FABRIC

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

Technical and user requirements

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
AAV	Aggregate Abrasion Value
AC	Alternating Current
ACC	Advanced Cruise Control
ADAS	Advanced Driver Assistance Systems
ADIS	Approved for FDIS Circulation
AMI	Advance Metering Infrastructure
ANSI	American National Standards Institute
ANW	Approved New Work
AWI	Approved Work Item
BCI	Bulk Current Injection
CBP	Circuit Breaker Panel
CEN	Comité Européen de Normalisation
C-ITS	Cooperative ITS
CISPR	Comité International Spécial des Perturbations Radioélectriques (International Special Committee on Radio Interference)
CPDC	Control and Protection Device Concentration
CWD	Charge While Driving
DC	Direct Current
DfT	Department for Transport (UK)
DMRB	Design Manual for Roads and Bridges
DoW	Description of Work
DSO	Distribution System Operator
DSRC	Dedicated Short Range Communications
E/E	Electrical and Electronic
ECE	See UNECE
ECU	Electronic Control Unit
EM	Electro-Magnetism
EMF	Electro-Magnetic Fields
EMC	Electro-Magnetic Compatibility
EPS	Electric Power System
ERS	Electrical Road System
ESD	Electro-static Discharge

ESS	Energy Storage System
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FDIS	Final Draft International Standard
FEHRL	Forum of European Highway Research Laboratories
FOR	Forever Open Roads project
GFL	General Feeding Line
HA	UK Highways Agency
HDV	Heavy Duty Vehicle
HGV	Heavy Goods Vehicle
HMI	Human Machine Interface
HSE	UK Health and Safety Executive
HV	High Voltage
HVIL	High Voltage Interlock Loop
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IEEE	Institution of Electrical and Electronic Engineers
ISO	International Organisation for Standardisation
ITS	Intelligent Transport Systems
JUG	Joint Utilities Group
kVA	Kilo-Volt-Amp(s)
kW	Kilowatt(s)
kWh, kWp	Kilowatt-Hours(s), Kilowatt-peak
LCZ	Length of Charging Zone
LDF	Local Development Framework
LDV	Light Duty Vehicle (sometimes Light Delivery Vehicle)
LEZ	Low Emission Zone
LHA	Local Highway Authority
LPA	Local Planning Authority
LTA	Local Transport Authority
LTP	Local Transport Plan
LV	Low Voltage
MfS	Manual for Streets

MHCW	Manual of Contract Documents for Highway Works
MOVA	Microprocessor Optimised Vehicle Actuation
MW	Mega-Watt(s)
MWh, MWp	Mega-Watt hour(s), Megawatt-peak
NRSWA	New Roads and Street Works Act
NTP	Normas Técnicas Particulares
ORR	UK Office of Rail Regulation
PAH	Landfill stuff
PCZ	Power per unit length
PMB	Protection and Measurement Box
PSRV	Polished Skid Resistance Value
PSV	Polished Stone Value
PV	Photo-Voltaic
REBT	Reglamento Electrotécnico de Baja Tensión (Spanish Low Voltage Code)
RESS	Rechargeable Energy Storage System
RF	Radio Frequency
SAE	Society of Automobile Engineers
SCOOT	Split Cycle Offset Optimisation Technique
SERRP	Strategic European Road Research Programme
SOC	State Of Charge
SRN	UK Strategic Road Network
SROH	Specification of the Reinstatement of Openings in Highways (UK standard)
SSD	Stopping Sight Distance
STDEV	Standard Deviation
SUMP	Sustainable Urban Mobility Plan
TC	Technical Committee
TDM	Travel Demand Management
TIILUP	Transport Infrastructure Integrated with Land Use Planning.
TS	Technical Specification
TSRGD	Traffic Signs Regulations and General Directions
TRL (technical)	Technical Readiness Level
UNECE	United Nations Economic Commission for Europe
UVA, UVB	Ultra-violet radiation, types A and B
Wh	Watt-hour(s)
WPT	Wireless Power Transfer

REVISION CHART AND HISTORY LOG

REV	DATE	REASON
1	12/08/2014	First draft, incorporating outputs from T3.2.1, T3.2.2, T3.2.3, T3.2.4 and T3.2.5
2	23/9/2014	Incorporate HGV requirements
3	21/10/2014	First nearly complete draft for participant comments
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5	21/11/2014	Final draft for peer review
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EXECUTIVE SUMMARY

The purpose of this deliverable is to examine and define the technological and user requirements for on-road power transfer solutions in order to design a system that is functional and can be integrated into the existing infrastructure. User needs and requirements aim to outline stakeholders expectations from a complete on-road power transfer solution. The requirements will feed into development of a gap analysis, specifications and on-road power transfer architecture. This deliverable integrates reports produced by FABRIC partners on each task; in total five reports were produced and each chapter covers the needs and requirements of specific stakeholders.

Road Authority Requirements

The requirements of road authorities were considered. Due to the limited number of current on-road charging equipment installations, when determining the requirements for such equipment, we have made no assumptions as to whether the equipment will use inductive or conductive power transfer, nor made any assumptions as the size of the equipment, whether it will need to be installed flush with the surface, can be buried below the surface or could be a pantograph system with overhead lines.

Firstly the physical requirements of the road owner were considered. These included size, weight, components (materials), strength, and robustness (heat resistance, fire resistance). As the road is a very harsh environment, and the cost of road maintenance is substantial, any equipment installed in or on the road must not compromise the longevity of the road or increase maintenance requirements.

The operation of the charging system must not adversely affect other users, both when operating and not operating. Further, the consequences of magnetic fields need to be considered, including the effect of magnetic fields on vehicles, people and pavements.

Installation and maintenance are key requirements for road operators. Road closures are expensive and disruptive so must be minimised both during installation and for maintenance. Further, the systems must not compromise the safety, ride quality and drainage requirements of the road.

The legal and regulatory requirements relating to road operators are examined, including overhead clearance, trench reinstatements, road installations, maintenance of strategic and non-strategic roads, roadside and in-road equipment and equipment safety.

The concept of the Forever Open Road (FOR) is considered. This is an initiative of the Forum of European Highway research Laboratories (FEHRL), which aims to create the next generation of adaptable, automated and resilient roads. The integration of power transfer infrastructure into the FOR will place significant requirements on the FOR.

Grid/distribution Requirements

The requirements for grid/distribution are usually based on standards that have been set by IEEE, IEC and national governments. These standards aim to ensure reliability and availability of the power supply, as well as safety and protection. There are no specific approved standard which outlines the connection of power transfer equipment to the grid but there are standards under development to address dynamic power transfer such as IEC 61980 and SAE J2954.

Different models have been assessed, in order to analyse the impact of power transfer infrastructure design on power fluctuations. It is concluded that gaps between power transfer pads should be avoided, in order to obtain a more continuous overall demand. The investigation into sizing for a storage system has been carried out for several traffic scenarios and several levels of smoothing – the process by which fluctuating power demands and outputs are compensated for to produce a more regular or smoothed power level. The main conclusion is that high-power and low-energy storage systems can reduce charging demand fluctuations effectively. The power requirement for the storage system is largely independent from the smoothing scenario, but dependent on the traffic model. All the traffic models considered give results in a range between 1 – 12 MW of aggregated power. Finally, the integration of solar PV has been studied. The daily profiles of solar generation and demand from on-road charging are very similar, which opens a great opportunity for self-consumption schemes. Although solar generation reduces energy demand, the daily power peak in the evening cannot be reduced significantly.

Local Authority Requirements

The requirements for integrating on-road power transfer infrastructure for electric vehicles (EVs) with transport and urban planning requirements from a national and local perspective are identified and examined.

The technical considerations section investigates the requirements for power distribution and how electrical power may be delivered to the charging infrastructure within existing regulations. Examples from existing inductive power demonstration projects are noted, as well as a tram project in France. The potential impacts of these distribution systems on local planning regulations are identified.

The requirements by city and local authority for on-road EV infrastructure that may be introduced into urban roads will be determined by a range of decisions made at national, regional or European level. How the various local planning bodies operate in this environment are considered, and includes a detailed study into regional and national and roles and policy development.

Finally, transport and urban planning requirements are considered. The key purpose of transport planning is to plan, design, deliver, manage and review transport, balancing the needs of society, the economy and the environment. A detailed description of the planning process operating in the UK is given. This includes:

- Land use planning which considers how land is allocated and used.
- Infrastructure design, planning and construction which considers the strategic and operational planning of road and rail infrastructure. Various planning guidelines and standards will need to be taken into account when implementing EV power transfer infrastructure.
- Impact on other road users, particularly in urban areas where roads are not just infrastructure, but are considered as a public place. Hence any infrastructure should take into account how the public use the road space, and planning needs to take this into account. Multi-modality and other travel behaviour issues also need to be taken into account.

Transport and traffic management can make use of policies and strategies to reduce travel demand during peak periods, and effective use of planning policies can assist in this.

Vehicle manufacturer requirements

This chapter concentrates on vehicle manufacturer's needs and requirements. There are existing standards for electrical/electronic devices, electrical vehicles and general vehicle requirements. IEC and SAE are also developing standards specifically designed to address dynamic or wireless power transfer methods, such as IEC 61980 and SAE J2954 which addresses electric vehicle wireless power transfer systems.

The power demand for a moving car is between 20-30 kW, and for a Heavy Duty Vehicle (HDV) it is 125kW. It can be concluded that the efficiency of the system should be higher than 85% for a car and 80% for a HDV. It is anticipated the frequency of the power transfer systems should be between 10-150 kHz for safety reasons. The typical voltage range for a car is normally 150-400 V; however, voltage range can be higher than 400V for HDVs. The battery packs should be sized to ensure that the range is sufficient. The current state of the art indicates that the average range of an electric vehicle is between 150 and 200 km.

Safety and EM environment

This section investigated the safety and EMC aspects in relation to the dynamic power transfer. The study covered human health and safety, electrical safety and EMC requirements.

There are standards with regards to electrically propelled vehicles; these are ISO19363, IEC61980, and SAE J2954. The safety limits for human exposure to electromagnetic fields are determined by the Institute of Electrical and Electronic Engineers (IEEE) and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). EMC requirements for on-board equipment are under consideration in IEC 61851-21-1. EMC requirements for installation of electrical and electronic components in vehicles can be classified in two categories tests at component level and tests at vehicle level. Electrical safety requirements for on and off board devices are based on protection, bonding, insulation, and temperature of the accessible parts.

1. INTRODUCTION

The purpose of this Work Package 3.2 is to examine and define the technological and user requirements for on-road power transfer solutions in order to design a system that is functional and can be integrated into the existing infrastructure. User needs and requirements aim to outline stakeholders' expectations of a complete on-road power transfer solution. The requirements will feed into the development of a gap analysis, specifications and on-road power transfer architecture.

The FABRIC project aims to assess the feasibility of both wireless and conductive on-road power transfer solutions. Therefore, when reviewing the stakeholder needs and requirements in WP3.2, it is important to consider both power transfer solutions. However, as there are not any defined specifications for power transfer power transfer solutions and the project partners may seek to recommend changes / amendments to proposed power transfer solutions in FABRIC, nothing should be excluded at this stage.

WP3.2 comprised five tasks which were undertaken by the project partners and which provided the inputs to this report. The five tasks were:

- **Task 3.2.1:** Needs and requirements for the existing road infrastructure.
- **Task 3.2.2:** Needs and requirements for the grid.
- **Task 3.2.3:** Needs and requirements for the transport and urban planning.
- **Task 3.2.4:** Needs and requirements for the vehicle manufacturer.
- **Task 3.2.5:** Requirements for on-road power transfer solutions with respect to electromagnetic fields and emissions.

The outputs of WP3.2 will be used for WP3.3.3 gap analysis, WP3.4 Specification and WP3.5 Definition of System Architecture. Figure 1 shows the deliverable inputs and outputs.

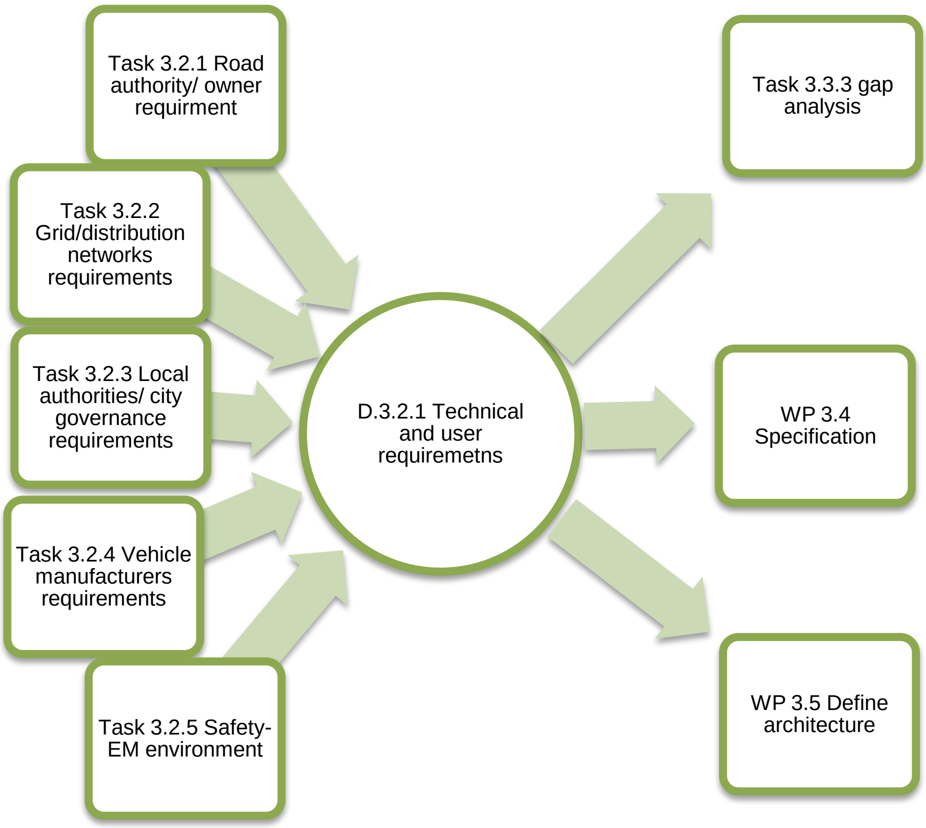

Figure 1: Deliverable inputs and outputs

2. METHODOLOGY

2.1. General approach to methodology in WP3.2 Tasks

This section describes the high-level methodology used to deliver tasks in WP3.2. The FABRIC partners represent a wide range of stakeholders with extensive expertise in the field of wireless power transfer, transport and transport infrastructure, vehicles, electrical distribution networks and transport research. In addition to their own expertise, many of the partners have wide ranging links into industry representatives to gather information where their own expertise may be limited. As such, this methodology has been designed to make use of this body of expertise as the most efficient way of capturing and refining the requirements for dynamic charging systems.

