Interactive speed advice systems in EVs can detect the posted recommended or maximum speed limits on the lane and advice the driver (or force the car) to keep within that limit.

2.3.3 Installation of dynamic power transfer systems in different environments

High power fluctuation is a challenge for electrical grids. Available information has shown that fluctuation is very high if the traffic is uncoordinated with a medium density flow. If coordinated, the demand power has a smooth variation that can be supported by the grid. Consequently, traffic coordination is an interesting option in order to reduce fluctuations at a low cost. However, it might be technically difficult to implement in real world driving environments.

In order to analyse the impact of power transfer infrastructure design on power fluctuations, different models have been used. The conclusion is that it is better to avoid gaps between power transfer pads.

Following the study on power fluctuations, the investigation into sizing for a storage system has been carried out for several traffic scenarios and several levels of smoothing. The main conclusion is that high-power and low-energy storage systems can reduce charging demand fluctuations effectively. All considered traffic models give results in a range between 1–12 MW of aggregated power.

Furthermore, also the integration of solar photo voltaic (PV) has been investigated showing that daily profiles of solar generation and demand from on-road charging are very similar [43] This opens an opportunity for reduction of storage support and self-consumption schemes. Although solar generation reduces energy demand, the daily power peak in the evening cannot

be reduced significantly. Storage sizing has been applied to the case of integrated solar PV generation.

2.3.4 Vehicle as energy storage

The new functionality of the vehicle as a large energy storage unit presents both the owner and the stakeholders of the energy market with significant advantages that conventional mobility could not offer:

- The vehicle owners may use the vehicle battery as an energy source that can power their house. They also may connect the EV to the smart grid and sell the energy to the energy provider thus becoming consumers and producers. The monetary gain potential may facilitate the adoption of electro-mobility by the general public.
- The vehicle becomes a means to transport energy to distant locations. In that way it becomes a decentralized power source.
- The dual function of the electric vehicle, which can operate both as an electric load and a power storage/generation unit shows significant potential as a means to lower operational costs in the energy market. Via the smart grid infrastructure, energy stored in EVs can be bought back when there is a demand peak, and the EVs can recharge at a lower cost when there is a lot of supply.
- EVs may offer the solution for storing energy produced by renewable energy sources, thus allowing their greater penetration and utilization. A direct result is the reduction of the overall energy production cost and cleaner environment.

2.3.5 Electro-mobility

Even though electro-mobility penetration levels worldwide are not impressive, the trend is upward and more car manufacturers introduce electric models to the market. Research during the recent years focuses on reducing the recharging time for static charging (wired and wireless) and in parallel explores the transition from static charging to stationary and dynamic charging which allow smaller batteries and faster recharging, alleviating many of the current EV charging issues. At the same time, investments in EV charging infrastructure continue to grow. As described in section 2.1, dynamic charging aims at alleviating some of the issues related to plug-in systems, thus easing the path towards large-scale adoption of electro-mobility.

2.3.6 Gaps

The assessment of the existing ICT solutions for the distribution system operator and grid management revealed some gaps related to demand side management and load balancing [1]. Load balancing is needed to test the compliance of the existing standard with the wireless charging dynamic needs and to provide the required architecture to integrate the dynamic charging infrastructure to the grid.

Lane Departure Warning (LDW) seems to be a relevant application in terms of keeping EVs in the correct trajectory for the charging infrastructure, but the required trajectories will need to be more restrictive than existing, thus special road markings allowing precise indication to the driver of the required trajectory of charging EVs are required. Therefore, LDW system for an EV need to meet the specific requirements of the new application.

The efficiency of the energy transfer between the charging pad and the vehicle pad will depend highly on the position of the vehicle and its speed inside the charging lane. Development of a specific assistance system for keeping the vehicle in a right trajectory within the dynamic charging corridor (by warning the driver about the correct trajectory) has emerged as a necessity, overcoming the state of the art [1]

3 ECONOMICAL FACTORS

In a feasibility study, the economic analysis is a crucial part. The purpose of economic analysis is to support the determination of the investment decision. The economic assessment will vary for different stakeholders [25]. As explained in the introduction, this deliverable is the first of a series of deliverables analysing and investigating socio-economic aspects of ERS. From an economic perspective, this deliverable lays the foundation for later more detailed development of possible business models and thus starts with outlining scenarios that could be feasible in the role-out of the dynamic charging technology. It is expected that dynamic inductive charging, static, stationary and conventional fast charging will co-exist.

As described above, the access to data, also economic data for ERS in general is limited. The economic analysis is therefore based on existing studies like [23, 24, 25], internal knowledge and information within the FABRIC consortium as well as based on a thorough analysis of the outcome of several previous projects. None of those projects fit exactly in the FABRIC frame, since the project scope is new, but these projects have partly investigated elements being relevant for FABRIC. The relations of projects that have been reviewed are listed in the references chapter at the end of this document [10], [11], [12], [13], [14].

Economic model design

The assessment of economic factors is based on some pre-determined scenarios. A priority ranking (in terms of time to market) will be established according to the impact of these factors in the short, medium or long term.

3.1 Possible stakeholders' business considerations & ICT infrastructure

In order to investigate different business opportunities for different stakeholders and the overall economic feasibility of ERS, technical and safety barriers as well as drivers like different charging systems, interoperability issues, market size etc. have to be considered. Such barriers will influence the business considerations. Secondly, the technical realisation will also influence any possible business consideration on service development; thus, the technical ICT architecture defines most of the main stakeholders. A successful deployment will only take place if all stakeholders agree, i.e. they will likely need to see a benefit for their company. Our analysis comprises the following stakeholders groups, which is in line with [15]:

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 analysis considers the cost structure for the different stakeholders (including the payments to other participants in the ecosystem) and calculates the prices that each actor needs to charge to obtain a profitable Business Model (BM). In this way, the price that the final EV customer needs to pay is calculated. Also the total cost of ownership (TCO) according to its dynamic charging forecast can be estimated. This is two of the key figures for being able to decide upon the economic feasibility.
A comparison with the TCO of the owner of an internal combustion engine vehicle (ICEV) making the same daily route, can be used as a benchmark.
In order to understand the different stakeholders' economic involvement, it is necessary to know the technical solution, which is illustrated in Figure 2 .

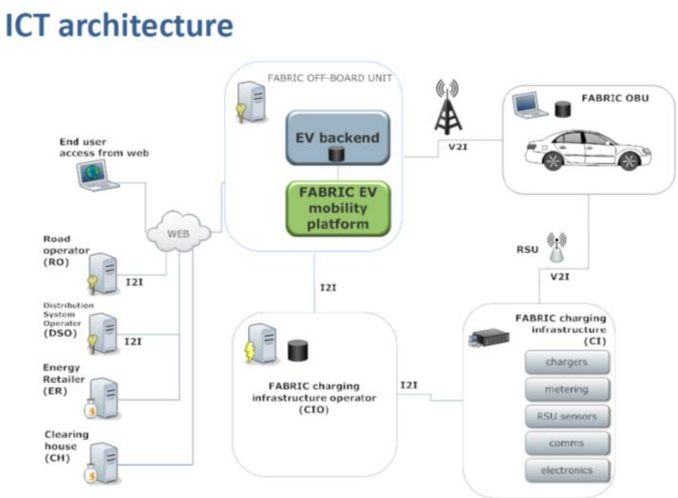

Figure 2: Fabric ICT architecture [15]

Deliverable D22.1 [15] defined the main FABRIC sub-systems, see Figure 11, their components as well as the services intended to be provided by FABRIC. Furthermore, it shows the interaction between the components. A description of each of the components and the stakeholders can be found in [15] as well as in 11.1 in this deliverable. A key for successful deployment of DERS requires that the involved stakeholder can identify a positive business scenario. Thus, in a first step towards the business modelling and based upon the FABRIC

architecture, services that might lay the foundation for a business case have been derived. Figure 3 depicts the different business opportunities for each stakeholder

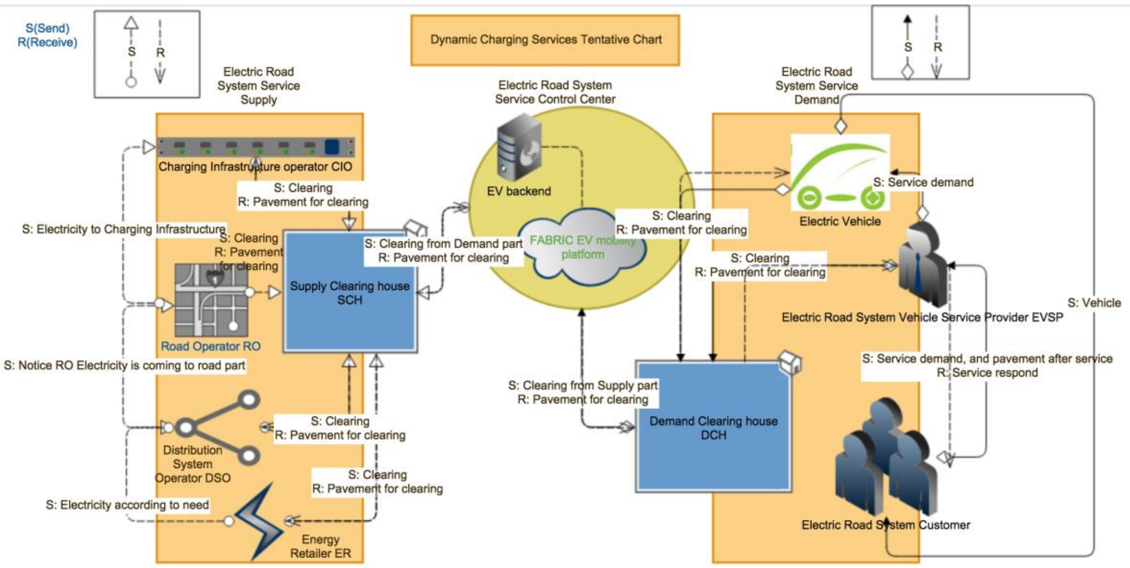

Figure 3: Dynamic Charging Services Tentative Chart

In the economic assessment of a possible business case, not only the technical restrictions, but also user acceptance, market size and requirements, mobility plans and needs, environmental restrictions, legal restrictions and regulations have to be taken into account. Also the related uncertainties and degree of incomplete information on which a decision will be made, will have to be assessed. An unforeseen change in any of these factors will affect the return of investment, the TCO and also the willingness of a customer to pay a certain amount. A systematic assessment of all these factors is therefore a key for determining the feasibility. However, since ERS is not deployed yet in a large scale, there are not enough available data, and each decision needs to be made based on uncertain information. In order to take some uncertainty into account, and thus be able to include a variation, the authors use scenario analysis (see section 8), based on a set of key indicators that are defined in the next section.

3.2 Key Performance Indicators

In order to assess the economic feasibility for each individual stakeholder in different scenarios, the authors use typical key performance indicators (KPIs) group.
KPIs can be used for a variety of reasons within an organisation or team. These reasons can be both strategic and operational, aimed at aligning long-term performance with the organisation's vision or improving processes to meet targets.
The following list provides a small number of examples of how KPIs can be applied:

- Development of a 'benchmark' for similar processes or services.
- Continuous improvement initiatives.
- Demonstrating and attributing business value from services.
- Evidential based improvement or changes to service delivery.
- Decision making for business and IT infrastructure planning.
- Development of Service Level Agreements (SLAs).

The KPIs assess the quality and effectiveness of e-mobility services provided through the system. For this first basic analysis, the authors have selected the categories:

1. Cost
2. Time
3. Quality of Service (QoS)
4. Service Performance.

These KPI categories comprise different aspects depending on the stakeholder (i.e. a stakeholder 'infrastructure operator' will have different costs than the user of ERS etc.). However, normally the authors would also have a category on margin/profit etc. In this early stage of the analysis, the authors have not included it, because there are too many uncertainties as long as the authors have not established any sort of business models. The four categories of KPIs will be mapped to the FABRIC building blocks. The KPIs will facilitate the assessment of the suitability of various Business Models for their use in the ICT framework. Measurement of the KPIs is difficult due to the low market maturity. However, the possibility of measurement will be examined further within the FABRIC Project.
An economic evaluation of technologies is often based on specific scenarios, but there are also other approaches using simulations [71]. The total cost of ownership (TCO) is a typical criterion for decision making regarding technology introduction [72]. TCO "is an analysis meant to uncover all the lifetime costs that follow from owning certain kinds of assets. For this reason, TCO is sometimes called life cycle cost analysis." [73] and will give a complete overview. However, as described previously, the deployment is not only related to technology-related and market risks, but the data needed in order to caluclute the TCO are still very uncertain and not accurate. Thus, methods allowing continuous instead of the usual discrete evaluation results (for each scenario), would be preferable [71]. In addition to the TCO, there will be several non-financial aspects like user acceptance, time to market, that will influence the decision making process of each stakeholder (the other elements of the PESTEL studies). As described in section 3.1, there is a need to identify business cases for each of the stakeholders that will give a positive RoI within a specific time horizon (will vary for different stakeholders), and thus for the FABRIC system a set of potential services and products have been identified. How much a potential user will be interested in paying for a service or a product will not only depend on the price, but also on the quality of the service he is buying. In many cases, this should be very similar to the service performance of the offering company, but in the case of DERS, there will be a significant difference in the two f.ex regarding power transmission- the sent and received will not be the same, since the loss in the transmission process is very high. This is likely to affect the business and pricing models considerably. Thus, based upon these initial consideration, the authors have identified four KPIs that will be relevant in order to calculate what a service can cost (i.e. the revenue side of the calculations will in this case not only depend on financial indicators, but also on non-financial like the service level, since a user might pay more for a better quality).