The requirement generation was divided into five tasks. These were:

- Road authority and road owner requirements
- Grid and distribution requirements
- Local authority and city governance requirements
- Vehicle manufacturers requirements
- Safety and electro-magnetic interference requirements.

Each of the tasks was assigned a task leader from a company with relevant expertise.

The lead partner for the work package developed an overall information gathering process. This is shown diagrammatically in Figure 2. The large box encapsulates the process to be followed by each task leader in capturing requirements. The output from each task was then combined into a single overall requirements document (this document) and checked for consistency by the work package leader, following which the document was reviewed by all partners, and finally by the FABRIC peer reviewers.

Each of the task leaders in this work package was asked to follow this methodology to gather information on their own particular area of expertise. It was recognised and encouraged that where appropriate, each task leader may want to adapt the methodology slightly in order to more effectively deliver the work required and maximise the use of available expertise from task partners.

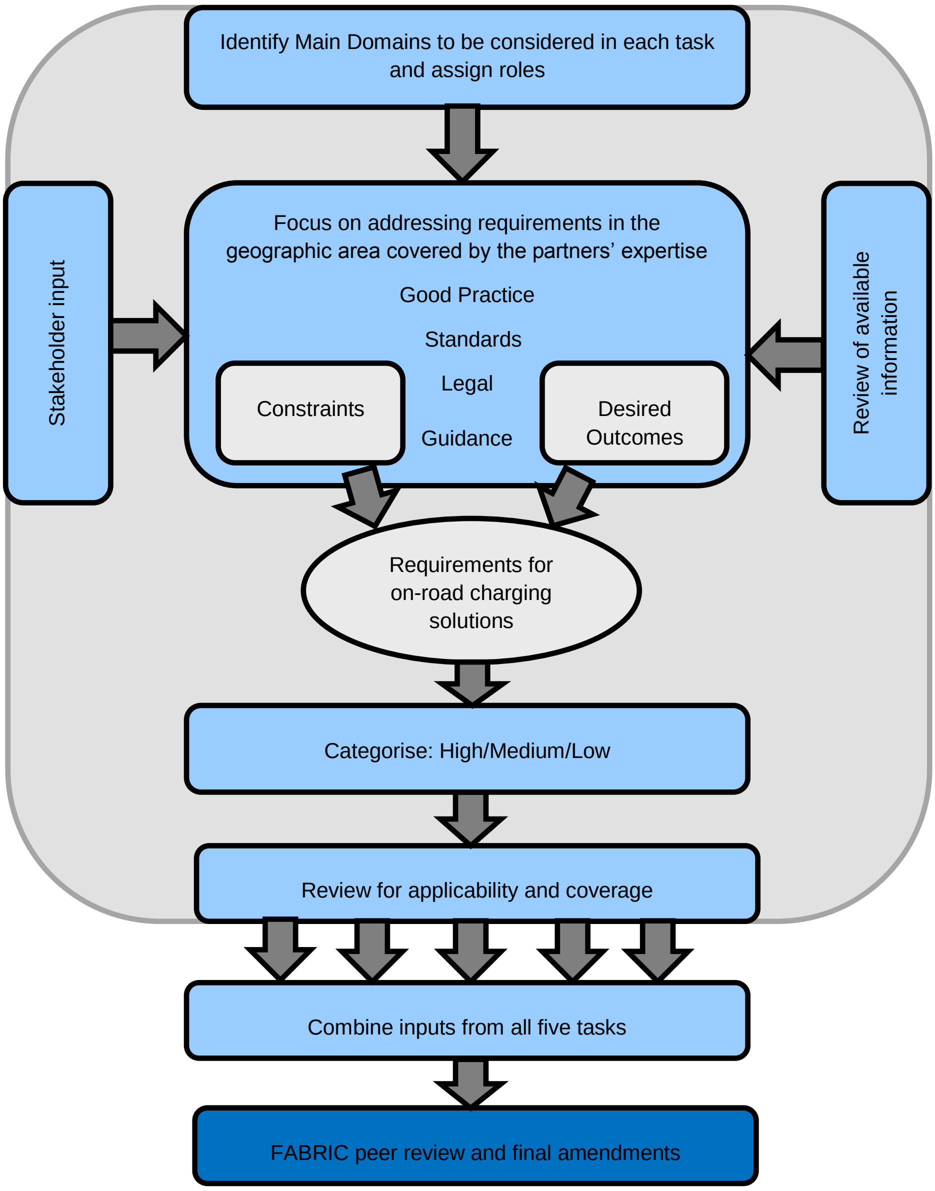

Figure 2: Methodology diagram

Generally the following key elements of the methodology were followed in each task in order to facilitate the integration of all the requirements into a single deliverable at the end of WP3.2:

As very few requirements specifically around on-road power transfer solutions are known to exist; each task leader was encouraged to use their expertise to identify key domains within their respective task topic that could be affected in the event of the introduction of on road power transfer solutions. This does not require an in-depth understanding of possible power transfer solutions or their exact specifications. The requirements are based on an in-depth understanding of the technical area being considered and the investigation of all possible

requirements (at this stage) given the predominantly undefined nature of on-road power transfer solutions.

Requirements could be based either on constraints around the current functionalities of the specific technical areas (i.e. corresponding to the tasks in WP3.2: Road infrastructure, Grid and distribution network, Local and city authorities, vehicle manufacturers, Safety of EM environment), or desired outcomes achieved by the implementation of on-road power transfer solutions by stakeholders in those same technical areas. Then these were turned into specific requirements for on-road power transfer solutions.

Requirements are broken down into the following four levels

- Legal
- Standards
- Good Practice, Guidance
- Policy.

The general approach was to make the best use of the expertise available in each Task and ensure all Task partners were involved in delivering the work as per the DoW. If the Task required a highly regionally-focused approach, such as road infrastructure construction, then the Task leader was encouraged to engage with the wider industry via industry bodies active in the task,.

The following sections take a more detailed look at key elements of the methodology.

2.2. Origins of requirement

It is very likely that there are very few existing requirements that are directly based on-road power transfer solutions. This is why it was important for each Task leader to use their expertise in the respective technical areas to make links between seemingly unrelated requirements and the introduction of on-road power transfer solutions. Crucially, this means that the aim has not been to try to second guess what the specification of the possible on-road power transfer solutions would be (this will not be clear until the end of WP3.4) but rather understand why these would be important – is there something specific about the technical area being considered that makes it important? What is a particular functionality or design element of an on-road power transfer solution? If so, then we need to understand why and turn this into a requirement for a future on-road power transfer power transfer solution. This means that some

requirements may end up obsolete if we find that no power transfer solutions breach them. Some may be discarded or combined before the final draft is produced but it is better to start with an exhaustive list and then work our way down then miss something potentially important at the beginning.

For example, in the case of road construction, there are currently no requirements that specifically address the installation of on-road power transfer solutions. However, there are very clear standards on road surface skid resistance, therefore, if on-road power transfer solutions are surface mounted (or flush with the road surface) then the limits stated in these requirements.

2.3. Nature of requirements

Requirements are based either on;

- Constraints around the current functionalities of the specific technical areas (i.e. corresponding to the tasks in WP3.2: Road infrastructure, Grid and distribution network, Local and city authorities, vehicle manufacturers, Safety of EM environment), or
- Desired outcomes achieved by the implementation of on-road power transfer solutions by stakeholders in those same technical areas.

Constraints are based on existing way of doing something in the technical area of WP3.2. These can form the basis of real requirements at present but of course as these do not take into account on-road power transfer solutions, there may be scope for the Business As Usual approach to be adapted to accommodate the on-road power transfer solutions. In either case, this will form the basis of the requirements.

The other nature of the requirements could be based on the desired outcomes from a particular stakeholder which may consider these as precondition or a “nice-to-have” functionality desired to make the investment, or to allow the introduction of on-road power transfer solutions in their domain.

For example, considering the example of road operator and road construction used above, requirements around impact of on-road power transfer solutions on skid resistance is based on an existing standard and is therefore is a constraint. However, it could be that after discussing with road operators, they would consider on-roach power transfer solutions viable if they are

able to perform some other functionality alongside energy provision, e.g. de-icing of roads or be used as sensors to assist with road integrity monitoring or traffic counting.

2.4. Categorisation of Requirements

All requirements are categorised into the following four levels:

- Legal.
- Standards.
- Good Practice / Guidance.
- Policy.

A well as categorising into these levels, each requirement has a subjective indication of its relative importance / scope for change. For example:

- High (Very important or cannot be easily changed due to current constraints, legislation or legal constraints or safety critical standards).
- Medium (Medium level of importance or cannot be changed without the intervention of national government, e.g. policy change, or change to non-safety critical standards).
- Low (Low level of importance, a nice to have requirement or can be easily amended based on good practice or guidance).

2.5. Use of expertise from each partner in each Task and peer review from industry bodies

The work has been distributed according to the expertise of each Task participant, in accordance with the DoW. Where the expertise or requirements are region–specific, industry bodies have been identified who would be willing to review the draft outputs from FABRIC in order to review their applicability to other European regions.

3. ROAD AUTHORITY / OWNER REQUIREMENTS

3.1. Introduction

The purpose of this section is to identify the key requirements for on-road power transfer solutions from the Road Authority / Owner point of view. The requirements may be based either on existing or foreseen constraints in terms of how the on-road power transfer solutions should interact with the road, the road operation and road maintenance but also, seek to identify potential opportunities, and additional services that could be made possible by the introduction of on-road power transfer solution.

Road Authorities / Owners prioritise the ability to provide road infrastructure that facilitates the movement of people and goods in a way that minimises adverse impacts of congestion while attempting to keep the cost of providing such infrastructure as low as possible. However, many Road Authorities / Owners are either owned, sometimes in part, by national governments or provide a service based on requirements defined by the national governments. Therefore, the increased attention on road transport decarbonisation is being gradually passed on to Road Authorities / Owners where, their role can be anywhere from directly reducing CO2 emissions from the road network they are responsible for to acting as an enabler for the national goal of road transport decarbonisation. It is therefore important to fully understand the requirements of this particular group of stakeholders as they will be key to any future implementation of on-road power transfer solutions.

3.1.1. Scope of this work

In Work Package 3.2, Task 3.2.1, the requirements for integration of on-road electrical power transfer solutions, with existing road infrastructure were examined and identified. Today's road infrastructure is complex and costly to integrate and maintain. Contact (conductive) and contactless (inductive) on-road electrical power transfer systems will require careful and thorough integration with road infrastructure in order to ensure their optimum functionality and minimise impact on safety and cost aspects of road infrastructure. During this task the following topics were addressed:

- Requirements for structural integrity of pavement.
- Requirements for safety of road surfacing.

- Requirements for maintenance and resurfacing.
- Requirements with the Forever Open Road (FOR) concept.
- Requirements for location of on-road power transfer system components by the road side.
- Requirements for interaction with, and effect on, other roadside equipment.
- Requirements for cost/complexity and time-frame for installation.
- Requirements related specifically to heavy duty vehicles (SCANIA responsible).

3.1.2. Methodology

The methodology used for undertaking work in Task 3.2.1 was based on the overall WP3.2 methodology; see Figure 2. In order to cover the topics described in the scope, the following requirement domains and sub-domains were identified and investigated:

The requirements were split in the following domains:

- Physical characteristics: size, weight, components (material), robustness, heat and fire resistance.
- Consequences of the operation of the system on the on-road power transfer solution such as; temperature, magnetic field, electric field.
- Performance of the services and their impact on: speed of vehicles, mix of vehicles, efficiency, switch on/off.
- Installation and maintenance: positioning, binding, procedure, time schedule for installation, dealing with seams, frequency of maintenance, waste of components.
- Safety: vehicles, passengers, pedestrians.
- Legal and Regulatory

The above requirement domains were then analysed regarding the following issues:

- Physical characteristics of the pavement: structure, evenness, skid resistance, waterproofing.
- Maintenance of the pavement.
- Network management: speed of vehicles, coexistence of the different types of vehicle, management of incidents and traffic jams on or near the power transfer zone.
- Engineering structures adjacent to the road: bridges, tunnels.

- Road side equipment: variable message signs, sensors, ITS transceivers (Bluetooth, DSRC, C-ITS).
- Communication devices for emergency and operation.
- Vehicle movement (deviation from lane centre line).
- People (drivers, passengers, pedestrians).
- Legal and regulatory.

Each requirement was classified in a category representing the origins of the requirement. The origin may be:

- Statutory legislation.
- Statutory rights.
- Relevant standards.
- Best practice guidelines.

An attempt was also made to prioritise the requirements based on how difficult is it to implement a change or influence this requirement. This was determined through a combination of the importance of the source and research team's expert opinion. For example:

- High (Very important or cannot be easily changed due to current constraints, legislation, legal constraints or safety critical standards).
- Medium (Medium level of importance or cannot be changed without the intervention of national government, e.g. policy change, or change to non-safety critical standards).
- Low (Low level of importance, a nice to have requirement or can be easily amended based on good practice or guidance).

This is a high level indication of possible importance and should be used for guidance only.

3.1.3. Geographic coverage

The work in this task was primarily carried out by SANEF and TRL and therefore, the majority of the requirements are based on the information available in France and the UK. However, in order to make sure that the outputs from this work are useful and applicable across Europe as much as possible, feedback was sought from other European countries' Road Authorities / Owners on the identified requirements. Where differences in requirements were identified, these were highlighted in the requirements tables provided in the appendices.

3.1.4. Considered technology

Whilst on-road electrical power transfer solutions currently exist, to date, installations in roads open to normal traffic are very limited and no performance data has yet been published from these sites. Therefore, in determining the requirements for such equipment, we have made no assumptions as to whether the equipment will use inductive or conductive power transfer, nor made any assumptions as the size of the equipment, whether it will need to be installed flush with the surface, can be buried below the surface or could be a pantograph system, with overhead lines. We have considered the system to look like any one of the options given in Figure 3, i.e. the system could consist of:

- A primary module either installed in the road (flush with the surface or buried), or overhead lines.
- Wires connecting these primary modules to
- Road side equipment.

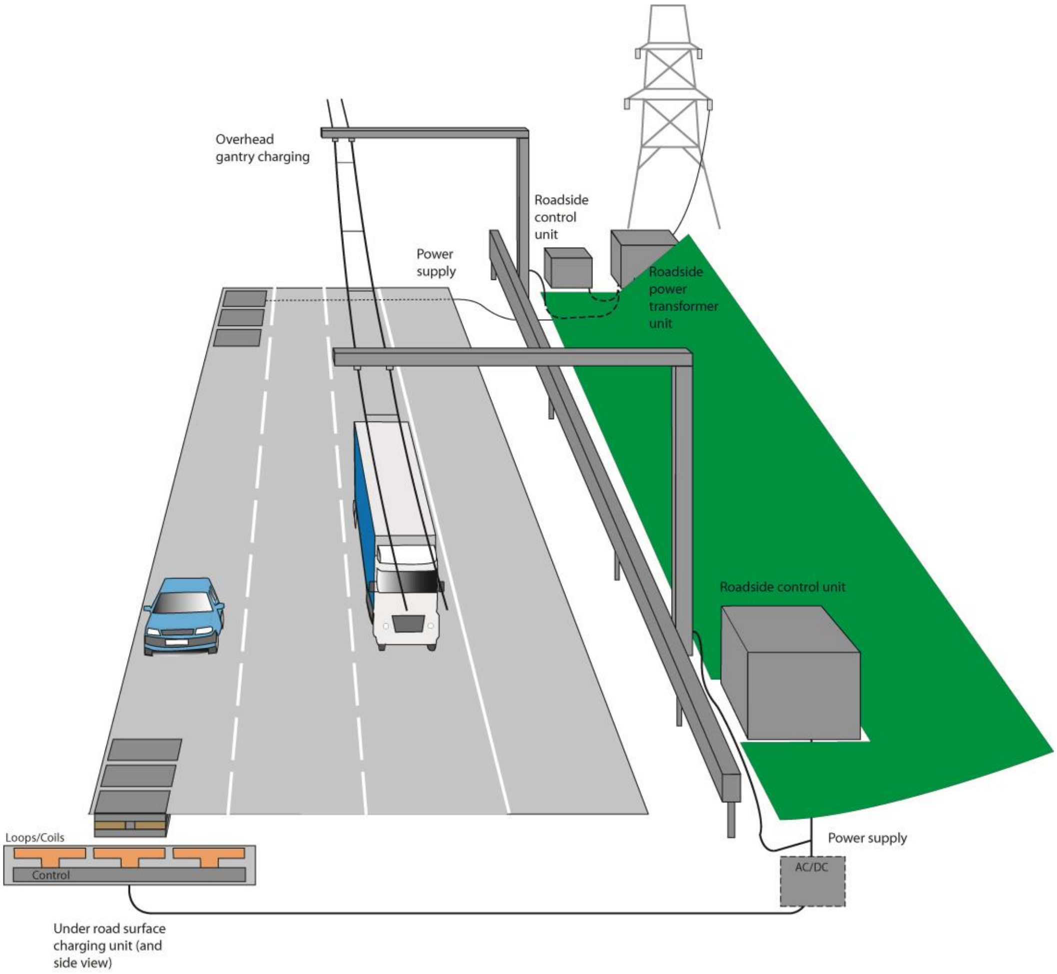

Figure 3: Representation of possible on-road electrical power transfer solutions.

This then results in 5 main variations of an on-road power transfer solution (from the point of view of installation) as detailed below. Within each of these there are anticipated to be differences specific to each power transfer solution in terms of topology, dimensions, additional equipment, and so on.

Five varieties of on-road power transfer solution installations:

1. Wireless systems buried in the road (Figure 4a)
2. Wireless systems flush with the road (Figure 4b)
3. Wireless systems on the road (Similar to Figure 4b, but with the wireless system protruding a few centimetres above the road surface)
4. Conductive systems flush with the road (Figure 4c)
5. Overhead line systems (Figure 4d).

(a) Wireless system under the road

(b) Wireless system flush with the road

(c) Conductive system Flush with the road

(d) Overhead line system

Figure 4: Different varieties of on-road power transfer solution installations

3.2. Road Owner Requirements

3.2.1. Physical Characteristics

This requirement covers any existing constraints on the physical characteristics of an on-road power transfer solution, which may impact the road infrastructure. These requirements are divided into further subsections as detailed below. Further information on physical characteristics can be found in appendix 9.1.1

- Size.
- Weight.
- Components (Material).
- Strength.
- Robustness, heat resistance, fire resistance.

Size: There may be existing requirement in some countries regarding the size of devices installed under the road (e.g. in the UK, the SROH section 1.8.1 states that any apparatus

greater than 20 mm external diameter will not be permitted in the road unless special circumstances exist), although these requirements would probably be adapted in case of installation of charging systems that do not exist yet. However, the size of the system must weaken neither the strength of the structure of the pavement, nor the wearing course.

Regarding the size of an “overhead” system, it must be compliant with the clearance of the bridges or tunnels and allow the safe transit of extra-large vehicles when authorised on the road. Indeed it would not be cost effective to rebuilt or readapt all the bridges or tunnels to install a charging system. Furthermore as overhead systems consist of exposed live conductors, minimum clearances to the ground are required for safety reasons, and these are often codified in regulations. For example, in the UK the minimum clearance to overhead live wires in publically accessible areas is 5.2m.

Weight: There are no specific requirements at present for the weight of an on road dynamic power transfer system. However, the weight of the system must not accelerate the ageing of the structure of the pavement. The acceleration of the ageing of the structure of the pavement results in the increase of frequency of maintenance operation and consequently significant costs.

Components (material): There are no specific requirements regarding materials that can be used in construction of systems that will be installed in or under the road surface. However, any undesirable chemical or mechanical interaction between the system components and materials, and the road material that results in damage to the road and environment should be avoided.

Strength: The system must be strong enough to withstand weight and vibrations of the types of vehicles that can be expected on the road regularly and in exceptional circumstances. For example the power transfer solution should be able to maintain its structural integrity under 40 tonne heavy vehicle or pressure exerted by the machinery during road works.

Robustness, heat resistance, fire resistance: Requirements for on-road power transfer solutions in terms of robustness heat and fire resistance should match those expected from the road in order not to minimise unnecessary maintenance and possible disruption: humidity, rain, frost, heat, snow, UVA, UVB, at least to the same standard as the road

The system must withstand;

- The heat of the mix (120-200°C) during the laying of the upper layers of the pavement.
- The impact of the de-icing salt.
- The system should be able to resist a fire on the road or a spill of hazardous material.

3.3. Consequences of the operation of the system

These requirements describe impacts of the system operation on the road surface that should be avoided. The system in operation must not alter the structure of the pavement. A change in strength, skid resistance, evenness, waterproofing all have an impact on the mechanical characteristics of the road and may result in safety problems or acceleration of the ageing of the infrastructure. More detailed information can be found in appendix 9.1.2.

3.3.1. Temperature

The temperature generated by the operation of the system must not alter the structure of the pavement. The temperature of the system combined with the ambient temperature of the pavement must be below 40°C.

3.3.2. Electromagnetic field

There are no specific requirements for magnetic fields beyond EMC standards for road-side infrastructure. The electromagnetic field generated by the system must not interact with the roadside equipment such as variable message signs, optical fibre, optical and magnetic sensors (including inductive loops), traffic lights, ITS transceivers and so on. The magnetic field generated by the system must not interact with communications devices used by emergency teams and maintenance teams.

It could be possible to improve the magnetic coupling and field direction through use of certain materials in the pavement. Industry suppliers of pavement materials can provide information on potential performance issues with the power transfer equipment within the pavement. Use of alternative materials is possible but may need approval from the relevant bodies, for example in the UK this would be from the road operator or the road authority.

Currently there is no legislation governing EMF emissions within pavement structures. The only legislation that could affect charging systems relies on the safety of workers or public (see §7.3).

3.4. Performance of the charging services

3.4.1. Effect on traffic flow

From a network performance point of view, on-road power transfer should not cause traffic conditions to change state from congested (but free-flow), to flow breakdown. Traffic theory indicates that for every flow level, two traffic states exist (free-flow and stop-start). Once flow break down has occurred, it can take several hours for conditions to recover. Further information can be found in appendix 9.1.3.

The performance of the charging system should cope with the following requirements:

- The system should be capable of operating at the average speed of vehicles in a particular lane. On the UK network for example, average speeds in the three running lanes of a typical motorway during the inter-peak period are 60, 70 and 80 mph (95, 115 and 130 km/h). It may be acceptable for a system to operate at a maximum speed slightly below the speed limit on the motorway, for example 100mk/h on a 130km/h motorway.
- The system should not slow power transfer vehicles down significantly. If vehicles are travelling at higher than the average speeds quoted above, and are forced to slow during power transfer, this could cause braking by following vehicles and the potential for flow breakdown with consequent safety risks.
- Stopping the charging system (e.g. in case of emergency) must not generate abrupt decrease of the speed of power transfer vehicles
- The system must deal with the gradient of speed generated by the mix of different kind of vehicles (light vehicles and HGV). HGVs travel at around 90 km/h (56mph). If the scheme caused power transfer vehicles to travel slower than this, then HGVs would be forced to lose speed. This would generate risky behaviours and be extremely unpopular with HGV drivers and freight companies.
- If not all lanes are being used as power transfer lanes, then the scheme could have an adverse effect on network management, depending on the number of power transfer vehicles in the vehicle fleet. If the proportion of power transfer vehicles is high, then the number of vehicles wanting to use the power transfer lanes will exceed the capacity of those lanes, causing congestion in the power transfer lanes.

- The system should be able to cope with vehicle deviations from the centre line in each lane and maintain acceptable efficiency at a deviation of 15cm from the centre line.
- The power transfer system will need to allow for two vehicles travelling close together, and potentially requiring power transfer at the same time. The most common time headway on busy motorways is 1.1 seconds, equivalent at 80km/h (50mph) to a gap between vehicles of 20m. In busy periods, the gaps between vehicles can vary widely - see Figure 5. 1% of drivers are travelling within 4m of the vehicle in front. This suggests that the power transfer system will need to be able to cope with vehicles arriving 4m apart, with some gaps down to as little as 2m.

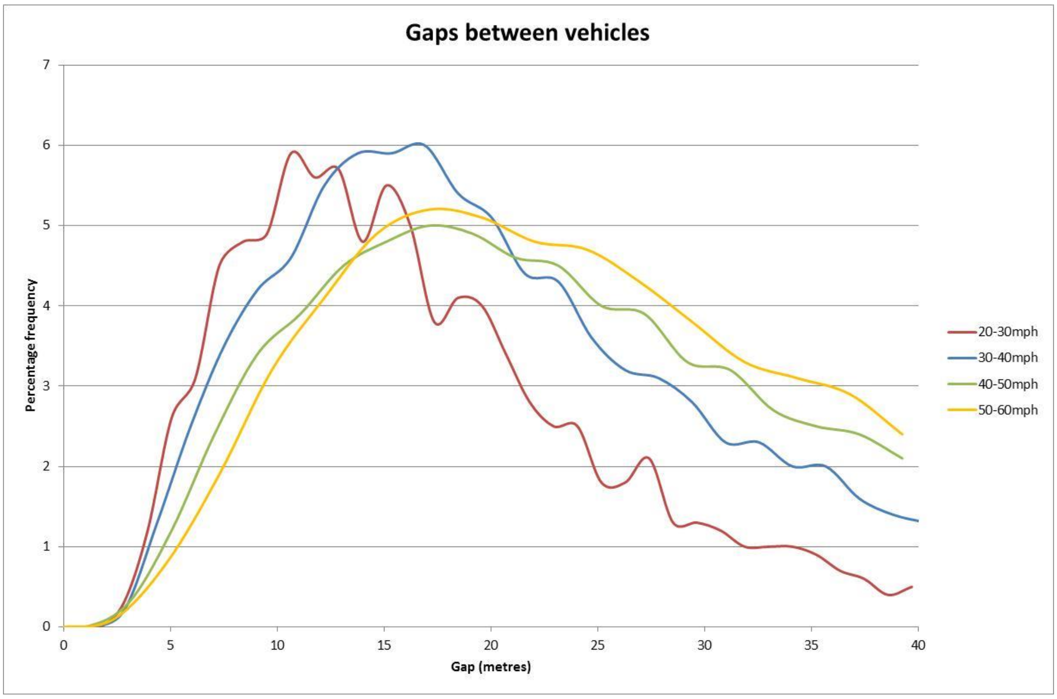

Figure 5: Headway between the vehicles.