Table 2, defined the KPIs by each stakeholder to demonstrate the feasibility to reach the targets in the Electric Road System Operation. These will be applied in each scenario in Chapter 8.

Table 2: KPI of groups in Dynamic Charging Services Tentative Chart

KPI CONCEPT /STAKEHOLDER	COST	TIME		QUALITY OF SERVICE			SERVICE PERFORMANCE	
CHARGING INFRASTRUCTURE OPERATOR(CIO)	CIO costs/year	Elapsed time between CIO request and clearing (supply)		Successful logging of valid charging data as % of total events			Daily occupation percentage over maximum	Amount of time/ day with the system busy
ROAD OPERATOR (RO)	RO costs/year	Elapsed time between RO request and clearing (supply)		% of correct transmission of info over total			Nº of requests successfully fulfilled per day	
DISTRIBUTION SYSTEM OPERATOR (DSO)	Energy Costs /year	Elapsed time between ER request and DSO		% not granted charging service request			Number of charging requests per day	
ENERGY RETAILERS (ER)	Energy costs/year	Respond time for charging service		% not granted charging service request			No. of charging requests/ day	Total energy supplied /day
CLEARING HOUSE(CH)	CH costs/year	Elapsed time with all the actors (demand and supply)		% of clearing mistakes with all stakeholders over total			Nº of clearing operations per day (demand and supply sides)	
MOBILITY PLATFORM (EV backend) (FEMP)	FEMP costs/year	Average time it take to identify and authenticate a user. Elapsed time between FEMP request and clearing (demand and		% not sent roaming authorization.	% of unsuccessful charging process events. Nº of services per day.	% of technical errors	Nº of log-ins per day	Nº transactions per day.
ELECTRIC VEHICLE CUSTOMER (EVC)	Cost of Ownership /year	Elapsed time between the OBU request to FEMP respond	Elapsed time between EVC request and clearing	Percentage of search results not fulfilled. Nº of request for consumption data completed as % of all requests received			Total CO2 emissions saved	Total extra mileage by dynamic charging
ERS VEHICLE SERVICE PROVIDER (EVSP)	EVSP costs/year	Elapsed time between EVSP request and clearing		% of successful charging processes over total attempts			Nº of new contracts created per day	Nº of transactions per day linked to the contracts

4 SOCIAL FACTORS

The social factors that can affect the feasibility of the ERS in its formative stages have many dimensions. While these dimensions and concerns are related directly with the ERS, from a socio-technical point of view factors affecting the large-scale adaptation of ERS are complex in nature. The mutual adaptation of the new system to the society is dependent on the flexibility of the new system to the needs of various groups within society.

The authors split this social analysis in two major sub-categories of social factors: those of the different social groups that are related to ERS in its daily operations and use after its deployment, and those of the stakeholders directly involved in implementing an ERS system.

4.1 Social groups, multiple perspectives

The design of the new artefacts on a large scale involves different user groups. The user groups can be based on similar interests or demographic aspects. Different function of the artefact can present problems to different social groups. Hence, the design needs to have enough flexible configurations that can be changed through a dialogue with the social groups. Interested stakeholders, such as businesses hoping to take the new artefact to market and public institutions, interested in the furthering the state of the system - as in the case of ERS, to a more sustainable state - should facilitate the dialogue between the social groups and the artefacts.

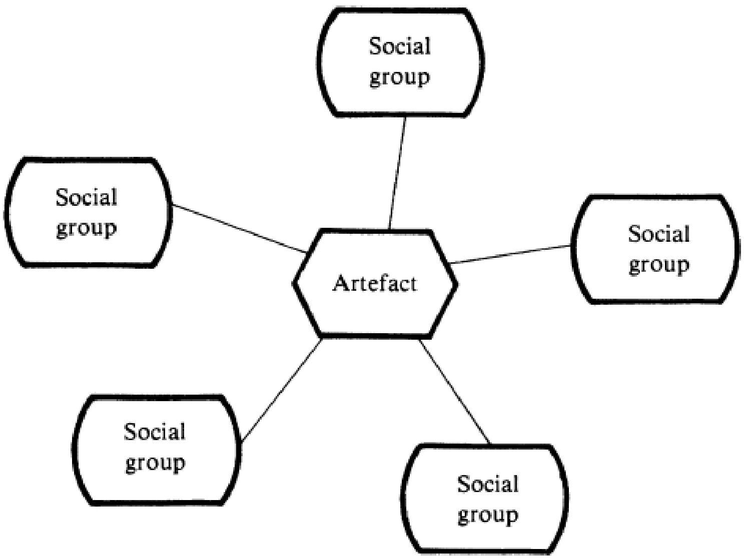

Figure 4: The relationship between an artefact and the relevant social groups from [4]

Presence of a platform, which may be used to educate and communicate with different social groups about the new system, may also be necessary to increase the acceptance of the artefact. Furthermore, also interaction between the social groups and the artefact is also necessary for societal transition and the design evolution of the artefact [5].

This communication may also be used as indicator of some of the emergent properties associated with complex systems. Since ERS design takes place within a complex system, it could be an advantage to get information that is actionable. This could present new opportunities to businesses, to capture and react to incoming information. In case of ERS, for example, high demand from an electrical road, in case of congestion can lead to questions on interoperability between different regions in terms of grid capacities. Though this can also lead to incentives on new economic models for dynamic increase of capacity and could also lead to co-operation.

4.2 User groups

The perceptions of users on different factors of ERS as identified in [27] and listed in chapter 3 are discussed in this section.

Overview of expected high level user needs

A system has a purpose when it fulfils the needs of a group of people, its users. Thus in order to define the desired functionality of a system and the way that it will interact with the users (use cases) one of the first steps is to enquire the user requirements and the gaps between users' needs and what existing systems offer.

The existing electromobility systems for private vehicles rely entirely on static charging. Static plugin charging nowadays is a mature technology and the norm in EV charging. There is already a large number of static electric plug-in chargers installed around the world[1] [7] and this number is increasing continuously due to government initiatives that promote the transition to electromobility [8, 9].

Figure 5: Static charging stations around the world.

[1] http://openchargemap.org/site/country

Plug-in systems have some inherent issues that hinder the wide adoption of EVs. A major obstacle is the time needed to recharge the batteries. Typically, recharging lasts for several hours when using low voltage and amperage power outlets, which limits the usage of EVs. The typical scenario of use for these vehicles entails usage during the day and charging during the night. Even though this scenario is feasible it causes a feeling of limitation to the EV owners, which when paired with the limited range of current EVs, prevents the large penetration of EVs in the transportation market. Furthermore, dedicated charging facilities are required at the user's home such as garages with dedicated power line, however this infrastructure is not easy to be found in apartment building dominated cities. Another scenario is charging during the day when the EV owner is working but this scenario also suggests the availability of infrastructure in large parking lots, while there is the additional problem of adding another load to the grid during demand peak hours. Advances in static charging technology have reduced the time needed to 30 minutes using fast chargers, however when travelling, this time is still long compared to refuelling time of conventional ICE vehicles that also have larger driving range.

A second factor for the low EV penetration is the cost of the batteries that is relevant to the battery size. In order to increase EV range the manufacturers are pushed to use larger batteries, which affect the car weight and price.

Finally, many users may not like the hassle associated with plugging in the EV for recharging, particularly for short periods.

Dynamic charging aims at alleviating some of these issues thus easing the path towards large-scale adoption of electromobility. The advantages of dynamic charging comparing to static are:

- Smaller batteries, since the EV will be able to pick up energy from the road while travelling. This should also affect the price of the EV.
- Hassle free charging. In theory, recharging the vehicle could be as unobtrusive as driving normally on a highway lane. No need to plug in cables thus also avoiding safety risks associated with worn-out infrastructure cables and vandalism.
- Charging on the go means that the EV will not have to stop to recharge which is an advance even compared to conventional ICE vehicles. The comfort factor is expected to be a major decision factor for buying an EV in the future.

On the other hand, dynamic charging would clearly require more expensive infrastructure compared to static charging (even in a future scenario where dynamic charging facilities are widespread) – the lower efficiency of energy associated with inductive charging will also raise costs. So it is likely that this cost will be reflected in the price to the end user unless governments pay the investments required via taxation in order to promote the transition to electromobility. Hence it could be considered complementary to static charging, used more on-trip to boost the EV range or where the user does not have time to effectuate a full charge using plugin technology.

In Figure 6 one can see that while plug-in technology can support only static charging. Conductive and inductive power transfer technologies can charge a vehicle while stationary but also on the move, adding significant flexibility to EVs.

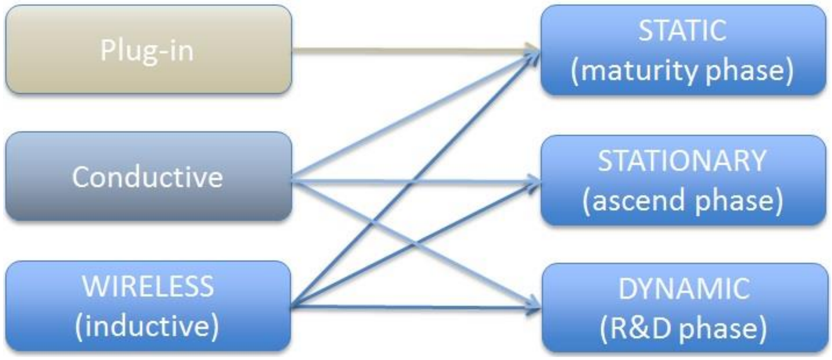

Figure 6: Charging types support by different charging technologies

Table 3 summarizes the factors mentioned in the previous section. For the social aspects of this figure, the comfort and increased mobility are the factors that touch most direct with the different stakeholders and requirements. In this section, pros & cons are only considered from a social perspective, but a comparison with Table 1 it is apparent that there are several common factors, however depending on the perspective, the influence on the feasibility is different. Whereas the maturity from a technological point of view is much related to the uncertainty and the risks in future deployment and development, as well as in the time frame- it is not possible to say exactly which technological difficulties have to be overcome, it is from a user and social perspective more a matter of user acceptance. No user will rely on a technology which is not robust and which may not work when you need it, unless there is no other alternative, i.e. they will not invest (i.e. not invest in the infrastructure) /consume (not buying a car), thus from this perspective it is necessary to have proof of concepts. The costs, at first sight more an economic factor, is from a social perspective more related to either the individual user preference (higher mobility, cheaper/too expensive cars). Examples here are the high costs for a pantograph or the high investment needed in the infrastructure of wireless dynamic charging is related to the user acceptance. The citizen, in case of public funding, needs to be willing to accept that financial resources, always being limited, are spent on such investment.

Plug-in		Conductive		Inductive	
Cons	Pros	Cons	Pros	Cons	Pros
User discomfort	Mature technology	Visual pollution	Easy installation	Expensive infrastructure	Smaller batteries
Long charging duration		Expensive pantograph systems	Smaller batteries		Cheaper EVs
Large and expensive batteries			Extended range		Extended range
Expensive EVs			Comfort		Comfort
Vehicle must be parked			Increased mobility		Increased mobility
					No visual pollution

Table 3: Advantages and disadvantages of EV charging technologies

4.3 Comparison of ERS with Static charging system for different user groups

The societal transition from mobility based on fossil fuel to one based on more sustainable mobility is likely to be a complex process, involving adaptation and evolution of envisioned ERS to unanticipated societal needs and societal learning regarding ERS. To understand the likely adaptations in mobility by user groups of the current road infrastructure, the authors make a comparison of alternative charging solutions. The user groups the authors mention in this section are consumers of infrastructure and vehicles, i.e. the future users of ERS. The specific stakeholder perspective on implementation and operation of ERS is discussed in the next section. The advantages and disadvantages of the different charging solutions are listed in Table 4. Introducing new technology such as ERS on a large scale puts emphasis on the initial installations of the technology. The reaction to the initial installations determine to a non-trivial degree, the path dependency of maturity and the acceptance of the technology by society. The experts of dynamic charging solutions are of the opinion that implementation of dynamic charging is more feasible for continuous stretches of at least 100 Kms. For better utilization of resources, owners of the EVs equipped for ERS, would need to estimate the percentage of travelled route, covered by ERS. Higher the percentage better is the utilization of the infrastructure and of the vehicle. Since implementation of such stretches would cause heavier disruptions in cities, it seems more beneficial to have ERS on highways initially. Table 4 lists the different factors relevant from a social perspective. Technical, environmental and economic factors that all will have a great influence on the overall feasibility of a specific scenario, are only considered if they influence a social factor (like no user acceptance of high public investment, or no willingness to buy a car).

Table 4: Summary of pros and cons of different charging solutions, for different user groups-social perspective.

Users groups	Dynamic Electrical Road System				Static Electrical Roads System			
	Wireless (Inductive)		Wired (Conductive)		Wireless		Wired	
	Pros	Cons	Pros	Cons	Pros	Cons	Pros	Cons
Trucks	Within ERS equipped region, there are no limitations for long-haul trucks. The battery is of lower costs, so might have lesser maintenance costs. Since the battery charges quickly, there are not high waiting times. This would be beneficial are long haul deliveries are especially time sensitive. Less degree of behavior change required by the user.	Need to stay within ERS equipped region. Can work most optimally for repeat travels.	Within ERS equipped region, there are no limitations for long-haul trucks. The battery is of lower costs, so might have lesser maintenance costs. Since the battery charges quickly, there are not high waiting times. This would be beneficial are long haul deliveries are especially time sensitive. Less degree of behavior change required by the user.	Need to stay within ERS equipped region. Can work most optimally for repeat travels.	Higher access to charging spots, as there can be more charging spots available	Range is limited by distance to charging station. Slower charging might not be suitable for time sensitive deliveries. Might need too many stops.	Higher access to charging spots, as there can be more charging spots available	Range is limited by distance to charging station. Slower charging and crowding for charging spots may lead of loss of time. Might need too many stops.
Buses	Can work very well for buses as the routes are known and contained within a region.	Since infrastructure investment is high, large number of buses should to be ready to ply on ERS. Can cause crowding on electrified stretches. Smart scheduling and behavior adaptation required.	Can work very well for buses as the routes are known and contained within a region.	Since infrastructure investment is high, large number of buses should to be ready to ply on ERS. Can cause crowding on electrified stretches. Smart scheduling and behavior adaptation required.	Higher access to charging spots, as there can be more charging spots available	Can cause crowding in popular charging spots.	Higher access to charging spots, as there can be more charging spots available	Can cause crowding in popular charging spots. Needs monitoring of charge and manual intervention to charge the vehicle.
Cars	Lighter battery, hence	Depends to a large		Not suitable for all	Higher	Time	Higher	Time constraints,

	lesser maintenance costs.	degree on technology buy in. Stretches of ERS might be confined to regions and hence not suitable for atypical travel. Does not allow flexibility. Personal damages could prove extremely expensive		vehicles when wires are placed at certain height.	accessibility, hence more flexibility for atypical travel.	constraints, although with smart scheduling can be avoided.	accessibility, hence more flexibility for atypical travel. Can have charging spots at home.	although with smart scheduling can be avoided. Crowding at popular charging points.
Taxis	Fast and dynamic charging, suitable for uninterrupted services.	Unpredictable pickups and drops might take the user away from ERS equipped region.		Not suitable for all vehicles as wires are placed at certain height.	Higher accessibility, hence more flexibility for atypical travel.	Time constraints, although with smart scheduling can be avoided.	Higher accessibility, hence more flexibility for atypical travel	Slower charging and crowding at popular charging spots, needs some degree of caution regarding charging, so as to not lose customers during waiting.

5 POLITICAL FACTORS

In this chapter, political factors are analysed from the perspective of existing and potential policies in order to determine the distance to market for dynamic inductive charging. The authors consider political factors as those direct actions taken by public authorities to boost the EV dynamic charging market or the associated infrastructures. This support depends on environmental awareness reducing emissions (both CO_2 and NOx), but also other considerations play a role (such as economic benefits, or gaining a technological edge or country macro-economics).

From the point of view of politicians, the dynamic charging ecosystem needs to be reliable as to satisfy their voter base with a reliable transportation infrastructure. Their support will depend on the accumulated advantages compared to existing alternatives. The following factors appear to be relevant for their decision-making:

- Attractive business cases: Several users groups will rely on the existence of a public dynamic charging infrastructure (to varying degrees). For operators in order to deploy and operate that infrastructure, an attractive business case is required, either so that they invest themselves or so that they can attract an investor. They need to reduce their costs (purchasing, installing, and operating charging stations) and increase incomes (by growing the utilisation rate of their facilities). Some agreements among stakeholders and politicians will be required at the beginning to ensure the use of the electric corridors. Politicians will only be pro-active if the business cases are attractive for the different stakeholders.
- Consumer acceptance: ERS is an expensive technology, which will require high public investments. Politicians have to verify that the use of resources is favourable for their community. Consequently, they need to be able to estimate a ROI for the community as a whole as well as to present the introduction and the heavy investment in such a way, that the consumers accept the use of financial resources. Probably, only businesses with fixed daily routes could be interested in the mid term for this technology. Consumer acceptance will move politicians to support the technology.
- Stable and efficient grid: Managing the dynamic charging process and designing the charging infrastructure in order to minimise the impact of EV charging on the electricity grid. This will reduce the amount of extra grid investment needed and ensure electric vehicles can charge at a competitive price. Electric vehicles can even be a means to improve grid reliability and efficiency. A complex grid management will jeopardise the political confidence in the technology.
- Interoperable networks: The various players in the charging infrastructure grid need standards in order to offer discrimination-free access to their services. This is a complex element that involves many stakeholders. It mixes technical, business and consumer-facing elements. The clarification of standards at European level will move policy makers to support the new technology. The main focus is to allow the EV drivers to dynamically charge in any EU country they visit.

- Carbon footprint reduction. The desire to reduce the carbon footprint, especially in heavy-duty vehicles and buses is a motivator for politicians. Some firms are even willing to pay a premium for the zero or low-emission alternatives to ICE. For example, 29% of Norwegian EV buyers cite "environment" as their primary reason for purchase.
- Balanced market development: most European countries have a strong approach to non-exclusive technology provision in public infrastructures, where for instance liberalisation of the energy and railway markets have been implemented in many countries. Currently, the provision of road infrastructure is more and more seen as a market issue.
- Smart Grids are automated electric power systems that monitor and controls grid activities, ensuring the two-way flow of electricity and information between power plants and consumers and all points in between. It uses information technologies to improve how electricity travels from power plants to consumers and it allows those consumers to interact with the grid. Finally, it integrates new and improved technologies into the operation of the grid. A smarter grid will enable many benefits, including improved response to power demand, more intelligent management of outages, better integration of renewable forms of energy and the storage of electricity. The deployment of smart grids and the associated industry (metering devices, ICT, etc) as well as the increased penetration/utilization of renewable energy sources (and the associated industry with jobs creation) will be factors to consider.
- Finally, another factor may be the introduction of this new technology which will require significant adaptations on road infrastructures and the development of new vehicles, OEM parts related to charging hardware and ICT services, leading to new jobs, companies, etc. This is more important to European countries with established vehicle industries and large exports.

Policy makers are part of the ecosystem. With their decisions related to supporting or not supporting a new technology at an early stage, they may significantly contribute to boost a solution to the market or also to make it fail. Above, the authors have listed some aspects that influence this decision making process and also indicate that due to the strong need of user acceptance, not only hard facts like reduction of GHG, costs etc count.

With their ability to make new laws and regulations, as well as through the fiscal and tax paying systems, politicians are given the opportunity to establish an environment fostering ERS. Through their actions and decisions on legal and macro-economic level, they may support the actions and initiatives taken at a micro-economic level, as well as on individual level in order to create an environment which satisfies the above mentioned requirements (business case, user acceptance, stable infrastructure) taking the needs and requirements of all stakeholder groups into account. A successful introduction of ERS will therefore need several political actions in various areas. Instruments politicians may use are explained below.

- **Appropriate governmental actions**: Such actions comprise plans, regulations, laws and procedures need to be aligned to support dynamic charging. These may be introduced at local and regional level, as f.ex in some US states [29]. Examples of such actions at regional level can be free car parking, or specific car spaces, but also fiscal support. Currently, such actions are in use for static

charging [30]. Even though the vehicle using ERS technology do not need specific parking spots, free and specific parking spots would still work as an incentive in many urban area. A second local incentive is to allow EV access to areas where normal cars are not allowed. In many cases national or international actions need to be implemented in order to achieve higher interoperability and larger potential markets for car manufacturer willing to invest in dynamic charging. These will need to be of fiscal, legal and regulatory character [28, 32]. Looking at current incentives for EV, the authors can conclude that political action plans contribute largely to increasing numbers of EV [29, 30] Policymakers and regulators of all levels (EU, national, local) need to set up a supporting framework and take efficient supporting actions.

- **Cost savings**. Without subsidies, EVs are significantly more expensive than ICE cars. Comparing the number of EV in countries like Norway [33] and Germany [35], two countries with very different subsidising rules, clearly indicates the role of cost savings for personal decisions. In some specific cases, as a result of government subsidies [28, 32], EV models are cheaper than their ICE counterparts. The increase in the price of an EV is mainly due to the battery cost, which on average reaches 25.000 € for heavy trucks and buses. The dynamic charging appliance in the vehicle and the shielding will increase substantially this price, so some subsidies will be required in the early stages. Consumers expecting to benefit from these types of regulations are drawn to EV, because they provide a cheap mobility solution in a period of high fuel prices in Europe, mainly due to fuel taxation. For example, in Norway, EVs are more attractive than ICEs on a TCO basis as a result of subsidies that include exemption from purchase tax, VAT, toll road charges, registration tax, and annual circulation tax [30]. However, due to the high numbers of new EVs some of the incentives have to be changed (like driving in the public transport lane) [31] very soon. Since this shows that such incentives work, specific subsidies for EVs endowed with dynamic charging capability would have to be considered, in order to move towards dynamic charging and not only static charging.

In most countries, there are some restrictions for heavy duty vehicles in specific dates, which have a limited impact. Driving restrictions hinder international road freight transport and make the planning procedures of transport operators more complex. The cost price effect of these restrictions is limited to a maximum of 5 percent. Especially in cases when the communication (of the adaptation) of a driving restriction has been suboptimal, strong negative effects can be expected for the transport sector. A recommendation could be made in eliminating traffic restrictions for heavy duty EV. According to the last EC reports, trucks, buses and coaches produce about a quarter of CO_2 emissions from road transport in the EU and some 5% of the EU's total greenhouse gas emissions – a greater share than international aviation or shipping. The European Commission has therefore set out a strategy to curb CO_2 emissions from these Heavy-Duty Vehicles (HDVs) over the coming years. While CO_2 emissions from new cars and vans are being successfully reduced under recent EU legislation, the HDV strategy, adopted in May 2014, is the EU's first initiative to tackle such emissions from trucks, buses and coaches. To that end, the Commission has developed a computer simulation tool, VECTO, to measure CO_2 emissions from new vehicles. With the support of this tool the Commission intends to propose legislation in 2015, which would require CO_2 emissions from new HDVs to be certified, reported and monitored. When this is in place, the Commission may consider further measures

to curb CO_2 emissions from HDVs. The most apparent option is to set mandatory limits on average CO_2 emissions from newly registered HDVs, as is already done for cars and vans.

Other measures could include the development of modern infrastructure supporting alternative fuels for HDVs (such as dynamic charging), smarter pricing on infrastructure usage, effective and coherent use of vehicle taxation by Member States and other market-based mechanisms. An impact assessment will be done to identify the most cost-effective option or options. Studies carried out while preparing the strategy suggest that state-of-the art technologies can achieve cost-effective reductions of at least 30% in CO_2emissions from new HDVs. All these efforts may be beneficial for the dynamic charging [37].
From the political viewpoint, the mandatory regulation will be the major driver for the massive introduction of the EV and the associated infrastructure. A strict regulation could easily move the freight players to opt for electric trucks and the municipality and private passengers companies for the electric buses with the required dynamic charging equipment in case of long distances.

In addition to regulatory changes, governments are investing in EV infrastructure and mobility programs to encourage supply. Many governments are making investments in EV-enabling infrastructure (e.g., charging stations, special parking spots). For example, Estonia installed fast chargers throughout the country (165 in total) and ensured that every city with at least 5,000 inhabitants hosts at least one station. Other examples of policies actions aiming at supporting the infrastructure are projects like [38, 39]. FABRIC has to design an outstanding business model to justify public investment in dynamic charging infrastructure.

In addition to the microeconomic perspective of the dynamic charging technology, the authors also have to consider macro-economics conditions, which could boost or jeopardise the introduction of the dynamic charging technology. All these aspects are related to the political performance. Whereas a comparison of specific tax reductions related to EV shows a direct impact on the deployment rate, general macro-economic indicators like tax burdens, GDP growth, unemployment rates and public investment in infrastructure will strongly influence the microeconomic and individual decision making process on investment in ERS technology. A more detailed description of these macro-economic factors is in annex. These factors will be analysed further in later deliverables.

In other to assess the feasibility of a rapid dynamic charging technology deployment, macro-economics affect the countries predisposition. Tax policy highly influences the introduction of new technologies (see Norwegian case). Some countries currently proactive in supporting the deployment of new technologies are affected by the economic situation (GDP low rates, unemployment, etc.). This is the case of Spain, Portugal or Italy and some of the Eastern countries. In case the public investment is minimised by government decision, some private investment could also be postponed, waiting for better opportunities. This might be the reason why Germany is very strict with the administration expenditure.

6 ENVIRONMENTAL FACTORS

6.1 Impact of dynamic charging in terms of GHG emissions in comparison to reference vehicles

In principle, dynamic charging solution allows power to be continuously supplied to the vehicle from an external source, thus enabling a significant reduction of the on-board battery size and, at the same time, reducing virtually to zero the time the vehicle needs to stop for the recharging operations and the related range anxiety.

The reduction in battery size allows a lighter vehicle to be realized in comparison to conventional BEVs. A reduction is therefore expected in terms of energy required for traction and related CO_2 emissions. In addition, CO_2 emissions related to the energy required for the production of the battery should also benefit from a reduction of the size of the on-board pack.