- Every network will have locations where the capacity is lower – typically close to busy junctions, in particular the merge areas. Traffic joining the motorway causes braking and lane changing by filling gaps between vehicles already on the motorway – see Figure 6. The installation of charging systems in these bottleneck areas needs to be carefully considered. On the one hand, the lower speed of vehicles in these areas improves the efficiency of power transfer, but on the other hand the installation of this equipment must not further compromise the already reduced flow at these points. If research shows that

charging equipment reduces capacity where it is installed, then it should be avoided in bottleneck areas.

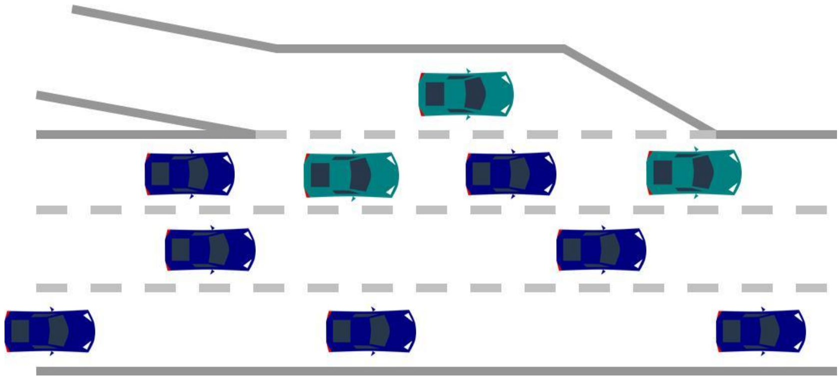

Figure 6: Merging in the motorway.

- Network operators should have an input into the operational design of the scheme to ensure the effect on traffic flow can be accommodated without detrimentally affecting other high-technology road management strategies like Managed Motorways.

3.4.2. Pavement requirements

- The charging system must be efficient through a wearing course of at least 4cm thick.
- The charging system must be efficient if the wearing course is soaked with water (especially in case of porous asphalt)
- Installation of systems flush with the surface, where the skid resistance of the surface is lower than that of the surrounding pavement, should be avoided at high risk locations e.g. on roundabouts, roads with tight curves.

3.4.3. Regarding emergency situations

- The charging system should be capable to be switched off remotely e.g. in case of an incident or road maintenance.
- Emergency stopping spots must be locally implemented (near the charging sites) to be activated in case of emergency.
- The system must stop automatically as soon as an abnormal condition is detected (e.g. hot spots).

3.5. Installation

3.5.1. Positioning

The number of lanes equipped must comply with the number of charging vehicles expected on a road. If not enough lanes are being used as power transfer lanes, then the scheme could have an adverse effect on network management, depending on the number of power transfer vehicles in the vehicle fleet. If the proportion of power transfer vehicles is high, then the number of vehicles wanting to use the power transfer lanes will exceed the capacity of those lanes, causing congestion in the power transfer lanes.

Concerning the “in-road” or “on-road” systems, it is recommended that these are positioned outside the natural wheel tracks to limit the physical constraints on this system.

The positioning of the “in-road” system in the pavement must not weaken the structure. Especially, it must not generate cracks or other distortions of the upper pavement layers (wearing course and binding course). Ideally, the system will be positioned in the binder, under the wearing course. This allows the system to be protected by the upper course of the pavement from the friction of the wheels and from weather impacts. Furthermore, it is compliant with maintenance practices (de-icing, snowplough) and allows a suitable transverse flow of water on the wearing course.

The positioning of the “on-road” system must not affect the skid resistance of the surface (especially for the safety of the motorcycles), the evenness, and the waterproofing of the wearing course. The system must also allow the transverse flow of water on the wearing course.

The positioning of an “overhead line” system must be compliant with the clearance of the bridges or the tunnels, and must allow the safe traffic of extra-large trucks when authorised on the road

The roadside equipment must be installed behind the roadside barrier if there is one. The safety distance between the edge of the pavement and the roadside unit must be respected. The distance depends on the type of the road (e.g. in France this is 10 m for motorways, 7 m for other new roads, 4m for other existing roads). Installation of road side equipment may not affect the highway authorities as their responsibility ends at the edge of the highway and in some

cases this would mean that road side equipment would need to be installed in private land adjacent to the highway, resulting in agreement with local land owners and farmers being required

The conductors connecting the charging unit to the roadside equipment must not prevent the traffic of the vehicles for winter maintenance (snow removal and the transit of vehicles for the maintenance of the shoulder (sweepers, mowers, trimmers etc.). Installation of road side equipment and the cables connecting the primary module to road side equipment should not disrupt the existing drainage at the edge of the road (e.g. gulleys, ditches) and the communication wires (e.g. optical fibres).

3.5.2. Binding

The "in-road" system must be firmly attached to the road in order not to be damaged by the movement of construction vehicles (finisher, compacter) during the implementation of the upper layers of pavement.

The "on-road" system must be firmly attached to the road in order not to be damaged by the movement of vehicles (regular traffic flow, acceleration, braking) and by winter maintenance vehicles (especially those equipped with a blade for snow removal).

3.5.3. Procedure

The time frame taken to install any equipment will have an effect on the capacity of the road network, if road or lane closures are required. Reduced capacity could cause congestion on heavily trafficked roads, particularly where a good quality diversion is not available. It will also affect journey times and road availability.

For cost-efficiency reasons, implementation inside the pavement of an existing road should be carried out jointly with a maintenance operation (that occurs every 12-15 years on intercity motorways in France – maintenance operation consists in scarifying the upper layers and then re-gravelling them).

The installation of a charging system has to be integrated as part of overall road construction and maintenance plans to ensure that the effects on the implementation of such a system are taken into account in the studies and in the definition of the procedure of roadwork.

In case the time schedule for installation is not compliant with a maintenance operation, a dedicated procedure for implementation must be defined case by case with the road operator to guarantee that:

- The needed roadworks are compliant with the legal requirements of the country of installation.
- The mechanical characteristics of the road are not affected by the implementation (strength, evenness, skid resistance, waterproofing – particularly if the implementation generates seams on the pavement).
- The safety and the traffic flow are well-managed during the implementation.
- No roadside equipment is damaged by the works.
- The engineering structures (bridges, tunnels) adjacent to the road are not damaged.
- The roadworks are conducted in a period when the traffic flow allows it (it may be restricted to the night, between 22h and 5h, or less, for the most used roads).
- Any required roadwork are performed according the state-of-the art for the kind of road and the country of installation

3.5.4. Time schedule for installation

In case implementation is conducted jointly with a road maintenance operation, the time schedule for the installation must fit with the global schedule of the maintenance for cost-efficiency reasons (e.g. losses generated by one night of delay in the laying of tarmac are around 150 k€ on a French motorway).

3.5.5. Dealing with seams

The installation of the system should be carried out in one operation. If not possible and if seams are generated, a dedicated procedure must be defined to guarantee the ride quality (that depends on the kind of road, and the country – must be agreed with the road operator case by case).

Ride quality is hugely dependant on the extent and location of the on-road electrical power transfer equipment (i.e. located in the wheel paths or not) as well as whether it’s flush with the surface of the pavement, or slightly above or below the top of the pavement. Any “stepping” between the inductive power transfer equipment and the pavement is likely to induce high

dynamic forces on the adjacent pavement which could lead to local failures and should therefore be avoided.

3.6. Maintenance

3.6.1. Frequency

The design life for heavily trafficked motorways and trunk roads is typically 40 years with less heavily trafficked roads designed for 20 years. Dependant on the volume of traffic and the type of bituminous surface course used, re-surfacing is expected at between 10 and 20 year intervals. For cost efficiency reasons, there should be no need to physically access the components buried into the road, except during maintenance operations on the pavement. That means that the system should be robust enough to work for a period of 10 to 20 years without having to change or fix the buried components. In case there is a need to access the buried components outside the periods of maintenance operation of the pavement, a dedicated procedure must be defined with the road operator (cf. § installation).

The frequency of maintenance of the “on-road” or “overhead” components should not affect the level of service of traffic flow. A dedicated procedure must be defined case by case with the road operator.

3.6.2. Waste of components

Scarification and planning of the pavement layer in which the components are installed result in the destruction of these components. Debris resulting from the planning of the pavement must not require a special treatment before landfilling or recycling (unlike asbestos or PAH).

3.7. Safety

If the system is installed according to the requirements detailed above, there should be no safety impact due to modification of the characteristics of the road. Consequently, the safety issues are restricted to the impact of the system itself on the people interacting with the road.

3.7.1. Vehicles

If the system is “off-line”, it must affect neither the non-electric vehicles nor the non-charging vehicles travelling on the road (especially their electronic components).

3.7.2. Vehicles passengers

Whether the system is “off-line” or “on-line”, it must not affect the driving abilities of the drivers (for all types of vehicles: electric or not, charging or not, motorbikes, bikes).

Whether the system is “off-line” or “on-line”, it must not affect the health of the passengers of the vehicles (for all types of vehicles, electric or not, charging or not)

3.7.3. Pedestrians

Whether the system is “on-line” or “off-line”, it must not affect the health of pedestrians walking on the road and near the road. (On motorways, pedestrians may be passengers from a vehicle stopped after an incident or maintenance staff or emergency staff).

3.8. Legal and Regulatory

This section describes the legal and regulatory requirements. Further information can be found in appendix 9.1.6.

Each roadwork undertaken for installation of charging system must take into account the legal framework of the country. As charging system in operation do not exist yet, the legislation has to be entirely built or revised to take them into account.

Nevertheless, we will give below a non-exhaustive list of topics that have to be investigated on a legal and regulatory point of view before starting any program of installation in a country.

- Overhead clearance – this is likely to be similar to and based on legislation for overhead power lines for trams and trolley-buses where these exist. They could be further guided by legislation for overhead power lines in the power distribution network.
- Trench reinstatements – existing guidelines and regulations on trench reinstatements are likely to be relevant to in-road power installations.
- Road installation – it is expected that all countries will have existing regulations and procedures on the installation of roads. These will vary considerably between countries.
- Maintenance of the roads – this will cover procedures, organisation, responsibilities etc. It is likely that regulations will differ both for different road types (for example, in the UK the Strategic Road Network is covered by different regulations from the non-strategic road network), as well as for different countries.

Safety – this is covered by a vast range of legislation which will need to be applied, and possibly adapted for the maintenance of charging systems.

3.9. Forever Open Road Concept

The Forum of European Highway Research Laboratories (FEHRL) has initiated the Forever Open Road Programme as the core of its Strategic European Road Research Programme V (SERRP V). The Forever Open Road (FOR) programme aims to create the next generation of road; one which is adaptable, automated, and resilient. It will demonstrate how to build and maintain roads where new technology can be easily accommodated and that are resilient to climate change. It aims to take the best of existing and future technologies, and fill the gaps to produce a solution suitable for all types of road, whether urban, rural or motorway.

The Forever Open Road will be suitable for new or existing roads, whether urban or interurban. It will be constructed from pre-fabricated elements, built and maintained using sustainable materials. It will have adaptable capacity provision (lanes, hard shoulder & central reserve), and built-in services and communication systems. It will measure its own condition, harvest energy and clean and repair itself. It will communicate with vehicles and will allow for automated driving. The concept will take the best of existing and future technologies, fill in the gaps, and produce a solution that can be adopted across Europe.

The concept of the Forever Open Road is built on three elements:

- The Adaptable Road: focusing on ways to allow road operators to respond in a flexible manner to changes in the road users' demands and constraints.
- The Automated Road: focusing on the full integration of roadside intelligence with ICT applications on the user and in the vehicle, the traffic management services and the road operations itself.
- The Climate Resilient Road: focusing on ensuring adequate service levels of the road network under extreme weather conditions.

Figure 7: The Adaptable road

The aim of the Adaptable Road (Figure 7) is to provide cost-effective and innovative methods to design, construct and maintain roads, which implies the development of new ways of building roads, including the use of prefabricated, upgradeable pavement structures with long-life characteristics that are capable of incorporating removable and changeable infrastructure services and accommodating new forms of powered vehicles and guidance systems. The Adaptable Road will provide a quick and cost effective method of constructing and maintaining roads. This will involve a re-think of how roads are built, including the use of prefabricated, upgradeable pavement structures with long-life characteristics that are capable of incorporating removable and changeable infrastructure services and accommodating new forms of powered vehicles and guidance systems. The adaptable element will be the key to making the concept work, supporting the automated and resilient elements.

The innovation themes that would contribute to the Adaptable Element are as follows:

- Future Proof Manufacturing, Design and Construction.
- Advanced Sustainable Materials Design, Construction and Implementation Processes.

- Flood, Snow and Ice Free Pavements, Tunnels and Bridges.
- Powering Vehicles.
- Durable and Integrated Pavements, Bridges, Tunnels and Structures.
- Advanced Utility, Sensory and Communication Systems.
- Low Cost, Rapid and Automated Maintenance Strategies.
- Safe Roads.
- Asset Management Toolbox and Performance Standards.
- Transport Infrastructure Integrated with Land Use Planning (TIILUP).