Figure 7 shows the estimated GHG reduction (expressed in percentage in terms of equivalent CO_2) for passenger cars and light-duty commercial vehicles implementing dynamic-charging technology with respect to a reference case based on conventional BEV solutions (some information can be found in [76]. WTW CO_2, eq emissions produced during both vehicle production and operation were considered (some information on this can be found in [74, 75].

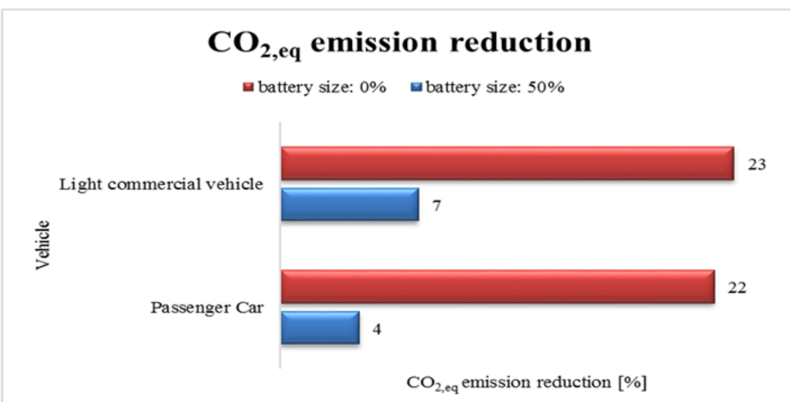

Figure 7: Estimated GHG reduction

The blue bars refer to a test-case in which the size of the battery is reduced to 50% with respect to a conventional BEV, whereas the red bars refer to the limit case in which no battery is present and the power is continuously supplied to the vehicle from the e-road. GHG emissions related to e-road construction and maintenance were not included in the global estimation, since data are not yet available at this stage of the project.

A zero dimensional kinematic model has been used for the vehicle performance evaluations, which is generally considered a good approach for energetic analysis. In this feasibility analysis, each component has been modelled with a constant efficiency (Figure 8) for each working conditions.

The estimation of the equivalent GHG emissions due to the battery production has been carried out taking into account the battery mass and the expected battery life. In this framework, it has been assumed to be equal as the vehicle life itself, i.e. 150.000 km.

The efficiency of the e-road charging system is a key factor for the project feasibility. For the test case in which battery size is reduced to 50% (blue bars), the results show that the equivalent CO_2 emission levels may be considered as comparable to those of the reference conventional BEV, as within the tolerance window due to initial approximations. This suggests that the positive impact of the vehicle mass reduction due to smaller battery packs might be almost counterbalanced by the lower efficiency of the dynamic inductive charging system with respect to that of the plug-in charger system.

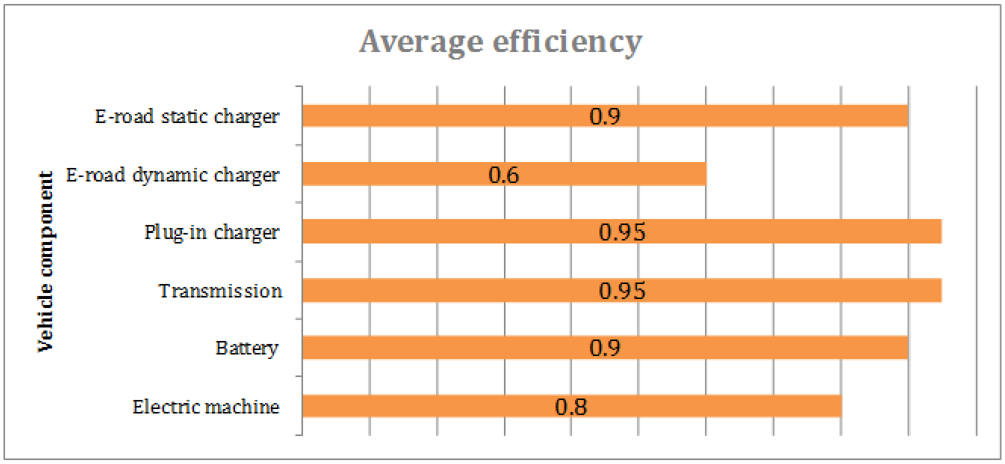

Figure 8 : Average efficiency of each vehicle component

CO_2, eq emission reduction appears to be much more significant for the limit case (red bars) in which no battery is present and power is continuously supplied to the vehicle from the e-road. Keeping in mind that GHG emissions related to e-road construction and maintenance were not included in these estimations, this outcome led to conceive a scenario in which the total equivalent CO_2 emissions of new solutions based on road-charging for passenger cars or LD commercial vehicles can be constrained to be equivalent to the ones from conventional BEVs. In this context, a comprehensive LCA involving both infrastructure and vehicle is fundamental and has to be carefully carried out in the second part of SP5 (assessment), when the result from vehicle operation on test sites will be available.

A similar analysis was also carried out for long-haul trucks. In this case, diesel truck was considered as the reference case, since a solution based on battery vehicles is not suitable to the typical mission of long-distance trucks. The bar labelled as “electric” shows the CO_2,eq emissions from a truck whose power is continuously supplied from the e-road for a mission at constant speed over a motorway. A small battery-buffer is considered to allow short detour from the e-road at derated performance. The CO_2,eq emissions are normalized with respect to those of an equivalent diesel truck on the same mission (bar labelled as “diesel”).

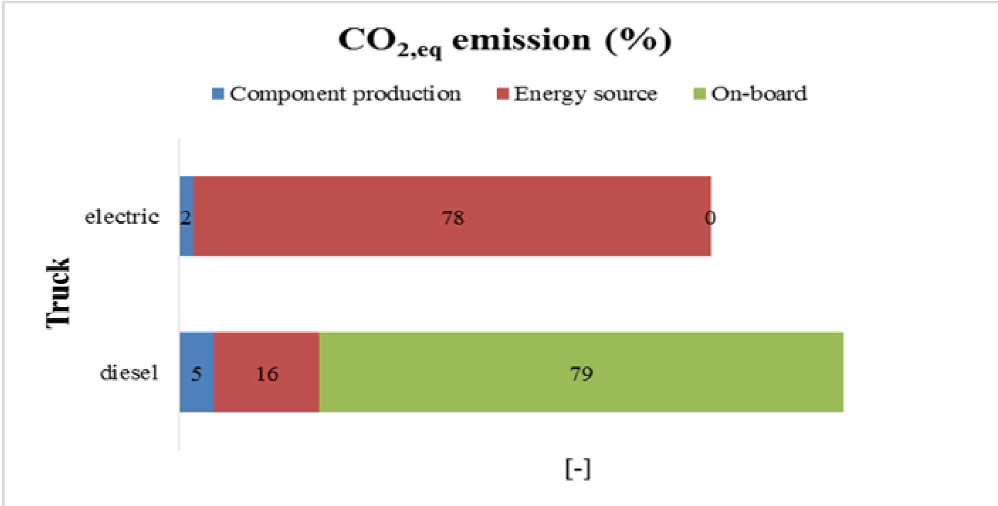

Figure 9 : GHG emissions for diesel truck and dynamic inductive charging electric truck.

As for passenger cars and LD commercial vehicles, WTW GHG emissions generated during both vehicle operation and production were considered. GHG emissions related to e-road construction and maintenance where not included in the estimation, since data are not yet available at this stage of the project. A 20% reduction in $CO_{2,}$ eq emissions is expected. In addition, road charging is a promising technology to foster long-haul transport electrification, leading to advantages in terms of decarbonisation of this sector (thanks to the shift from diesel oil to electricity).

Another application field of dynamic charging is that of urban buses or long-distance buses. For long-distance buses, similar conclusions to those drawn for long-haul trucks can be expected. For urban buses, a thorough analysis should include a comparison with other mobility solution such as the battery swapping. The need for this analysis will be discussed and considered in the second part of SP5.

6.2 Ecological aspects of dynamic charging in terms of pollutant emissions in comparison to reference vehicles.

The amounts of WTW pollutants emitted by an electric vehicle are relatively low to almost zero if compared with a traditional one. This of course depends on the source of energy.In addition, the WTW emissions can be decentralized from the city centre to the source of energy production, for urban mobility applications. Harmful products of the combustion generated by ICEs, such as CO, NO_X, PM (Particulate Matter), SPM (Suspended Particulate Matter) and O_3 precursors, can be therefore significantly reduced in urban centres. As an example, the contribution by sectors to the pollutant emission in an urban centre (Milan district) is shown in Table 5

Table 5 : Contribution by sectors to the pollutant emission in Milan district; percentages (ARPA Lombardia, 2012).

	SO_2	NO_x	COV	CH_4	CO	N_2O	NH_3	PM2.5	PM10	SPM	O_3 precursor
Energy production and fossil fuel transformation	1	5	0	0	1	1		0	0	0	3
Non industrial combustion	17	12	3	1	23	11	0	28	24	21	8
Industrial combustion	74	7	1	0	4	1	0	3	4	4	4
Productive processes	1	0	5	0	1	0	0	1	3	3	2
Extraction and distribution of fuels	/	/	6	46	/	/	/	/	/	/	3
Solvent	0	0	58	/	0	/	0	0	1	1	28
Road transport	2	70	10	1	64	13	5	55	58	60	41
Other mobile sources and machines	4	4	1	0	4	0	0	2	2	2	3
Waste disposal	2	1	0	30	0	14	1	0	0	0	1
Agriculture	0	0	12	22	1	60	93	2	2	3	6
Other sources	0	0	2	0	1	0	0	7	6	5	1
Total	100	100	100	100	100	100	100	100	100	100	100

This framework appears not to be significantly affected by the technology used for the EVs. Therefore, ecologic advantages related to the introduction of the dynamic road-charging solution can be relevant for those applications where dynamic charging is seen as the best technology to foster the shift to electrification. As already discussed in the previous subsection, long-haul trucks and buses can be the most suitable applications from this point of view.

On the other hand, some concerns for electro-magnetic field exposure must be considered. Protection from electro-magnetic field is in fact a critical issue for on and off-board devices that are employed for dynamic charging. Specific requirements for on-board equipment are under consideration in IEC 61851-21-1. The installed device is required to be conformable to electro-magnetic requirements and tests both at the component and at the vehicle levels.

One well-known standard organization that defines the magnetic field exposure is the International Committee on Non-Ionizing Radiation Protection (ICNIRP). At the frequencies of interest in IPT systems (10-150 kHz), a maximum of 6.25uT is allowed as body exposure. It should be noted that this is an averaged exposure limit and the averaging technique is thoroughly described in the Australian Radiation Protection And Nuclear Safety Agency (ARPANSA) standard. To calculate the spatial average, a standing person is required to take an averaging of four single measurements at the head, chest, groin, and knees. In addition, none of the individual field strengths are allowed to exceed the 6.25uT limits by a factor of 4.472 (√20).

7 LEGAL FACTORS

The concept of ERS is a very difficult one from a legal point of view. The following section provides an overview of the legal aspects involved in ERS that can be identified as barriers or at least need adaption, before deployment of ERS can be a reality.

Legislation on road ownership

In most European countries, public institutions own roads, in predominantly national – regional – local organisations of road administrations. In most countries, i.e. Italy, The Netherlands, UK, Germany and Sweden, these institutions do not have legal authority over one another, which means that mutual consent is required to decide upon for instance the regional to national road network connections. Typically, this is done on the interfaces, which in traditional roads are relatively simple, as the pavement just needs to connect to another pavement. In case of electrified roads, it will mean that either legislative frameworks need to change, or that the charging system changes legislative boundaries as soon as one crosses a national / regional / local border.

In several aspects of road systems, these problems are dealt with through standardisation, like for instance with signage and rutting profiles. Standards are so far national, which means that at least between countries the problems will remain. This is expected to be not so crucial for cars, taxi's and light vehicles, but is crucial for trucks, since a major source of fuel consumption is actually the trans-European freight trucking logistics.

Another aspect of road ownership is the risk taking. If electrified roads are publically owned, who is then allowed to provide the charging services? Under all European laws, major contracts for public services need to be procured. Under a procurement scenario, the standardisation will be much harder and potentially leading to a myriad of local solutions.

A legal solution could be to go for Public-Private Partnership contracts (PPP), or even full commercial road ownership by private charging providers, but this does not solve the issue of standardisation, and might lead to separate roads or lanes for on the road charging and for other vehicles. The feasibility of such a scenario in the densest metropolitan areas with a lot of trucking is very low, since already the major metropolitans are dealing with challenges of space for infrastructure.

Legislation on fuel provision

Many countries have legislation on what companies are allowed to provide fuel. This has already led to difficult revisions of legislation and procurement frameworks when static fast-charging stations were deployed (example from The Netherlands). Providing energy to vehicles at the major arteries is in many countries limited to a range of companies that qualify to operate petrol stations. While solutions have been found for fast-charging stations in multiple countries via a widening of what could be perceived as fuel, and to include some other criteria for qualification, this is yet to be examined for dynamic charging.

Important to note here is that some legal experts have mentioned their concerns over a combination of the legislation on fuel provisioning and road ownership. Since many public authorities have the explicit legislative responsibility to minimise risks to and from their assets, allowing commercial companies to install

and operate foreign technology in their road infrastructure will largely violate this, unless the risks are very well quantified. Owning the charging infrastructure themselves is also not possible regarding the laws of fuel provision and competition, where the state is not allowed to compete with the commercial sector on unequal terms. Consequently, before large scale deployment can become reality it is necessary to solve the various legal challenges as well as clarify the uncertainties in application of specific laws and regulations.