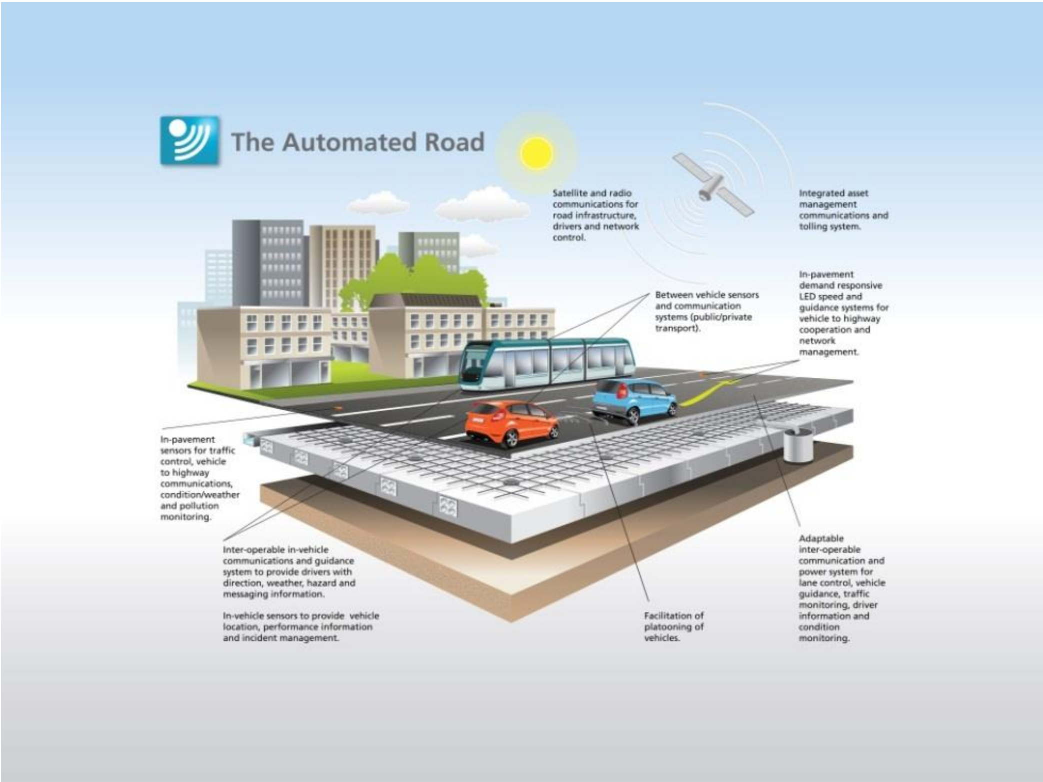

Figure 8: The Automated road

The ability to pick up electric power from the road will have a significant impact on the ability of the network to support the mass movement of electric powered vehicles, and the cost of transport. This applies equally to private cars, buses and trucks, both in urban and inter-urban areas. Close cooperation with vehicle manufacturers, including jointly funded demonstrators, will be required to ensure that the vehicle to road interface is practical, cost effective and safe.

The Automated Road (Figure 8) will integrate road side intelligence with ICT applications in the vehicle, the services and the operator. The sensory and communications technology involved

will enable the deployment of advanced (e.g. dynamic) guidance and management systems tailored to respond to in situ requirements, in effect improving reliability and efficiency of the network management. The Automated Road Element will include:

- Comprehensive, interoperable communications systems linking road, driver, vehicle and the operator.
- Advanced vehicle and user guidance, speed control and direction guidance, including in-road guidance to manage traffic.
- Integrated traffic control, monitoring of traffic and road conditions to improve reliability and efficiency.
- Incident monitoring and automated response systems to reduce delays.
- Effective road power transfer and tolling.
- Efficient electric vehicle power provision.

Figure 9: The Resilient road

The Resilient Road (Figure 9) should be resilient to extremities of weather, such as temperature and rainfall, and also mitigate the negative aspects of road construction and operation, such as air and noise pollution.

Thus, for on-road power transfer equipment that is installed in the pavement to be compatible with the FOR concept, the equipment would need to be able to be installed in a modular pavement. Consideration would also need to be given to the location of other infrastructure services and also where there may be services installed in the future.

4. GRID / DISTRIBUTION NETWORK REQUIREMENTS

4.1. Introduction

FABRIC will investigate the system feasibility from the power system end user perspective, by taking into account the integration of renewable energy sources and power system distribution requirements.

This section defines Grid and Distribution user needs and requirements. The focus is to investigate standardization and generic requirements regarding distribution, distributed energy source integration and wireless EV to power transfer infrastructure power transfer that cover essential power system aspects. There are standards under development, and the collection of these standards and requirements will pave the way towards the design and development of a system that will take essential energy transfer requirements into consideration.

The distribution side of an energy system must essentially provide continuous and reliable power to the connected loads with maximum efficiency. Distribution systems should have the following characteristics:

- Service continuity
    - Supply is supported by multiple sources or services.
    - Support of multiple connection points to the loads served.
    - Support of alternate consumer based energy sources.
    - Use of high quality electrical equipment and conductors.
    - Provision of system alarms, monitoring and diagnostics.
    - Use of preventative maintenance systems or equipment.
    - Fault location and restoration.
- Flexibility and extendibility
    - Use of transformers with increased capacity or sophisticated cooling systems.
    - Use of power monitoring communication systems and advanced metering infrastructure (AMI) in order to capture data for system growth estimation.
    - Ability to reconfigure feeders.
- Electrical efficiency
    - Minimisation of losses in conductors.
    - Minimisation of losses on transformers.
    - Selection of proper operating voltage level for equipment (transformers, etc...).

- Minimization of maintenance cost
    - Use of alternate power circuit in order to take equipment out of service without dropping loads.
- Power quality
    - Consideration of load input requirements (input voltage, current, power factor) in the design phase.
    - Consideration of load immunity to harmonics of the basic 50 Hz frequency.
    - Consideration of harmonic frequency generation by the load.
- Overall distribution system operational efficiency
    - Support of distribution management systems.

Requirements regarding the grid distribution electrical and communications system have been proposed from the following standards among others.

- IEEE 61850 (Substation automation).
- IEC DLMS/COSEM 62056 (Advanced metering infrastructure).
- IEEE 80 (Guide for safety in AC substation).
- IEC 61968 (Distribution management systems).
- IEEE Std 386™-2006, (Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V.
- 1366-2003, IEEE Guide for Electric Power Distribution Reliability Indices.
- C135.61-1997, IEEE Standard for the Testing of Overhead Transmission and Distribution Line Hardware.

As grid and distribution requirements are defined by national governments, it is not possible to create definitive requirements for grid and distribution networks supplying FABRIC. This section will therefore consider generic requirements for grid connections, particularly those based on international standards, illustrated with examples from specific countries in the EU.

4.1.1. Distributed energy resource integration requirements

The overall increase in power system loads due to the demand from additional actors such as electric vehicles and the increase in supply from sustainable energy generation based on wind or solar energy has resulted in the need for more distributed energy sources to the power grid,

thus making power generation more decentralized. Smart grid architectures must be designed in a way that enables seamless integration of both grid and consumer.

One of the basic standards in distributed energy source integration is IEEE 1547 which defines physical and electrical interconnections between utilities, distributed generation (DG) and storage. IEEE 1547 covers the following topics:

- Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.
- Standard for interconnecting distributed power resources with electric power systems.
- Guide for monitoring, information exchange and Control of Distributed Resources Interconnected with Electric Power Systems.
- Guide for design, operation and integration of distributed resource island systems with electric power systems.
- Draft technical guidelines for interconnection of electric power sources greater than 10MVA to the Power Transmission grid.
- Recommended practice for interconnecting distributed resources with electric power systems distribution secondary networks.
- Draft guide to conducting distribution impact studies for distributed resource interconnection.
- Recommended practice for establishing methods and procedures that provide supplemental support for implementation strategies for expanded use of IEEE Standard 1547.

Generic physical-electric requirements defined by the 2002 IEEE P1547 unapproved draft is as follows:

Voltage regulation: The Distributed Resource (DR) shall not actively regulate the voltage at the point of common coupling. The DR shall not cause the area electric power system service voltage at other local electric power systems shall not exceed ANSI C84.1, Range A

Integration with area electric power system grounding: The grounding scheme of the DR interconnection shall not cause over voltages that exceed the rating of the equipment connected to the area electric power system and shall not disrupt the coordination of the ground fault protection on the area electric power system

Synchronization: The DR unit shall operate in parallel with the area electric power system (EPS) and shall not cause any voltage fluctuation that exceed ± 5% of the prevailing voltage level of the area electric power system at the common coupling point. And meet the flicker requirements of clause 4.3.2.

Distribution Secondary Spot Networks:

- Network protectors shall not be used to separate, switch, serve as breaker failure backup or in any manner isolate a network or network primary feeder to which DR is connected from the remainder of the Area electric power system, unless the protectors are rated and tested per applicable standards for such an application.
- Any DR installation connected to a spot network shall not cause operation or prevent reclosing of any network protectors installed on the spot network. This coordination shall be accomplished without requiring any changes to prevailing network protector clearing time practices of the Area EPS.
- Connection of the DR to the Area EPS is only permitted if the Area EPS network bus is already energized by more than 50% of the installed network protectors.
- The DR output shall not cause any cycling of network protectors.
- The network equipment loading and fault interrupting capacity shall not be exceeded with the addition of DR.
- DR installations on a spot network, using an automatic transfer scheme in which load is transferred between the DR and the EPS in a momentary make-before-break operation, shall meet all the requirements of this clause regardless of the duration of parallel.

Inadvertent Energization of the Area EPS: The DR shall not energize the Area EPS when the Area EPS is de-energized

Monitoring Provision: Each DR unit of 250 kVA or more, or DR aggregate of 250 kVA or more at a single PCC shall have provisions for monitoring its connection status, real power output, reactive power output and voltage at the point of DR connection.

Isolation Device: When required by the Area EPS operating practices, a readily accessible, lockable, visible-break isolation device shall be located between the Area EPS and the DR unit.

Protection from Electromagnetic Interference: The interconnection system shall have the capability to withstand electromagnetic interference (EMI) environments in accordance with

ANSI/IEEE C37.90.2. The influence of EMI shall not result in a change in state or mis-operation of the interconnection system.

Surge Withstand Performance: The interconnection system shall have the capability to withstand voltage and current surges in accordance with the environments defined in IEEE/ANSI C62.41.2 or IEEE C37.90.1 as applicable.

Paralleling Device: The interconnection system paralleling-device shall be capable of withstanding 220% of the interconnection system rated voltage.

In addition to IEEE P1547, IEEE 2030 addresses the interoperability of energy technology and information technology operation with the electric power system, end use applications and loads. The standard aims to integrate power and communications subsystems in order to ensure safe and reliable operation of distributed energy resources. Therefore it addresses both electrical and communication oriented requirements that enable an efficient power flow. The standard consists of three parts;

1. Draft guide for electric sourced transportation infrastructure.
2. Draft guide for the interoperability of energy storage systems integrated with the electric power infrastructure.
3. Draft standard for test procedures for electric energy storage equipment and systems for electric power systems applications.

4.1.2. Wireless electric vehicle power transfer requirements

Requirements for energy transfer between electric vehicles and wireless power transfer systems have been considered in IEC JPT 61980 Electric vehicle wireless power transfer (WPT) systems. This standard consists of the following three parts:

1. General requirements.
2. Specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems.
3. Specific requirements for the magnetic field power transfer systems.

This standard is still in draft stage. Part 1 is forecast to be completed in early 2015 while the third part is only forecast to become available in 2017.

The Society of Automotive Engineers has produced SAE J2954 Wireless Charging of Electric and Plug-in Hybrid Vehicles (Guideline scheduled for 06/2014). In this standard an assessment of efficiency and safety of the energy transfer has been performed in order to produce the best common approach.

A detailed description of requirements regarding the power transfer solutions designed and adopted in FABRIC can be found in vehicle manufacturer's requirements.

Moreover requirements for energy transfer between electric vehicles and power transfer infrastructure have been derived for conductive systems. Even though requirements regarding physical and electric interfaces do not apply to inductive power transfer, high level communication related requirements define communication objects and data that could be ported to inductive power transfer systems.

ISO/IEC 15118-1 defines the communication requirements within the context of the OSI reference system. According to the ISO/IEC 15118-2 protocol, after establishing a physical connection between the EV and the Electric Vehicle Supply Equipment (EVSE- The grid side endpoint of communication and control defined in the ISO/IEC 15118 reference architecture), an IP based connection is built up in order to;:

- Control a battery power transfer session.
- Authenticate for payment.
- Control the interactions between EV (Electric Vehicle), EVSE and smart grid for negotiation of grid usage.
- Provide additional services.

The aforementioned aspects enable control of the electrical subsystem and provide support for services from the business side point of view. Requirements regarding each of these categories have been derived by taking into account some of the main aspects of ISO/IEC 15118:

- Controlling a battery power transfer session
    - The battery power transfer process is controlled by the EV.
    - The EV can calculate a power transfer schedule based on information from the user, power transfer point and grid. The calculated schedule should be transmitted back to the infrastructure in order to allow the power planning of other vehicles.

- The user should be able to interrupt the power transfer process from the vehicles HMI unit.
- The user can monitor the power transfer progress from the vehicles HMI unit.

- Authenticating for payment
  - The communication protocol should allow for exchange of information between the EV and the Electric Vehicle Supply Equipment.
  - An indication of acceptance/rejection should be displayed on the vehicle's HMI unit.
- Control of interactions between EV (Electric Vehicle), EVSE and smart grid for negotiation of grid usage
  - The user should be able to initiate power transfer process from the HMI installed in the vehicle.
  - The grid endpoint should generate a power transfer profile that will be able to full-fill the load levelling constraints of the electrical grid and the EV energy demand requirement.
  - The power transfer profile provided by the Electric vehicle Supply equipment to the vehicle should not exceed the maximum power limits of local installation's or the vehicle. The EV should be able to provide a signal to the Electric Vehicle Supply Equipment (or the grid endpoint to which it is connected) to request the termination of power transfer process.

This section covers several aspects of distribution grid requirements. In subsection 4.2, Requirements for high power connection interfaces are analysed. These are mainly based on current grid codes, established by the local DSOs and also international IEC standards. In subsection 4.3, a power flow analysis is carried out for typical grid configurations, analysing the impact of additional demand, introduced by charging lanes. Subsections 4.4 and 4.5 are dedicated to the analysis of additional equipment and infrastructure, which would be necessary, including the installation of potential renewable energy and storage. Therefore, at first, demand patterns for power transfer to vehicles are evaluated in subsection 4.4. Based on the results, in subsection 4.5 additional equipment is studied, such as solar PV and energy storage.