Legislation on safety

In a feasibility study for ERS in Sweden [40], it was found that the safety concerns are uncertain considering transportation of dangerous goods and accidents involving electric vehicles, for both inductive and conductive technologies. Regarding dangerous goods the opinions diverge within the industry whether it could be a challenge to operate freight vehicles on high voltage ERS. Interviewees within the ERS industry do not believe that it would become a significant challenge while the dangerous goods industry argue that it might not be an easy task due to comprehensive adjustments of both vehicles and regulations. As one example of vehicle adjustment there is a concern regarding how to create an earth connection for freight vehicles operating on inductive roads. On inductive roads, the vehicle on rubber wheels has no mechanical contact that could serve as earth connection, which is one main difference from the conductive technologies. Possible heating from electromagnetic fields or possible sparks from the conductive solutions and whether it might affect transportation of dangerous goods remain uncertain as well. Studies related to accidents with electric vehicles concern mainly passenger cars but raise an interesting safety aspect. There could be an increased risk of EVs catching fire after an accident and studies show that extinguishing an EV on fire requires a sufficient amount of more water compared to a conventional vehicle. In addition, emergency services might need new approaches when entering an accident with EVs involved. In the same way, it seems reasonable to investigate further the same aspects for both inductive and conductive ERS in relation to freight vehicles.

A main issue mentioned in previous sections is related to EMC and EMF and its potential health risks for humans. Thus several countries have introduced limits for human body exposure [50] and list how different countries have limits described in [51, 52,53, 54]. Furthermore, [48, 50] refers to the fact that wireless charging also needs to comply to the standard defined by the International Commission for

Non-Ionization Radiation Protection (ICNIRP) in [47, 53]. In order to calculate the possible exposure time for a human being, the different country specific limits will have to be used. This indicate a regulatory and legal challenge both for cross border traffic as well as for manufacturer of the affected parts which needs to carry out different calculations to get approval for their vehicles. Recent studies carried out by the HEMIS project [55] has however showed “The current situation regarding automotive EMC standards is lacking in test limits and methodology to fully account for the different electromagnetic environment generated by an fully electrical vehicle (FEV)” (p. 43). Regarding EMF, the same report conclude that there is a general recommendation, but at the time of the study (2013) were “no relevant product standards that specify how to measure in-vehicle field levels and interpret the results in terms of the recommended exposure limits”(p.44), but that a proposal was recently submitted, “however, methods for assessing electromagnetic field exposure will be required for both vehicle occupants and bystanders.” (p.44). A complete list of the identified gaps can be found in Annex A in [55]. Consequently, these findings indicate that there is an

urgent need for first identify, define and test the correct assessment methods. Thereafter to standardise this and finally to integrate these standards in national and international regulations and laws.

Legislation on accessibility

Road owners are by law required to provide accessibility to all vehicles that want to use a particular road. Only special purpose lanes (like for busses in inner cities) are excluded from this rule. Even toll roads are open to all who want to use such a road, for as long as the fee is paid. The fee must be non-discriminatory and based upon physical requirements like the weight or length of the vehicle.

Roads that are equipped with ERS will have different usage patterns; as for instance one lane on the highway equipped with charging is likely to change the traffic pattern depending on the rate of charging vehicles. The demand management and booking of the charging service as proposed in for instance the FABRIC ICT requirements can be perceived as violations of the accessibility. It is uncharted legal territory on what level of accessibility that the infrastructure provider needs to provide once vehicles are not only using the infrastructure to drive on, but are also dependent on it for their battery levels. Accessibility to the road network at large could be affected by the accessibility of the charging infrastructure.

8 FABRIC PESTEL ASSESSMENT FRAMEWORK & SCENARIOS ANALYSIS

This chapter first establishes the framework derived from the analysis of the different factors described in chapter 2-7, before feasibility analysis are carried out for ten different deployment scenarios.

8.1 FABRIC PESTEL assessment framework

The sustainability of the FABRIC solution will depend on the technical feasibility. However, even though there is still a lot of research to carry out in this field, ERS as such is proven to be technically possible. As mentioned before, the technical feasibility in some settings is not enough to ensure the long-term sustainability and market uptake. In addition, a main factor is the economic viability. As described in chapter 3, from a micro economic point of view all stakeholders that are involved need to be able to calculate the return in investment (ROI) within their time frame. This will depend on several other parameters, like tax reduction, direct subsidiaries, business models, but also on legal restrictions, investment climate and the acceptance among users and citizen. In the case of ERS, it is not only a matter of user acceptance. Even though, several European countries have private roads not accessible for all, roads and road infrastructure are in most European countries perceived as a public good, accessible for all who are willing to pay. Large-scale deployment of ERS may affect and change this, the authors do not know yet, since no business model is available. However, in order to foster investment in something having depreciation time of 20 years or more, it is a pre-requisite that the investors find a politically stable environment, and for this a larger acceptance for ERS among the citizens is needed. Consequently, the factors the authors have identified in chapter 2-7 differ from deployment context and transport means, but it is also worth to mention that hardly any of those factors are independent. This has to be taken into account in our multi-dimensional framework. The different factors are listed below (Table 6).

Table 6 FABRIC PESTEL assessment framework

Technological	Economic	Societal	Political	Environmental	Legal
Interoperability (Communication, Safety, Charging efficiency)	Cost	User acceptance	Stakeholders acceptance	GHG reduction	Existing legislation at regional, national and international level regarding fuel provision
Standards	TCO	Reduction of range anxiety	Tax actions	Carbon footprint	Existing legislation at regional, national and international level regarding safety
Booking and billing systems (system response, identification)	RoI	Usability in terms of comfort	Benefits for mutual stakeholder groups	Electro-magnetic field exposure	Existing legislation at regional, national and international level regarding accessibility
Integration into existing infrastructure	Time		Macro-economic benefit	Safety	
User data privacy and system security	Quality of service (QoS)	Regional limitation (needs the infrastructure)	Level of political decision-making freedom in order to implement specific actions		
Vehicle as	Service				

energy storage	Performance				
Power transfer control					
Maturity of technology					

The main objective of this deliverable is to analyse the feasibility of deploying ERS in different environments from different perspective (the PESTEL). However, the overall feasibility of the realisation of ERS in a specific scenario require first of all that the technical solutions has reached a maturity level that allow full scale deployment and market uptake. Thus, for each of the scenarios, the different factors have been assessed, and it has been analysed under which conditions these factors turn positive, if at all. In the case of the technological factors, the assessment is based on the assumption that the barriers will be overcome (hence no uptake), so here the assessment have been the time expected to take to solve (short, medium, long). In the case of the economical factors, the main factors considered in this firs analysis have been costs and expected RoI. All social and political factors have been considered equally. However, if in any scenario the likelihood of finding a positive business case (also by changing incentives, legal and political factors) is not given, the scenario will not be further investigated.

8.2 General introduction to possible deployment scenarios

The deployment scenarios for ERS can be derived from different scales of deployment as well as different types of vehicles. The scales of deployment are: Metropolitan areas, National corridors, International corridors. The different types of vehicles are: Long haul trucks, buses, cars, taxis. The feasibility of deployment scenarios arising from the combination of these factors are indicators of mobility patterns, and can be further analysed based on PESTEL analysis. Based upon previous work in FABRIC the authors have defined four different metropolitan cases and six on freight corridors. In this first analysis the authors have excluded combination of different scenarios.

Table 7 Deployment scenarios

Nr	Name	Description
1	Metropolitan deployment for heavy freight vehicles	A scenario in which the major arteries used by heavy vehicles for freight (trucks above 3,5 ton) will use dynamic charging as their source of energy. Other sources of energy and/or batteries are required outside the metropolitan region and off the major arteries
2	Metropolitan deployment for busses	Regular bus lines in line services will be charged continuously along the majority of the path.

3	Metropolitan deployment for general light vehicles	Deployment of dynamic charging in special places accessible to delivery vehicles to charge while in duty. Charging strips are dynamic alternative to static charging.
4	Metropolitan deployment for service vehicles / taxi's	Deployment of dynamic charging in special places accessible to service vehicles (municipality, waste, etc) and taxis to charge while in duty. Charging strips are dynamic alternative to static charging.
5	International freight corridors	Electrification of the major international road corridors between metropolitan hubs or a harbour and inland metropolitans for heavy freight vehicles. Typically along existing European highways
6	Long-haul national freight corridors	Electrification of the major road corridors between metropolitan hubs or a harbour and inland metropolitans for heavy freight vehicles.
7	Short-haul freight corridors	Deployment of special charging solution for a particular heavy-traffic stretch with back-and-forth traffic.
8	National deployment for general light vehicles	A nation-wide deployment along all major arteries to allow general light vehicles (under 3.5 ton) to be charged while driving, and to reach their destination on a very small battery or alternative fuel source.
9	International deployment for general light vehicles	Europe-wide availability of compatible on the road charging solutions for seamless dynamic charging cross-border for light-duty vehicles
10	International deployment for all vehicles classes	Europe-wide availability of compatible on the road charging solutions for seamless dynamic charging cross-border for all classes of vehicles

8.3 Metropolitan deployment for heavy duty vehicles

In this scenario, inductive dynamic charging will be possible and used by heavy vehicles at the major arteries within the metropolitan region. It is aiming at freight transportation sectors. Since dynamic charging will only be possible on some roads, this scenario requires access to other energy resources and/or batteries with sufficient capacity for driving outside. From a technological perspective, the main drivers are that there are bypass routes between main store and neighbour warehouses. Secondly, E-roads can be realized giving priority to more traffic-dense zones. This is a good starting point, however there are some barriers first of all related to the E-road requirements to guarantee interoperability with different vehicle types. This is currently not given. From an economic point of view, this scenario is less likely to bring a return on investment. This is due to the fact that the implementation of ERS will lead to expensive tariffs for dynamic charging due to reduced number of EVs and that the infrastructure be will too expensive, since

specific corridors need to be built. With this scenario, it is also a high risk of getting insufficient number of heavy vehicles using the dynamic charging facilities. However, there are also some drivers since such a local scenario will make it more likely to establish pre-agreements with delivery companies with heavy cargo vehicles placed in industrial parks close to city centres. From a political point of view, implementations of such scenarios depend heavily on the political will of supporting ERS by establishing relevant incentives. Thus, the authors expect here to see large variances within the European Union, so that no specific conclusion can be made on a general term. However, a main barrier are existing restrictions on the movement of heavy vehicles over 3,5 tons per urban roads during festivities, seasonal holidays or mass movements of vehicles or safety reasons, which the authors see in many urban European areas today. The main economic risks related to this scenario is related to the uncertainty of whether there will be enough supporting incentives from public authorities. A further boundary is that several cities do have restrictions on the operation hours of heavy duty trucks (i.e. no access between 22.00 and 06.00, not on Sunday, not in rush hours etc.), so that this reduces the possibility to degree of utility of the infrastructure.

From a social perspective, in this scenario, the heavy trucks might be stationed outside the city and the smaller vehicles would have to ferry the goods from these vehicles to their destinations. This could create new opportunities for the SMEs for distribution of goods and for city logistics, in collaboration with fleet owners of the dynamically charged vehicle; but could hinder progress for small independent distribution companies.

From an environmental perspective, there are no real drivers compared with other ERS, but the EMC and the effect on health due to exposure to EM fields are main barriers, that also will affect the social acceptance (compare discussion on wind mills, mobile cell tower installation). The main risks are that the reduced GHG emissions during operation phase of the vehicles couldn't compensate higher emissions related to infrastructure realization, maintenance and dismantling. Regarding the legal factors, this will again depend heavily on the country and in some cases the regional location of the metropolitan region. It is also the matter of regional vs. national legislation. In order to foster investment in ERS in this field it is however necessary that a clear legal basis is established up-front of investments.

Conclusion

Although this scenario seems poised to be feasible, there is a circular dependency of infrastructure being available, on number of dynamic charging enabled electric vehicles using this infrastructure. There might be need for encouragement from policy drivers to make this scenario more feasible. While this scenario provides opportunities for economic development in the metropolitan area, it is still unclear how it might affect the distribution chain eco-system. Since reduction of emissions is one of the drivers for ERS, it is still unclear, if during the life-cycle of this system, it will manage to do so.

8.4 Metropolitan deployment for buses

In this scenario buses in regular line service will use ERS for charging while driving. From a technical perspective, this is possible, however there are some concerns related to the interoperability with different vehicle types. It will require adaptation of bus lanes, i.e. will be with an extra cost, and E-roads can be realized giving priority to more traffic-dense zones. However, the investments are high and the main

barriers are that the Municipality Transport Company (or equivalent) will have limits in possible payments for the bus adaptation and that this also holds for the municipality. An increase in CAPEX might increase the ticket price. However, this will make the user acceptance rapidly declining, thus the investment cost can also not all be added to the ticket price of the end user, since this might also have a major social impact. However, this scenario opens up for dynamic charging business model being superior to conventional night charging plus static wireless. The major risk form an economic point of view is again that it might be an insufficient number of buses and/or other vehicles using the adapted corridors to justify the investment (both in buses and infrastructure). This risk will affect the political dimension as the authorities concerns are more on transport ticket costs than introducing costly environmental solutions (as dynamic charging). However, drivers could be that both regulations to allow wireless charging on route as well as incentives like Public Innovative Procurement could be put in place by high enough environmental awareness of authorities. There are, however, some risks related to the political dimension, however very related to economic perspective, too and that is that no investment in the technology possible due to over costs and consequently need to increase the transport ticket. Secondly, a number of EU countries are still facing macro-economic crisis and high unemployment rates. This will impede infrastructure investment. In addition, also a nonexistence of innovation culture is a challenge in some regions. From a social perspective, there are indicators of acceptance of this scenario, as users like the low noise and vibration levels in the buses. This scenario could also work very well when bus lanes are available, after the installation. The effects of installation of the system on the overall transport system and the safety concerns of the large scale dynamic charging system in close proximity of the general public is unknown. As for all scenarios, the main environmental barriers are related to EMC and the Effect on health of exposure to EM fields. The main risks are that the reduced GHG emissions during operation phase of the vehicles couldn't compensate higher emissions related to infrastructure realization, maintenance and dismantling. As for the scenario on metropolitan freight transport, there will be differences from a legal perspective. As mentioned under the political perspective, there need to be legislation put in place that regulate the wireless dynamic charging, and also for regulating PPI. The latter will be less dependent on local, since this is also a part of the EU regulation.

Conclusion

There are a number of projects in the EU and around the world, realizing this scenario which seems quite viable. There seems to be social acceptance towards the electrical buses. To the metropolitan areas deploying these buses, the return of investment in terms of reduced emissions is unclear. The safety aspect of exposing the general public to the EMF is also unclear.

8.5 Metropolitan deployment for general light vehicles

This is a typical city logistic scenario drawing advantages upon that most delivery vehicles has a limited radius of operation. The vehicles can charge while driving in specific places. It is an alternative to static charging. The drivers are high number of E-vehicles in circulation, that it is possible for the ERS systems to charge the vehicles in short corridors inside the cities and that E-roads can be realized giving priority to more traffic-dense zones. However, the users must be confident with the charging on route, so that they

are willing to use and pay for this option. Since it requires specific information about the drivers and also on payment models, data management and security/ Rules and rights for data management is an issue that will have to be solved according to national laws. As in the previous two scenarios there are some barriers related to the interoperability. For urban scenarios, the acceptance is of high relevance. Citizen acceptance is often related to health and environment, therefore again, the main barriers are EMC and the Effect on health of exposure to EM fields. The main environmental impact risk is that the reduced GHG emissions during operation phase of the vehicles cannot compensate higher emissions related to infrastructure realization, maintenance and dismantling. From an economic point of view, big investments are required, might be too high for a municipality, thus PPP is required. There must also be a high number of EV with dynamic charging. Specifically for this scenario is that it requires a very complex ICT system is required to charge the vehicles in short corridors inside the cities, and the technology must be intrinsically safety for end users to take decisions of usage. Furthermore, there is a need for special measures like using the bus lanes have to be approved for EV, which leads us to looking into the political and legal perspective. In order to force the uptake of ERS, it is necessary to implement new strict standards to phase out conventional diesel or gasoline vehicles to reduce emissions. It would also require a remapping of the city roads is required and a set of new regulations. However, most decisions on deployment are made by looking at the economic factors. From an economic point of view the infrastructure adaptation prices must be affordable, which again will only be the case if the technology introduction has a strong support with clear incentives. However, the financial situation of most municipalities is a major drawback. Thus, there is a high risk that manufacturers will wait until a high support from public authorities (very expensive EV transformation). Furthermore, this scenario needs to be implemented in an already existing urban environment, thus the risk of not having enough space to bury the dynamic charging coils in the city roads and for high power electricity connections has to be carefully addressed in each single deployment case. The social impact of availability of ERS in the metropolitan region only, would restrict the usage of the vehicle outside ERS enabled areas, restricting the development of the eco system around ERS to metropolitan areas, while providing opportunities for businesses operating only ERS enabled vehicles.

Conclusion

This scale of this scenario, in terms of vehicles and the repercussions of having so many electric vehicles and the infrastructure needed to engage them are unknown. Even though examples like the PRIMVOVE projects etc. have shown stationary solutions that does not require large changes in the infrastructure, and thus could be applied at traffic lights and intersections, a large number of general light vehicles charging at these intersections would have other effects, such as causing heavy traffic disruptions, for example. Along with the technological change, changes in societal realm would also be necessary, as this scenario affects a large portion of vehicles and stakeholders. Thus, in the current context, technologically, economically, politically, socially and environmental seems unable to bear such a huge change in the system, in the near future, as this scenario affects a large portion of the transport system [47].

8.6 Metropolitan deployment for service vehicles / taxi's

This scenario is similar to the previous one, service vehicles or taxis can charge while in duty, and dynamic charging will be an alternative to static charging. Again, the dynamic charging will take place in a specific area. The technical drivers are the same as in the other metropolitan scenarios, and mainly related to the adaption of bus lanes that must be adapted to wireless dynamic charging at acceptable cost, however E-roads can be realized giving priority to more traffic-dense zones. The scenario would only be economic feasible if a large number of vehicles are in operation (justification of the investment costs). However as for the light vehicle scenario, a main barrier is that within the metropolitan areas, there is not space available for a complete dynamic charging in random trips, so EV must mount likely triple systems (plug in, static wireless and dynamic) resulting quite expensive. Related to this circumstance is the risk that triple systems (plug in, static and dynamic wireless) are too expensive to be profitable. Furthermore, in this scenario there is also a risk that the infrastructure required is too expensive and covering the whole town area. If this would be the case it would also affect the political factors, since offering such a service at high community costs can hardly be realised if only a part of the citizen (i.e. if they take a taxi somewhere or for their waste service). Furthermore, in chapter 7, the issue of regulation and legislation of health and safety was raised. This is insufficient covered today, and thus new regulations are required in terms of health safety when charging. A barrier that affects several perspectives might also be because it is difficult to make this scenario as a convincing solution in terms of value for money, policy makers will doubt on the implementation, since actually other competing solutions are equally environmentally friendly at lower cost. The main legal and political barrier is however related to the fact that the regulatory frame is quite complex to modify the required infrastructure and that there often a challenge to get public decision makers to invest in technology. As already, mentioned from the technical point of view, there will be necessary to invest in charging infrastructure. This installation of charging **corridors** would need to be dispersed throughout metropolitan area as taxis would need to be uninhibited from carrying passengers. Installation in specific areas might restrict the adaption of ERS. Safety from EMF of passengers and the driver while charging remains a concern.

Conclusion

Taxis should be able to ferry passengers to any remote area that is potentially far from the charging corridors. This could induce range anxiety. Although "green" taxis might be acceptable to the public given the right political drivers, the cost of adaption to the taxi owners remains unclear.

8.7 International freight corridors

This scenario aims at electrifying major international corridors between metropolitan hubs or harbours etc. for heavy weight fright transport, most likely would be to use already existing high ways. The international aspect is of the key issue here. One issue is related to the lack of common standards influencing the interoperability. In order to realise this scenario international freight corridors require compatibility among different systems in different countries, which would call for international homogenisation of regulation and legislation, preferable by giving an international standardization body the task of identification of the

best solution. The positive effect is that it would reduce the complexity and therefore reduce the cost. The disadvantage is that it requires a political will to compromise and introduce a specific standard and would increase the cost of implementing a new standard in some areas. Furthermore, on the political level, the realisation is also depending on the awareness and the priority in different regions and countries, which will lead to a more complex decision making process. Furthermore, it would also require a synchronised the implementation of corridors n close countries using compatible systems and EV Service provider would need access to roaming to allow the access approval of E-corridors at international level. The social issue will be related to the safety of driver and the bearers of responsibility in case of any incidents, either with the driver or on the corridor, are unclear. Interoperability between countries is of a concern. The fleet owners of these vehicles would need to have dedicated vehicles for operation on ERS enabled corridors, restricting the movement and usage of the vehicle. This could lead to concentration of such corridors in certain regions, affecting the overall adaption of ERS. As in all the previous cases, the main barrier is EMC. From an environmental point of view, there is also a driver, since ERS is an enabler of long-haul truck electrification, and contribute to reduction of GHG emissions and decarbonisation, even though it is a risk that the reduced GHG emissions during operation phase of the vehicles couldn't compensate higher emissions related to infrastructure realization, maintenance and dismantling. In addition to this risk, there are also risks related to the excessive complexity to synchronise upcoming technologies in the short term in different countries. T

Conclusion
The scenario seems feasible for freight transport, but interoperability is a major concern is all dimensions. Furthermore, this scenario will likely need more years to be implemented due to the high complexity with international stakeholders, the need of harmonising regulations as well as the high investment.

8.8 Long-haul national freight corridor

This scenario is similar to the previous one, however only at a national level. Again, the intention is to use existing highway between metropolitan and hubs, and the competitive vehicle is again a heavy-duty vehicle using gasoline or diesel. As for the previous scenario, a main barrier is the high infrastructure investment (around 1mio€/km), and it is expected that stakeholders only will invest if pre-agreement with long and short haul freight companies are signed. Taking the different time lines of standard freight contracts (long term 1-3 months) and the time it takes to build the suitable infrastructure (years) into account, this represent a high potential risk for not finding private investors, unless the transport corridors are already in place and can deliver satisfactorily rate of road utilisation. Furthermore, if no corridor already in place, a further risk is also that freight companies will not adapt their vehicles to dynamic charging and vice versa. From a micro economic point of view, a sustainable business model is above all depending on the number of EV using the corridors and will in order to reduce the risks for the investors, require pre acceding contracts. Regarding the social and environmental aspects, they are more or less similar to the previous one, mostly related to the reduction of GHG, driver safety and interoperability. The first is the same, but for the latter the problems on clustered development and adaption of ERS that might occur, would be of a lesser concern. The main differences in this scenario compared with the previous one at the political and

legal side. From a political point, the two main barriers seems likely to be the regional cooperation, specifically if there is no national corridor in place. This is mainly due to different local priorities. The second is related to the technology and its business model, which has to be convincing and leave money in the region of those paying the infrastructure. A key here, also related to the high investment costs will depend on the ability of stakeholders to co-invest in the infrastructure (PPPs) and the vehicles adaptation and at what basis. Regarding the legal aspects, as mention is chapter 5 and 7, there will be some regional regulations that needs to be changes (but only for a few countries), mostly only national regulations and legislation will be involved, since the scenario intends to utilise highways. However, as pointed out in chapter 7, there are several legal concerns related to aspects like accessibility (for specific lanes), road ownership and who may provide services to the users.

Conclusion

The patterns of movement of national freight transport are well known, hence ERS can be deployed effectively such that there is utilization of the corridor and range anxiety is reduced.

8.9 Short-haul freight corridors

The major distinction between this and the previous one is the distance. Also this aims at freight transport with heavy-duty vehicles, but with back and forth traffic. There are no specific technical barriers. Short-haul freight corridors are easier to implement, but limit the use of E-vehicles at national level. However, on risk is related to the willingness of EV OEMs to invest on adapting their vehicles, another is related to the infrastructure cost for a single regional authority. From the political perspective, such a local scenario has the advantage that politicians with environmental awareness may invest in pilot test sites with the help of European funding, however also in this case it will only work if EV OEMs to provide the vehicles, that will convince politicians to support the technology. Consequently a main risk and potential barrier is that EV OEMs and freight companies will not support the project enough at local level, consequently there is a need for having a clear commitment from the freight companies to use the local corridors. Furthermore, for local scenarios it is difficult to establish convincing business models and the Overall business model unclear, short term impact of the pilot site will jeopardise decision making of politicians and also the high investment cost may impede the project implementation. From a social perspective, this scenario is feasible when there is a lot of activity in the short haul, with maximum utilization of the system, which leads us assess that such activity is present in certain regions, such as regions where mining of material takes place. As this scenario is contained within a region, it would lesser amount of time for deployment, but local politics and local industries could play a major role in acceptance of ERS. Regarding legislative issues, it depends on whether such scenarios need national regulation or if local authorities may regulate enough. A simplification compared with the national scenario is that local authorities can change restrictions of access in specific regions.

Conclusion

As it is more contained compared to the previous scenario of deployment of freight vehicles on national scale, it is also more feasible. This scenario is feasible when there is a lot of activity in the short haul, with maximum utilization of the system, which leads us assess that such activity is present in certain regions,

such as regions where mining of material takes place. As this scenario is contained within a region, it would lesser amount of time for deployment, but local politics and local industries could play a major role in acceptance of ERS.