4.2. Requirements for high power connection interfaces

Each country has its own specific grid connection requirements, usually based on international standards, modified or supplemented by local standards. In this section we consider the connection requirements for Spain and France as an example of grid connection requirements which power transfer systems will need to meet.

4.2.1. Grid Requirements in Spain

Installation Requirements

Currently all of the EV high power transfer solutions that are analysed in FABRIC project are supplied from low voltage point. Nevertheless it is possible to connect to the public electric grid from the low (LV, under 1000 V in AC) or medium voltage (MV, 1000 to 35 000V in AC). Figure 10 and Figure 11 show examples of connection points to the distribution grid

The distribution grid must meet the requirements of IEC 50160 standard, regardless of voltage connection point. Besides this standard, EV inductive power transfer points power supply must meet specific inductive power transfer standards such as IEC 61980-1 (now in draft stage), which sets the following requirements:

- Nominal voltage under 1.000 V, and the equipment shall operate correctly within ±10 % of the standard nominal voltage
- Frequency rated values is 50 Hz ± 1 % or 60 Hz ± 1 %

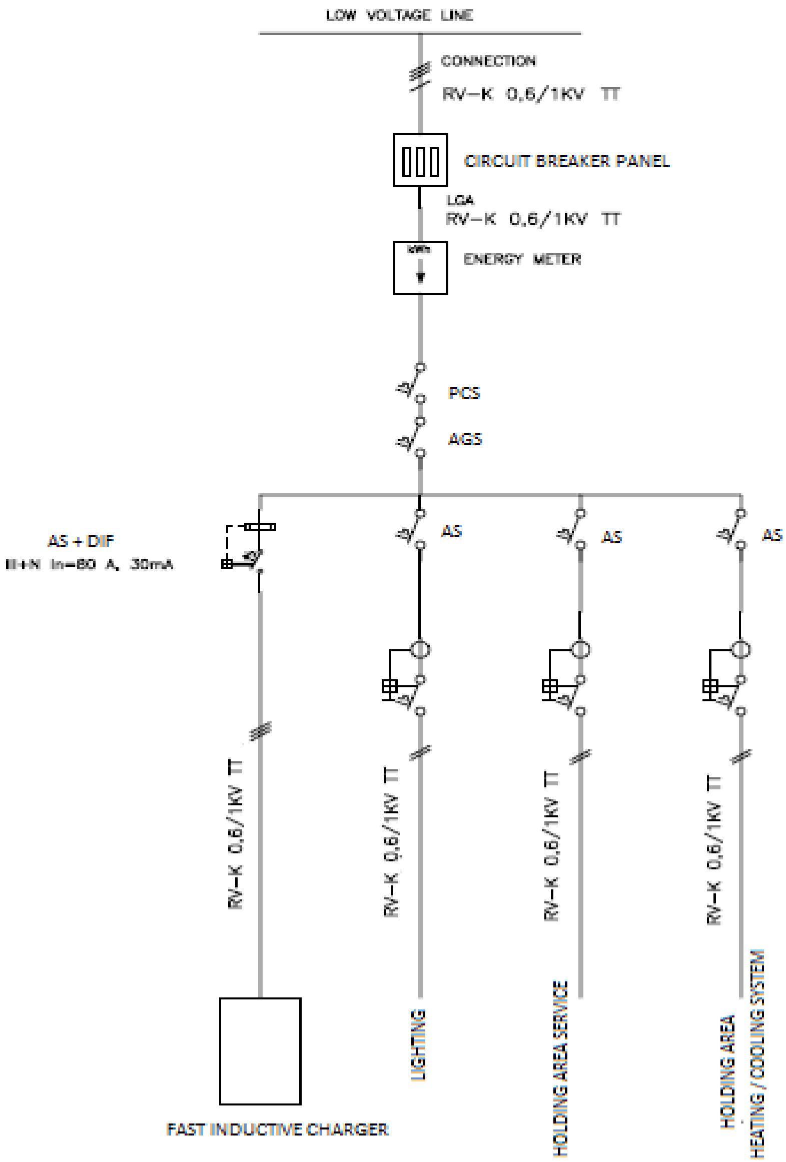

Figure 10: Example of low voltage scheme

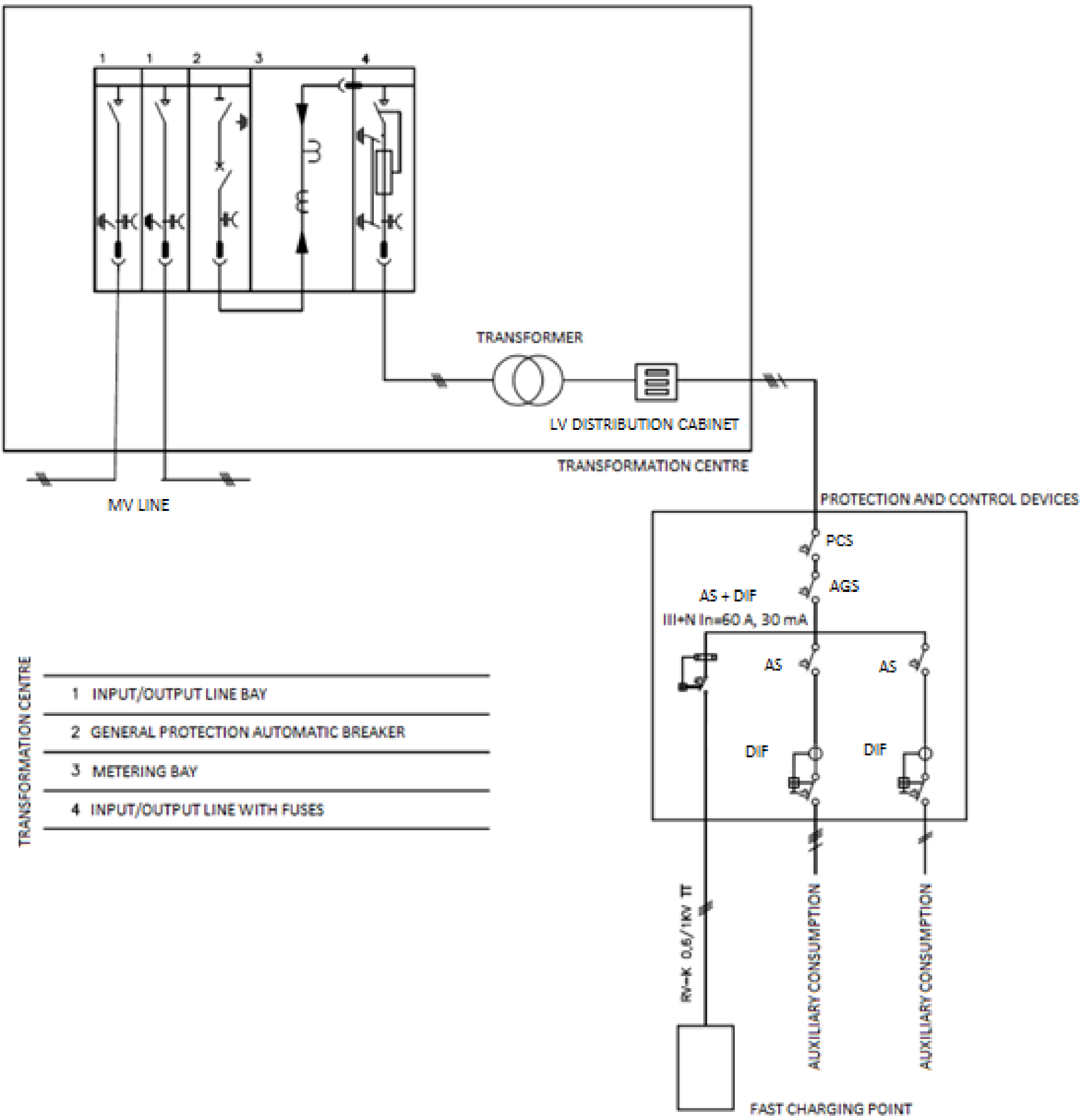

Figure 11: Example of medium voltage scheme using a MV/LV transformation centre

In both low and medium voltage connection case, the distribution grid connection facilities must meet the national codes and the specific standards of the area DSO (Distribution System Operator). In Spain, these connection facilities must meet the Spanish Low Voltage Code (REBT for its Spanish initials, “Reglamento Electrotécnico de Baja Tensión”) and the DSO NTPs (for “Normas Técnicas Particulares”).

Spanish Low Voltage Code (REBT)

The Spanish Low Voltage Code (REBT) was approved by a Royal Decree 842/2002, and it establishes the low voltage technical complementary instructions (ITC-BT), affecting each component in a low voltage installation. As this document states, the main components to be placed between the grid and the power transfer point are:

- Connection (Acometida in Spanish).
- Circuit breaker panel, CBP (Caja General de Protección in Spanish).
- General feeding line, GFL (Línea General de Alimentación in Spanish).
- Meters (Contadores in Spanish).
- Individual derivation, ID (Derivación Individual in Spanish).
- Power control switch, PCS (Interruptor de Control de Potencia in Spanish).
- Control and Protection Device Concentration, CPDC (Dispositivos Generales de Mando y Protección in Spanish).

Further information on Spanish Low Voltage Code can be found in appendix 9.2.1.

4.2.2. Grid requirements in France

This sub-section describes the connection requirements for EV fast charge points in France, based on the general requirements imposed by the French electrical network dedicated to distribution [1].

The architecture and design of the electrical distribution network must be in accordance with the basic rules on voltages (minimum and maximum), taking account the standards for the consumer and cable sections considering the required power.

The French grid is divided into two groups, single phase and three phase connection and the power levels are organised in 3 major categories:

- Up to 36 kVA.
- 36kVA to 250 kVA (can be 160 kVA).
- Over 250 kVA.

These power levels determine the cost of grid subscription, which is adjusted by taking into account the peak power. These conditions should be adapted to the current regulations in each country and to the particular technical regulations of the area distribution company.

Installation Requirements

As already specified, at this point of time, the EV fast charge points can be fed from the low voltage grid. Their connection to the medium voltage grid must be performed using transformation centre which comply with the corresponding regulation and the particular technical regulations of the area distribution company. A power transfer point can be equipped with several power transfer units. In these cases, the power demand from the units could exceed the normal distribution voltage of 400 V-3ph-50Hz.

The French grid architecture is organized in accordance to the power requirement level, and the cost and consumption is s directly linked to the power supply level in Table 1 shows the power supply levels of French grid.

The main components required to connect the power transfer point to the low voltage network are:

Disconnection box (DB)

- Connection.
- Circuit breaker panel (CBP) and protection for human safety.
- Meters.

Table 1: Voltage levels for different power levels on French grid.

	≤ 36 kVA LV	**> 36 kVA ≤ 250 kVA LV**	**> 250 kVA HV**
Monophase LV 230 V	3 to 18 kVA		
Triphase LV 400 V	12 to 36 kVA		
Triphase LV 400 V		36 to 250 kVA	
Triphase HV 15/20 kV			≥ 250 kVA

Table 2 shows the voltage limits for single and three phase systems in LV supply point, the power transfer solutions shall comply with these voltage levels.

Table 2: Voltage limits of LV connections (± 10%).

	Minimum	Nominal	Maximum
Monophase	207 V	230 V	253 V
Triphase	360 V	400 V	440 V

Harmonics

Harmonic distribution must satisfy Afnor standard NFC13-200 and IEC standards 61000-3-2 and 61000-3-4, which specify the limits for harmonic current emissions for equipment input current ≤ 16A and ≥16A per phase, respectively, considering both single-phase and three-phase connections.

The standards define the measurement methodology of harmonic current, and the limit fixes a maximum value for a given integration time.

4.3. Evaluation of charging demand patterns

In this section, traffic simulation models are described. These models have been employed to obtain power transfer demand patterns. Two models have been developed; one from ICCS and another from POLITO. Results for urban and inter-urban environments are presented.

The objective of this subsection is to create the basis for the study on possible effects of integration of energy storage and renewable generation such as solar Photo-Voltaics (PV). Once the demand patterns are calculated, the requirements for storage systems can be derived (see next subsection).

4.3.1. Coordinated Scenario

In this scenario a fleet of 500 vehicles passes over a power transfer lane at a steady speed of 36 km/h with 3 second (30 m) headway as shown in Figure 12. The lane consists of 267, 50 kW consecutive power transfer loops; each loop is 30 meters in length. As shown in Figure 12, each power transfer pad will be immediately occupied by vehicles following the leading vehicle. All vehicles charge at maximum power of 50 kW.

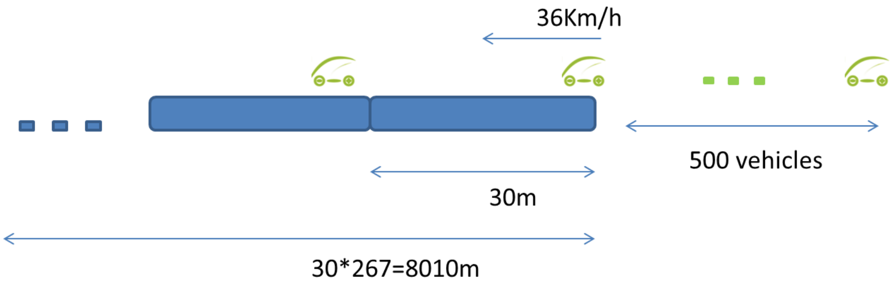

Figure 12: Scenario of a fleet of vehicles passing over the charging lane.