8.10 National deployment for general light vehicles

This scenario foresees that light vehicle (under 3,5ton) will operate on national corridors and charge while on duty. However, this scenario brings some risks, since light commercial or non-commercial vehicles cannot ensure a daily use of e-corridors as they move randomly and with a seasonal character. Randomised flow of vehicles, which does not guarantee the daily use of e-corridors and thus impeding a stable income scheme and a lack of a sustainable business models (i.e. without state aid/financial support), imposed by a risk connected to the uncertainty of the use of e-corridors by random customers. Also the Data management and security/ Rules and rights for data management as in the light vehicle metropolitan scenario is a technical barrier. From an environmental perspective, the benefits are less clear than for heavy-duty, since these vehicles also can use other charging systems such as battery swapping or stationary charging. . If the scenario for heavy-duty freight vehicles works, additional light EV could be a must, which actually means a dependency on a different market segment. Looking into the investment, the main barrier is caused by an uncertainty in the daily use, thus such investments on e-infrastructure considering the first entrance of light vehicles at national level is quite risky as daily use. Thus, it is expected that politicians first need a conservative scenario with a sound business model. Furthermore, in order to attract different private investors (the different stakeholders), a national strategy is needed and that requires mature and proven technologies and a significant deployment of EVs and the compromise of OEMs and other actors. From social perspective, this is a much larger scale scenario than the earlier one on metropolitan light vehicles; the preparedness of the whole system is of a concern. Services such as repair shops, mechanics and auto parts, will become highly specialized.. Re-training, re-tooling of these groups will have to be examined. The environmental concern is as in previous scenarios. From a legal perspective, the national limitation will make regulatory required actions less difficult to implement and easier to adapt existing legislation to the needs of ERS. These would mainly be regarding who can provide services, who owns the infrastructure and accessibility, as well as Data management and security/ Rules and rights for data management. However, bearing in mind that some national market are very small, and that there are several different standards, this might be a drawback since there is no need for international consent on interoperability standards. This will diminish the interest of EV OEM to adapt vehicles for national market of unclear size (i.e. the risk of the daily usage)

Conclusion

A large overhaul of the transportation system needed, in all considered dimensions. Due to the large uncertainties in potential market, it is less likely to be implemented in short term.

8.11 International deployment for general light vehicles

This scenario is the same scenario as the national scenario in the previous section, but with the additional complexity of international interconnections. However, as one of the main concerns in the previous scenario was the lack of large enough markets for OEM to invest, the market here is global and thus it is more likely that the OEM would see a market opportunity. On the other hand, from the legal perspective the authors argued in the scenario above, that it would be easier to implement the necessary regulatory actions. This would in this scenario be much more difficult, since international agreements on technologies, deployment of common ramp up, standardisation, market homogenisation as well as on data management and security/ Rules and rights for data management are needed. In addition, as described in chapter 5 and 7 the speed of deployment will be different for each country, depending on decision making process, internal structure (regional vs central power), fiscal policy, economic capacity and national priority. The scenario requires big investments with unknown results, i.e. need to look for PPP and country support in order to share the costs. However, other clean solutions may be more appropriate. An additional barrier in this scenario is that the stakeholders might be unable to select from different wireless technologies represented by competing companies as well as the incapability of politicians to agree upon the best solution, due to the need of taking local interests into account. Furthermore, like in the previous case the business model comprises large risks, and there might be distrust among politicians to invest in a technology with unknown market. Furthermore, other cleaner and cheaper competing technologies could let the technology offside. In addition, from the social perspective, interoperability of the electrical and payment systems between countries would be of a concern, although it does provide opportunities for partnerships. This is an extension of the previous scenario and hence the problems and the opportunities are magnified. The environmental barriers are as in all other scenarios and related to EMC and how much GHG will actually be saved in a LCA.

Conclusion

A large overhaul of the transportation system is needed, in all considered dimensions, before such scenario could become reality. The authors therefore conclude this scenario as highly unlikely in the near future.

8.12 International deployment for all vehicle classes

This is the broadest scenario, in which all classes of vehicles can be dynamically charged all over Europe. It will provide an European wide accessible, seamless charging infrastructure. Due to the international character, and all types of vehicles, it has a high complexity, however also a high number of potential users, which is important for sustainable business models. Due to the widespread implementation, it is more likely that the OEMs are interested in investing in adaption compared with the national and metropolitan scenarios. However, such a complex and widespread scenario also requires a complete mind-set change for all involved stakeholders and due to the very high investment costs, the technology needs to be mature. As in all international scenarios, there is a need on globally accepted agreements on technologies, deployment of common ramp up, standardisation, how to deal with data management & security as well as the corresponding rules and rights for data management. The deployment will probably follow different time

lines, as described in previous scenarios, since macro-economic situation in some countries impede to make so large investment transforming the transport sector and there will be issues to solve (political and economic) since local industry and technology players are different per country. From an economic perspective are main risks that the dynamic charging so far is a very expensive solution, thus it is also a risk that some countries do not have the financial capacity to make so large investment due to major internal problems and priorities. Since this scenario comprises all vehicle classes, the concerns about sustainable business models remain for some of the vehicle classes. A major issue from the political perspective is the need of international agreement of switching to this specific technology at international level. A suggestion is that diesel and gasoline vehicles should be forbidden by lack of fuel or by environmental regulations, and other long-term options as fuel cells vehicles should be discarded. However, this seems quite unlikely since diesel and gasoline vehicles are progressively adapting to a most strict environmental regulation, and new reserves are under exploration. In addition, there are other competing clean technologies as FC Vehicles are has a more advanced technology readiness level. Since this scenario is a combination of all the above scenarios. To support the entire transport system as a ERS, many charging sites would be necessary; the operation of such a system would have to re-invent all the services associated with the transport system. Safety services and environmental impacts of having many charging sites would be a major concern also the environmental factors remains the same. From a legislative perspective, this scenario, as the most complex one, also require the most work on regulatory and legislative issues, which is expected to take long time.

Conclusion

This scenario would imply a very large change in international transportation systems, with overhaul needed in all considered dimensions. It is therefore considered as highly unlikely in the foreseeable future.

8.13 Summarising

This chapter has outlined ten different scenarios for metropolitan, national and international transport with different vehicle classes. For each of these, the authors have analysed the feasibility from different perspectives. Technically, it can be summarised, that even though there are challenges related to standardisation and interoperability, the technology seems to be possible to implement. Current navigation systems of vehicles already fulfil many requirements of ERS vehicles (namely trip planning, low charge level warning, routing to charging infrastructure) and ERS will have an impact on traffic congestion. For ERS there is a concern about the EMC and the safety of drivers in all scenarios. However, a major concern in most of the scenarios is the risks related to the business models and legal factors. For some vehicle classes, it seems unlikely that a sustainable business model can be found, for some it is expected that this will be possible, but that there will be a need for incentives and strong public involvement for a long time. However, the authors have to point out that the information used for conducting the feasibility studies do comprise several uncertainties. Next chapter will therefore discuss this issue in more detail.

9 SUMMARY AND CONCLUSION

The design of the ERS takes place within an existing transport system- However, there are always stakeholders within the system and social and institutional structures which are resistant to change [2]. However, actors interested in transition to a more sustainable system could gradually introduce new systems in "protected" spaces, thus creating a "technological niche". Within such a niche, emerging socio-technical systems that are promising (and desirable), but not yet mature enough for true commercialization can be developed further to the point at which they can compete in the marketplace [2]. In the formative stages, the configuration of the new system is often flexible in terms of technological, organizational and institutional design. However, a multi-stakeholder and multi perspective communication between all actors affecting and being impacted by the new system is imperative for successful adaptation of the new system. [3] presents an overview of current state of formative phase of ERS in different European countries. The PESTEL for the ten defined scenarios shows, that only for a few the authors can currently conclude that they will be feasible.

Table 8: Summarised PESTEL analysis of our ten scenarios concludes:

Nr	Name	PESTEL Conclusion
1	Metropolitan deployment for heavy freight vehicles	Possible, but high circular dependencies lead to high risks. Strong policy involvement is key for implementation. The economic feasibility seems to be given.
2	Metropolitan deployment for busses	There are examples of such scenarios already, thus feasible if enough incentives given.
3	Metropolitan deployment for general light vehicles	Currently, this scenario is not feasible. High economic risks for stakeholders, and unsure if manufacturer will invest in the necessary ?
4	Metropolitan deployment for service vehicles / taxi's	Currently, it is unlikely to be realised. Economic feasibility not given
5	International freight corridors	Seems feasible for freight transport. Main concerns are interoperability and legal agreements
6	Long-haul national freight corridors	Feasible, but high risks due to utilisation
7	Short-haul freight corridors	Even though several risks and more precise data, this scenario seems feasible.
8	National deployment for general light vehicles	Not feasible
9	International deployment for general light vehicles	Not feasible
10	International deployment for all vehicles classes	Requires large changes, thus unlikely to be feasible.

The implementation of ERS on public roads will be a reality only if all the actors that are involved with contradictory interests agree and cooperate to find the optimum solution. This does not mean that only one technology has to be chosen but that there is a need for a consensus how to implement ERS generally.
In those scenarios for which the authors have concluded that they are feasible (scenario 2, 5, 6, 7), there is still a need for high investments. Thus, the authors would like to summarise the key findings for economic feasibility, before the authors shortly outline how this influences the industrial and governmental stakeholders, i.e. those who have to invest.

From the economic point of view, the authors must highlight that:

    - The EV customer will be a key participant, since it will be the one actually buying the EV with dynamic charging capacity. Besides, the CIO, who will invest in the charging infrastructure, and the EVSP, who will be providing value-added services for EV customers, will also be key actors. As stated above, in EV-related BMs, several actors interrelate with each other and all call for a positive business case. Hence, EV customers' total cost of ownership (TCO) and the BMs for the CI Operator and the EVSP are strongly correlated. A change in the fee to be charged by the CIO Operator will influence the price to be charged by the EVSP to the EV customer for EV charging and, hence, customers' TCO. Likewise, as the TCO decreases, the number of EVs will increase and, thus, the number of potential EV customers for the CI Operator, so the fee for EVSE access can also be lower.

    - In addition, the mass roll-out of EVs with dynamic charging capacity needs the collaboration of some other actors, such as the DSO, whose activities (and profitability) are strongly influenced by the electricity demand increase derived from EVs. If EVs are to be extensively adopted, all the actors involved in the EV environment must see a positive profitability and, thus, the Business model analysis will need to assess the impact on all these actors too.

- As an advanced conclusion from the economic viewpoint, dynamic charging could be only possible in the medium term if the following conditions are fulfilled:

    - There must be a sufficient daily vehicles transit independent from seasonal traffic flows. This condition limits the type of vehicles to those making the same route on a daily basis regardless of the time in the year when this happens.

    - The major advantage of the dynamic charging is the possibility to reduce the size of the battery and improve the economic performance of the vehicle, but if this reduction is done on a conventional car, ,the autonomy is also reduced generating range anxiety if the electric car is used inside the city. So, this reduction could be useful to incorporate a new class of EV into the highways, which nowadays are not possible because the current battery size

requirement, should be too large. The authors are referring to heavy-duty vehicles and intercity buses. In this specific niche they compete against ICE or diesel trucks and buses.

- Another barrier for the introduction of the dynamic charging is the requirement of a specific corridor prepared for dynamic charging. This condition open a new opportunity inside the cities as the bus corridors are already in place, so they can be adapted to the technology specially in environmentally protected areas as the old town in many cities.

How the different participants are imagining the future is a central question within the development of electric roads since the cooperation is needed in order to progress [41]. In order to understand the different perspective, the authors refer to two Swedish studies. One study investigated the conditions for cooperation in the Nordic context between the different participants, incentives, blockers and attitudes towards electrified roads, as well as to what role the government should play to support the cooperation. The companies contributed by sharing their beliefs about the electric road systems in the future. Some of the companies and institutes contributing to this development are AB Volvo, Scania, Volvo Cars, BAE-Hägglunds, ABB, Ericsson, Vattenfall, Göteborg Energi, Eon, Fortum, ICT Viktoria, Chalmers, KTH and LTU. [42] also investigated stakeholders involved in ERS and there are many different presented, see **Figure 10**. This report also states that it is essential that the government provide predictable long-term conditions in order for the stakeholders to be willing to invest in the electric road system.

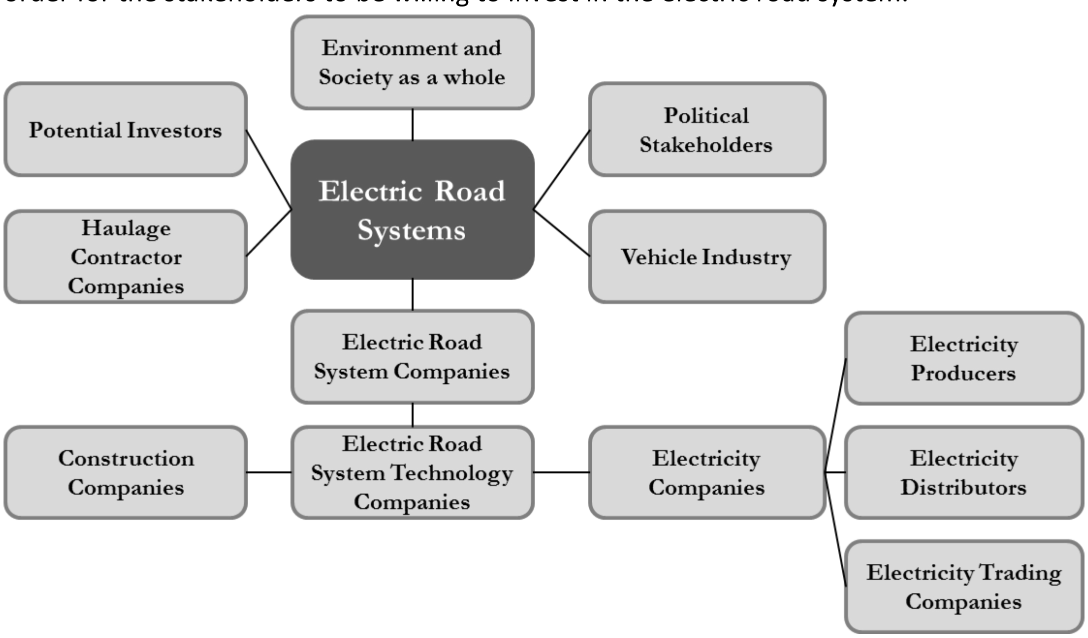

Figure 10: Electric Road System stakeholders [42].