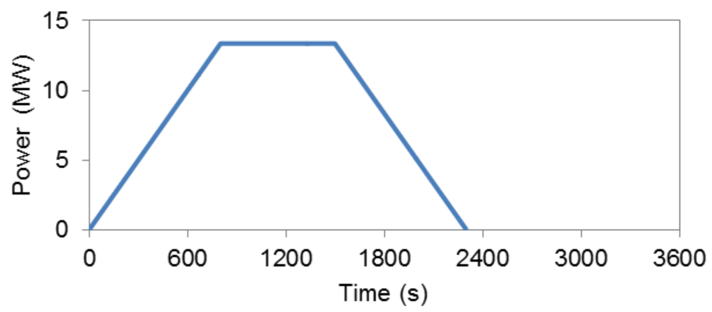

Figure 13: Power transfer demand for a coordinated use scenario.

As a result, power transfer demand increases while new vehicles are entering the lane, then it is constant at maximum power of 13.35 MW, and finally decreasing until the last vehicle leaves the lane. The power demand curve is shown in Figure 13.

This scenario represents an ideal situation where a fleet of vehicles moves in co-ordination, with the same velocity and headway and at some point gradually enters and exits the power transfer lane. It is presented here only as a reference, and as an example for the urban case. The actual study, which follows below, is carried out with the uncoordinated scenario. Nevertheless, this scenario is relevant in a future of e-roads, where at least small groups of vehicles might be remotely controlled and form platoons with smooth demand characteristics as shown in Figure 13.

4.3.2. Uncoordinated Scenarios

A probabilistic simulation model was developed in order to study the effect of the traffic on aggregated charging demand. In this model, the probability of entering one power transfer pad can be set in order to capture the effect of traffic over the charging lane. It can be assumed that in un-coordinated charging the vehicles can continuously charge for a limited amount of time, in

contrast to the coordinated charging scenario where the assumption was that vehicles entering the lane can continuously charge until the end. A set of three traffic conditions representing light, medium and heavy traffic has been derived in order to demonstrate the effect of the traffic on aggregate charging demand. In order to model light traffic, the probability for a vehicle to enter a particular power transfer pad is assumed to be 15%. For medium traffic, this probability rises to 50% and for heavy traffic, 75% is assumed. The following table summarizes main simulation parameters.

Table 3: Basic simulation parameters for the un-coordinated traffic scenarios.

Scenario	Pad entrance probability (%)	Vehicle speed (km/h)	Min. head-way (m)	Vehicle length (m)
		urban / inter-urb.	urban / inter-urb.	
Light traffic	15	36 / 108	5 / 10	5
Medium traffic	50	36 / 108	5 / 10	5
Heavy traffic	75	36 / 108	5 / 10	5

As in the coordinated case, power transfer pads have a length of 30 m and it is assumed that all vehicles receive power at a constant rate of 50 kW.

In the case of an urban environment, it is assumed that each vehicle travels at a speed of 36 km/h, Thus, the overall charging time per pad is 3 seconds for a particular vehicle. The minimum headway is set to 5 meters and a vehicle length of 5 m is assumed. The headway has been decided based on results presented in Figure 5 (section 3.4 of this document). In this configuration, up to 3 vehicles my receive power from one pad at the same time.

Figure 14 shows model results for the urban case over a simulation time of 10 min. Sharp power peaks can be observed which are caused by the effect of vehicles randomly occupying power transfer pads. With increasing traffic density, power transfer demand increases. It is worth noting here that maximum demand almost reaches 40 MW for heavy traffic. This is due to the fact that vehicles enter power transfer pads every second with a probability of 75%. This means that at most pads, there will be 3 vehicles present and it is assumed that all three will receive maximum power transfer of 50 kW.

It is interesting to observe that the standard deviation (variability) of the demand is highest for medium traffic. This can be explained by the fact that with heavy traffic the system is almost saturated. In the case of light traffic, the lower number of vehicles causes fewer fluctuations as it

happens fewer times that there is more than one vehicle situated over the same power transfer pad.

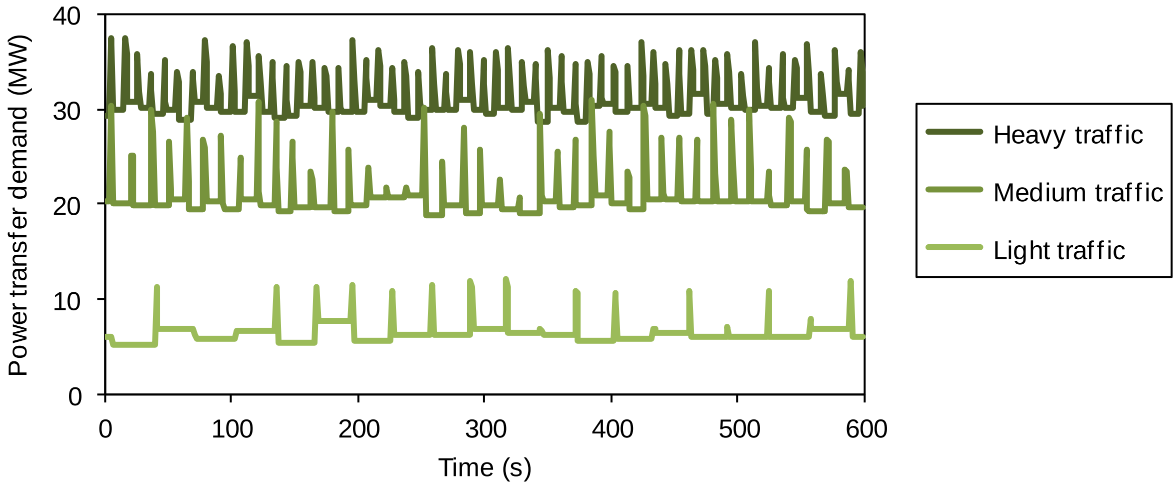

Figure 14 : Power transfer demand of an un-coordinated use with light, medium and heavy traffic in an urban environment.

Figure 15 shows the same situation for an inter-urban environment, with an assumed constant vehicle speed of 108 km/h. The headway has been set to 10 m. In this case, each vehicle passes over the 30-m pad in just 1 s.

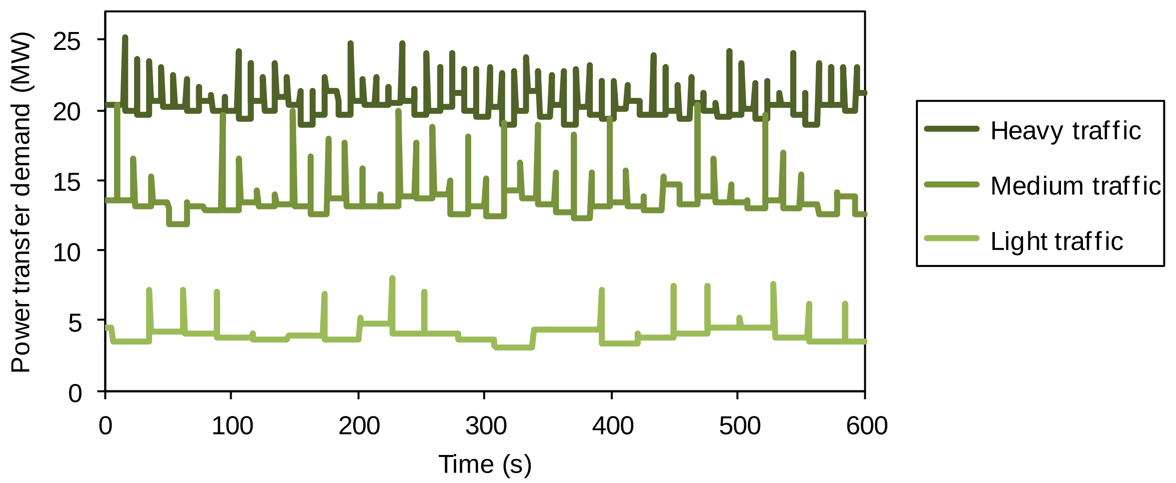

Figure 15: Power transfer demand of an un-coordinated use with light, medium and heavy traffic in an inter-urban environment.

The same tendency can be observed as for urban traffic, but the main difference is that overall power transfer demand is lower and also fluctuations are much lower. Charging power is lower as vehicles circulate with larger distance between each other (a headway of 10 m is assumed here). In this case, at most 2 vehicles can be at the same time on a pad.

Table 4 summarises the power demand results from the simulations of different driving environments in un-coordinated power transfer scenario. Average demand, standard deviation and peak demand are represented, in order to show energy transfer (average) and variability (STDEV and MAX). The graphs for aggregated demand in the uncoordinated scenario can be found in the appendices.

Table 4: Basic statistics for un-coordinated traffic scenario in urban and inter-urban environments.

Scenario		Average [MW]	STDEV [MW]	MAX [MW]
Urban	Light traffic	6.33	1.07	12.05
	Medium traffic	20.61	2.18	31.05
	Heavy traffic	30.80	1.88	37.50
Inter-Urban	Light traffic	3.95	0.52	8.20
	Medium traffic	13.29	0.89	20.30
	Heavy traffic	20.15	0.82	25.15

4.3.3. Discussion

By comparing the basic statistical properties of the urban and interurban scenario it is interesting to notice that the change in headway has an impact on the average demand. This is expected since smaller headways enable a higher density of vehicles on the power transfer lane. This means that at the same power transfer level, less energy is transferred to individual vehicles.

It is also interesting to notice that the variability (expressed by the standard deviation) in the urban case is higher than in the interurban case. In the first case, vehicles occupy a power transfer pad for 3 seconds, therefore for a given simulation iteration, some vehicles are already in power transfer (2 at maximum per pad) and more vehicles are added to the set of vehicles

that is already in power transfer mode (1 vehicle per pad maximum). In the interurban case, for a given iteration of the simulation (the granularity of the simulation has been changed to 0.5 sec in order to simulate the interurban case), 1 vehicle could be already charging at maximum whereas 1 vehicle at maximum could be added to the set of vehicles that are charging. Intuitively this difference in the range of possible values contributed by each charging pad to the overall demand, leads to the difference of the standard deviations for the inter-urban and urban setups.

4.3.4. Simulation Scenario From POLITO

Data from another traffic model have been provided by POLITO. The parameters for this traffic model are given in Table 5 and Table 6. Further information on the POLITO model can be found in appendix 9.2.3

Table 5: Traffic parameters assumed in the POLITO model.

Traffic parameter	Value	
Average density for input traffic flow	10	veh/km/lane
Critical density corresponding to max capacity	30	veh/km/lane
Number of simulated vehicles	500	veh
Coefficient of variation of the headway	0.2	
Minimum traffic headway	1.5	s

Table 6: Infrastructure parameters assumed in the POLITO model.

Infrastructure parameter	Value	
Total length of the road	20	km
Average slope	0	%
Length of the charging zones (LCZ)	20	m
Interdistance (I)	30	m
System efficiency	0.85	
Power per unit of length (PCZ)	50	kW/m
Minimum technical headway in CWD lane	1.5	s

Figure 16 shows 5 second interval of power transfer, as shown, the power demand is fluctuating between 2-8 MW several times in just 5 seconds. It is obvious that such a demand profile would cause severe problems for the feeding grid, therefore the power peaks need to be smoothed to an acceptable level.

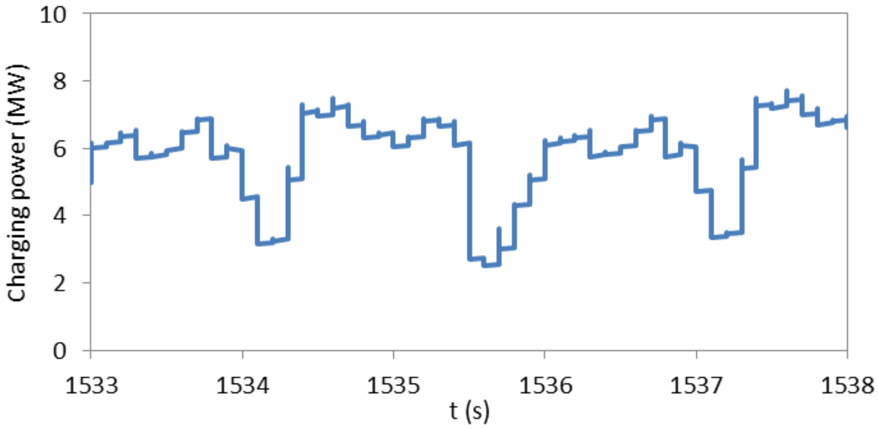

Figure 16: Detail of 5s of power transfer demand from POLITO traffic model

According to Marcos et al. (2014)[1] ramp rates of large PV power plants have been limited, for example in Puerto Rico 10% per minute (percentage of nameplate power). Standard PV plants (without any control) show fluctuations of up to 90% per minute. For a 1-MW plant, this is 0.9 MW/min. In our case, assuming 10 MW of installed power, the fluctuations mentioned above represent 20-80% per second. As pointed out by Marcos et al. (2014), it depends very much on the strength of the local power grid, up to which limit such high fluctuations can be tolerated. Puerto Rico set up rather restrictive limits due to its weak grid. Anyway, it is supposed here that fluctuations need to be reduced in order to reduce the requirements of grid connection.

4.3.5. Simulation scenario conclusions

Results from both models reveal very high power demand fluctuations thus causing severe noise to the grid infrastructure. This indicates that there is a need to smooth the demand with a storage system installed at the grid connection point. Smoothing is the process by which fluctuating power demands and outputs are compensated for to produce a more regular or

[1] J. Marcos et al., “Storage requirements for PV power ramp-rate control”, Solar Energy, 2014, 99, 28-35.

smoothed power level. For example, a storage battery may be used to rapidly absorb excess power during short term demand troughs, or supply power during demand peaks. Nevertheless, fluctuations depend very much on the system architecture; larger power transfer zones will produce fewer fluctuations. On the other hand, as shown in the ICCS model, if all the vehicles are co-ordinated, in the ideal case a very smooth demand curve would be obtained. Even though this ideal case is not realistic; it shows that a coordination of the vehicles may reduce drastically demand fluctuations (e.g. applying traffic control strategies) and thus the need for additional equipment such as a storage system.