As explained in chapter 3 and 6 two main drivers are the cost of fuel, which is currently 30 % of the total costs for HDV and the GHG emissions. According to [42] another benefit is longer vehicle lifetime. Drawbacks might be that the haulage contractor companies have to adapt to a completely new system and that the vehicle price will be higher. It is therefore crucial for these companies that the ERS is guaranteed to

be developed and functional in the future, both because of the ability to use the system and the ability of a good second-hand market for the vehicles. As stated in chapter 5, it is therefore necessary that the government or other relevant public authority make enough investments in order for haulage companies to start changing their fleets[2].

For the vehicle industry today, the internal combustion engine (ICE) is what is giving them a competitive advantage [42]. This component is included even in the hybrid vehicles.

Furthermore, the introduction of ERS may also attract companies currently not involved in the automotive, like energy, construction and the ERS technology companies. The large scale introduction will also require that construction companies to build infrastructure, electricity distribution companies to build additional power grid needed, energy companies to take care of the increased demand of electricity, and the ERS companies are those providing the different technologies [42]. As discussed in chapter 5, a key success factor is the involvement of political stakeholders in order to prepare an environment fostering the introduction of ERS. Even though it is stated that an ERS might lead to decreased energy usage, cost and CO_2 emissions, they highlight that the investment cost is high. Infrastructure investment, research funds, financial support and economic incentives are included in the investment cost. The current situation is that the uncertainties of ERS are still many but that the politicians want to learn more. The main question is; who will pay? In the ten scenarios the authors have defined, the business model will vary, but in all cases, there need to be public investment in the infrastructure, either only as public funding or through a private-public partnership due to the high risks of failure of ERS deployment

In an assessment by [41] there are positive aspects from electrified roads such as industrial policies, aspects of economic policy, transport policy considerations and environmental benefits, whereas the environmental feasibility study in this deliverable, only expect to see environmental benefits in very specific cases. The key findings regarding interoperability and legal implications supports also the findings in the feasibility studies of our ten scenarios, and also the risks (investment, ROI, TCO) etc are in line. This study present also a SWOT based on the input of twenty key stakeholders participated to discuss risks that can be identified in the ERS for heavy vehicles above 3,5 tons. Therefore, even if this SWOT is made for the Swedish market, the authors expect that it will holds for industrial stakeholders involved in ERS also outside Sweden.

[2] Interview with Swedish Energy authority.

Table 9: Results from SWOT analysis, translated from [41].

Strengths	Weaknesses
- Many want this, attuned stakeholders - Cost efficient and energy efficient transports - Technology experts within the transport sector - Follows transport policy goals - Secure energy supply (domestic) - We have an opened mind in Sweden – we don't get stuck - Quickly implementable, substantial benefits - Good energy mix in Sweden, lower direct CO_2 emissions - We don't have any oil industry - Relatively cheap, using existing infrastructure (compared to railways) - Far ahead in the development	- Technology development remains - Heavier and more expensive vehicles - Lack of knowledge about technology and maintenance of roads and systems - Sensitive and vulnerable infrastructure - Expensive infrastructure (compared to 0) - Not thinking enough in a long term, sub optimizing (passenger cars? – might lose business case) - We haven't chosen a technology - We fail to utilize the whole concept, we lack knowledge
Opportunities	**Threats**
- Could take a leading role in the work of standardization - Possibility of "Bonus Malus - truck" (tax-switching policies) - At the European level the cities have started – want to have a better environment - Demo is requested – basic industry enables - Competing technologies delivers sharp solutions - Business to do!	- Sweden may become marginalizing (small country) - Europe could slow down – slower transition, don't see the same possibilities, another electricity mix and agenda - Threatening existing political perceptions and business models - Goes against the existing mantra - Long term profits, the risk is now (needs a push from the public) - Hydrogen might become a competitor - Different standards may be developed - Other potential energy sources

Before future ERS can become widely implemented it is believed that the government will play an important role in infrastructure investment, incentives and decision-making. It is stated that the government will have to invest a lot of money upfront to make future users believe in the system[3]. It is probably necessary to electrify before haulage contractors and others will invest in ERS.

The European Commission generally promotes that the existing government green policy should be taken into consideration in each step of each project. In order to achieve energy efficiency improvements, CO_2 emissions reduction, reliable logistics and mobility, there are three "pillars" representing key areas, namely;

[3] Interview with Energy authority.

electrification of road transport, long distance transport, logistics and co-modality. In chapter 6 it is shown that from an environmental point of view, ERS is seems to have a positive environmental effect for example for HDV, since the comparative vehicle normally will use diesel or gas. It also shows that there are uncertainties related to the LCA. In addition, the macro-economic situation will to a large extent influence the political decision making process, which again will impact on the legal and regulatory work.

This deliverable was the first of several deliverables related to the socio-economic impact of a large-scale deployment of ERS and the FABRIC solution. Next step is to analyse in more detail and also taking country and regional specific aspects into account. In order to understand the different aspects (PESTEL) and also the different perspectives of the stakeholders, the authors need more data and information. An extension of the Swedish study for the European area would support this work. This might be achieved by carrying out a Delphi study as well as thorough analysis of the data delivered by the technical work packages in FABRIC.

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11 ANNEX

11.1 FABRIC ICT components

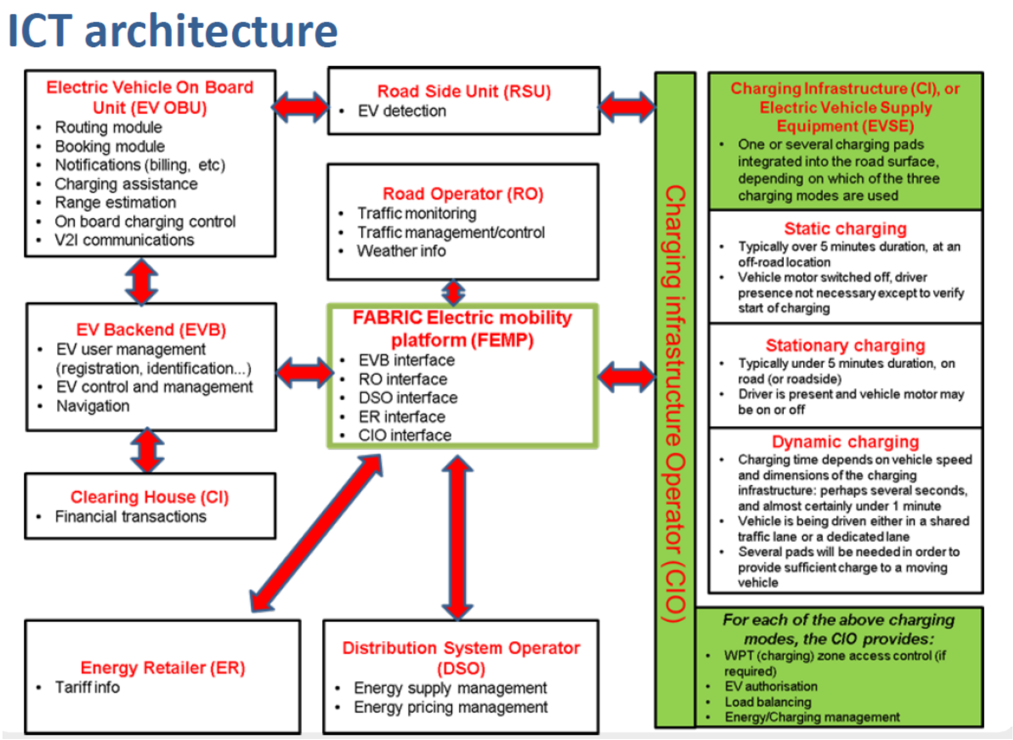

Figure 11 : Overview ICT component [15]

Stakeholders and subsystems:

- 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.
- Charging infrastructure (CI): This includes EV supply equipment (EVSE) at roadside for Wireless Power Transfer (WPT) to EVs.
- Road Side Unit (RSU): An RSU includes communication hardware (e.g. Wi-Fi, UMTS, etc.), and potentially gateways to interface with roadside infrastructure or with WPT infrastructure. Its main purpose is to enable communication between EV and charging control infrastructure.

- 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 Operator (CIO): This is the CI backend comprising the infrastructure management and operator interface. Therefore, it includes communication hardware (e.g. Wi-Fi, UMTS, etc.), application tool, and energy provision equipment for power transfer.

- The backend operator (EVB) is in charge of managing, operating and monitoring all charging functionalities. It also provides services to assist the EV charging process such as authentication, authorisation, accounting, monitoring of power transfer, etc.

- 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 perform access control and enforcement functions (if needed, i.e. in a closed access system).

- Those sub-systems marked in bold, represent the main stakeholders. In addition, the authors have to consider some other actors described below:
- EV customers (EVC): According to [EURELECTRIC 2013], the “e-mobility customer is a party that consumes e-mobility services using an electric vehicle, including electricity and charging services”. By considering the EVSP definition (RO) in [ISO_IEC 15118], EV customers are the parties who sign the contract with the EVSP. Likewise, EV customers also fall within the definition in [ISO_IEC 15118] for driver: “Person or legal entity using the vehicle and providing information about driving needs and consequently influences charging patterns”.

- Electric Vehicle Service Provider (EVSP): According to the concept of e-mobility Operator, as defined by [ISO_IEC 15118], the EVSP is the “legal entity that the customer has a contract with for all services related to the EV operation”. Therefore, an EVSP offers e-mobility services to EV customers, so that they can recharge their EVs, including the roaming service (eventually at any EVSE across Europe), or benefit from additional services while driving/charging. This provision of services, including the EV charging services (either at home, at work or at any other public parking location), is the feature that characterizes the EVSP.

- Clearing House (CH): Based on the definition in [ISO_IEC 15118], the CH is the entity mediating between two or more clearing partners to provide validation services for roaming regarding contracts of different electricity providers. In the context of FABRIC [Fricke 2012], the CH provides a couple of services which enable roaming: the contractual clearing and the financial clearing, which can be on top of the contractual clearing.

11.2 Additional policy factors

This section lists some more information policy and social factors as well as on projects that are relevant for the FABRIC project. The information on the different fiscal and social factors also indicate why the uptake of EV is so different within Europe.

Since this deliverable focus on feasibility, the section authors have been analysing existing research results in these projects in order to obtain the latest information on research progreass. These will be monitored also in the future.

EU projects on cities by fast chargers (Chademo or Combo technology).

- Rapid Charge Network (http://rapidchargenetwork.com/)

- Central European Green Corridor (http://www.verbund.com/cc/de/news-presse/news/2014/10/08/emobilitaet-schnellladenetzwerk-roaming)

National projects:

- In Spain and Portugal there are another two projects under preparation- an Atlantic corridor and a Mediterranean one. The highways included in these projects and some others that will come later, suppose and opportunity to make a test in real conditions, placing a dynamic charging corridor as prove of concept.

Additional fiscal and social factors influencing the take up of DERS

As explained in the main section, there are several policy factors that heavily influence both potential customer as well as service and product providers in their decision making process. Below, a short overview of the differences across Europe. These will play an important role in developing the right business models for the different areas.

Tax burdens

In 2014, the edition of the publication "Taxation trends in the European Union", compiles tax indicators in a harmonised framework based on the European System of Accounts (ESA 95), allowing for an accurate comparison of the tax systems and tax policies between EU Member States. The overall tax ratio in the euro area2 (EA18) increased to 40.4% in 2012 from 39.5% in 2011. In 2013, Eurostat estimates show that tax revenues as a percentage of GDP are set to continue rising in both zones. The tax burden varies significantly between Member States, ranging in 2012 from less than 30% of GDP in some countries to 45% in some others. Anyway, tax burden does not seems to be relevant as some

countries have a relative high level of taxes but are very proactive on EVs support (i.e. northern countries).

GDP Growth

Some countries clearly in a growth process are at the same time pro-active in EVs support. This is the case for Estonia 3%, Ireland 3%, Sweden 3%, Luxembourg 2,7%, United Kingdom 2,5% Norway 2,2%. Some other countries regardless the clear growth expectations as Latvia 4,1%, Lithuania 3,7%, Slovakia 3,1% Greece 2,9% or Spain 2% are no so active, as they have some other priorities requiring strong focus.

Public infrastructure investment

Another factor which could strongly affects the deployment of the electric infrastructure and the subsequent sales of EVs is the public investment. This is associated the public debt and the internal policy. Some countries with Germany at front are reluctant to expend in excess and some others consider just the opposite. Public investment is quite high in the Easter countries such as Estonia, Latvia or Lithuania due to the fact that they are receiving funds from the EC to converge with Western countries and due to the prepared and comparatively cheap manpower, but the authors must highlight that again countries as Netherlands, Sweden or Norway keep also a high public investment allowing and easing the deployment of electric infrastructures for EVs.

Unemployment's rates

Finally, the authors consider also the unemployment rates. Regardless the public investment or the GDP growth, if there is a huge unemployment problem, the country priority will be to solve that, consuming national resources to overcome and reverse the situation. Unemployment negatively affects countries as Greece (24%), Spain (24%), Cyprus and Croatia (18%), Portugal (14,8%), Slovenia or Italy.