We can therefore conclude that a smoothing capacity will be required to cope with the significant power fluctuations likely to result from uncoordinated dynamic power transfer systems. However, the actual requirements need to be defined in terms of the effect they have on overall grid load, which in turn will be derived from national grid stability requirements.

4.4. Sizing of a storage system to mitigate power peaks

This section evaluates the requirements for additional equipment such as energy storage systems and integration of solar Photo-Voltaic (PV) generators. These studies take as input data of the power transfer demand patterns, described above.

Moving averages were introduced as a simple model to define smoothing requirements. The storage duty is obtained from the difference between the original demand pattern and the smoothed time series. From this storage duty (power time series), the power and energy requirements are derived for simplified storage system. Finally, high-resolution solar power generation data is included in the study and the storage requirements are assessed for that combined scenario. In addition, a high level estimate is calculated for a possible self-consumption scenario.

The objective is to calculate parameters for the possible additional equipment, therefore, the results are based on simplified models (for example, storage losses are not included). Most interesting results in this chapter are the assessment of power transfer demand fluctuations, storage requirements (energy and power) and the impact of integration with solar PV generation. Further information on models can be found in appendix 9.2.4.

4.4.1. *Storage sizing method*

This section describes requirements for Energy Storage Systems (ESS) which could be used to reduce demand peaks. The power transfer demand data is analysed to develop the requirements. Different smoothing windows between 1s and 1min have been tested for available results from the two traffic models.

The objective is to study two crucial areas to specify ESS requirements;

- How much the maximum power transfer demand can be reduced by installing storage systems?
- What are the storage requirements (power and energy capacity) in order to achieve a certain level of smoothing?

Answers to these two questions will give valuable information on feasibility of ESS from the grids point of view. Further information on storage sizing can be found in appendix 9.2.4.

The analysis of traffic data shows that there is a typical daily cycle, with a steep increase in the morning and another steep decrease in the evening. These traffic ramps, converted in demand ramps produce a temporal bias in the storage duty. This is due to the typical time lag of moving averages. This daily charging cycle is an artefact of the smoothing technique. It can be widely removed with another moving average applied on the storage duty power[2]. As a first guess, a smoothing window of 1 min has been found for that temporal bias correction.

In Figure 17, the effect of that temporal bias correction is illustrated with an example of the State Of Charge (SOC) of a storage system applied to data from inter-urban traffic (ICCS model). In the upper graph, large excursions of the SOC can be observed. The power ramp-up in the morning and the ramp-down in the evening can be clearly seen, especially for the 60-s smoothing. In the lower graph all these temporal tendencies have been removed without compromising the smoothing effect. This simple technique reduces the energy requirement in this example from almost 150 kWh down to less than 15 kWh for the 60-s smoothing window.

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[2] H. Bludszuweit, "Reduction of the uncertainty of wind power predictions using energy storage", PhD Thesis, Universidad de Zaragoza, 2009

On the other hand, the much smaller storage system is continuously charged and discharged during the day.

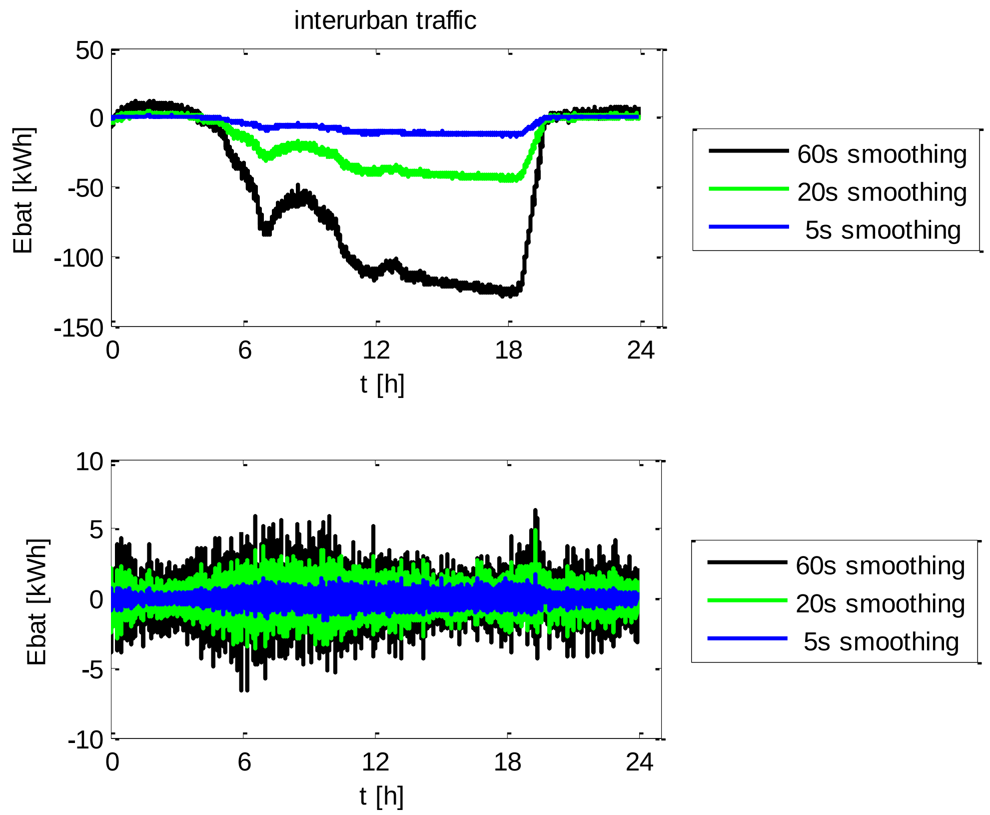


Figure 17: Evolution of ESS state of charge without (above) and with temporal bias correction (below).

The study used smoothing windows from 1s up to 60s, with increment steps of 1, 2, 5, 10, 20, 30 and 60s in order to calculate the storage requirements.

4.4.2. Storage sizing with ICCS Traffic Model

The ICCS model considers scenarios in urban and interurban conditions under low, medium and high traffic.

Table 7, shows all results for storage sizing parameters. It can be observed that the requirement for storage power P_{ss} is almost independent from the smoothing window. On the other hand, traffic density affects power requirements. Interestingly, intermediate traffic density is the most demanding scenario, because with high traffic density, the overall power rises, but the fluctuations are reduced. Contrarily, energy capacity E_{ss} is mainly affected by the smoothing window width and much less dependent from traffic density. The required energy capacity

increases proportionally with the increased smoothing window width. For more information on ICCS traffic model, refer to appendix 9.2.5.

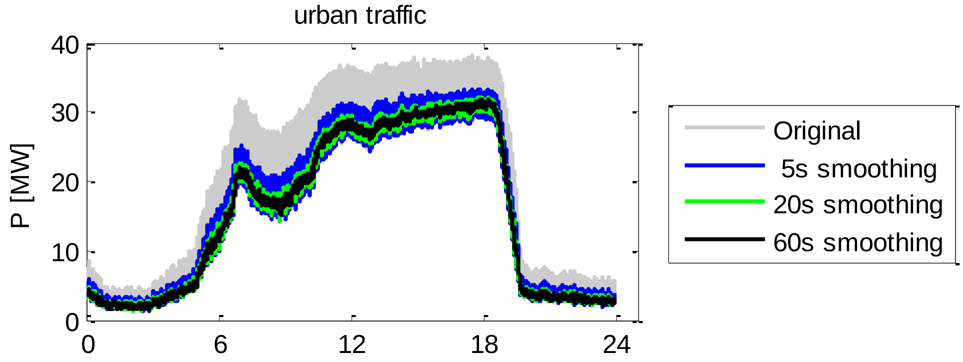
Table 7: Parameters of storage requirements for different window widths of moving average smoothing and different traffic scenarios.

	Urban (36 km/h)			Inter-Urban (108 km/h)		
Smoothing (s)	**Pss (MW)**	**Ess (kWh)**	**Tss (s)**	**Pss (MW)**	**Ess (kWh)**	**Tss (s)**
light traffic						
1	6.1	1.9	1.1	1.3	0.5	1.4
2	6.1	2.7	1.6	1.3	0.8	2.0
5	6.1	3.7	2.2	1.4	1.4	3.8
10	6.1	5.2	3.1	1.4	2.4	6.2
20	6.1	8.4	5.0	1.4	4.1	10.3
30	6.1	11.6	6.9	1.3	5.2	14.4
60	6.0	12.1	7.3	1.3	7.6	20.5
medium traffic						
1	11.1	3.5	1.1	1.9	0.7	1.3
2	11.1	4.4	1.4	1.9	1.1	2.0
5	11.1	5.6	1.8	1.9	2.1	4.0
10	11.1	6.6	2.1	1.9	3.7	7.1
20	10.7	9.1	3.1	1.8	5.4	10.9
30	10.5	10.7	3.7	1.7	7.3	15.3
60	10.6	14.1	4.8	1.6	8.3	19.2
heavy traffic						
1	8.0	2.8	1.3	2.1	0.7	1.2
2	8.0	3.6	1.6	2.1	1.1	1.8
5	8.0	5.2	2.4	2.1	2.1	3.5
10	7.5	5.8	2.8	1.8	3.2	6.3
20	7.3	7.7	3.8	1.5	4.6	10.9
30	7.2	9.0	4.5	1.6	5.4	12.5
60	7.1	10.0	5.1	1.4	6.7	17.0

It is possible to observe the major differences by comparing the urban and the inter-urban case. In the interurban case the power demand variation is lower which is reflected in significantly

lower power and energy requirements for the ESS. Power requirements are reduced more than energy requirements, which lead to higher values of the typical discharge time T_{ss}. While in the urban case range of discharge times is between 1 and 7s, in the inter-urban case the range is much wider at 1 to 20s. This means that especially for wider smoothing windows, more storage energy is required.

In order to study the daily demand-generation balance (see next section on Sizing of a storage system including solar PV power), the traffic model described above has been expanded over 24h for the urban and inter-urban case. In Figure 18 these two daily demand profiles are shown with several smoothing examples. It can be observed that the urban scenario shows a very similar daily pattern compared to the inter-urban scenario. The reason for that similarity is that both scenarios are based on the same assumption of traffic density, which has been inspired by Zhang (2012)[3]. The main difference can be observed in the fast fluctuations, which are higher for the urban scenario, as already observed before.



[3] P. Zhang et al., "A Methodology for Optimization of Power Systems Demand Due to Electric Vehicle Charging Load", IEEE Transactions on Power Systems, 2012, 27, 1628-1636.

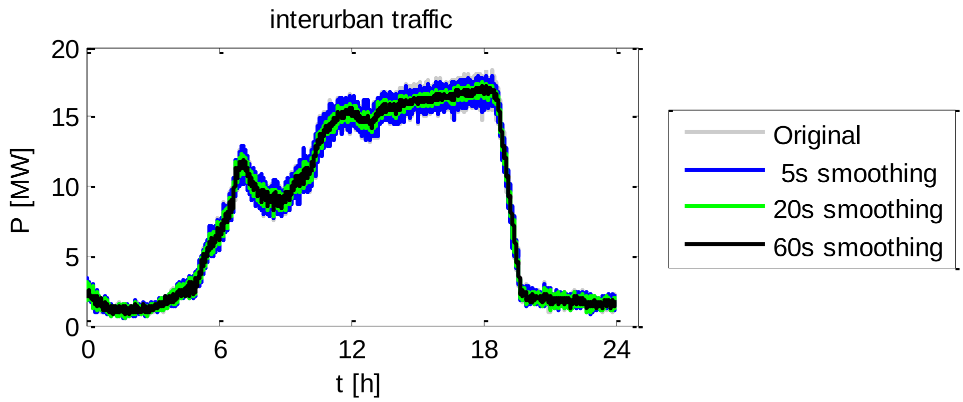


Figure 18: Demand from traffic model for urban (36 km/h) traffic (above) and inter-urban (108 km/h) traffic (below).

4.4.3. Storage sizing with POLITO Traffic Model

As shown in Figure 19, smoothing window of 5s reduces to a very large extent the power fluctuations. The effect in this case is even more accentuated, due to the fact that power peaks in this model configuration are very short (below 1s).

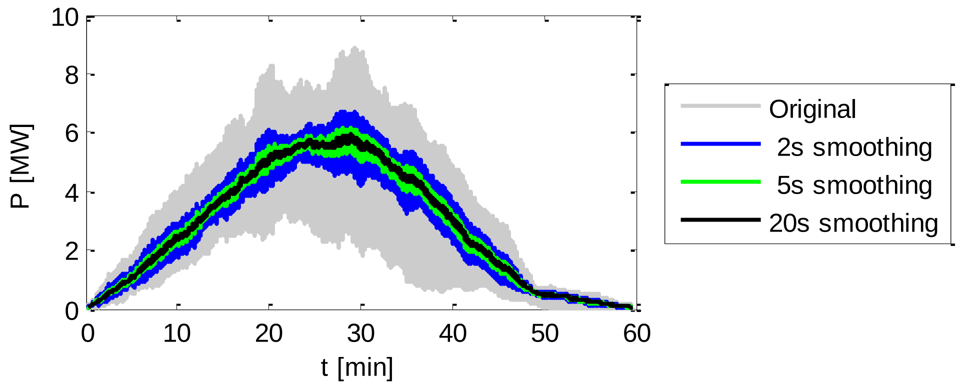


Figure 19: Charging power demand for POLITO highway traffic model for different window widths of moving average smoothing.

Table 8 shows the storage sizing parameters produced by POLITO model, the table shows that the requirement for storage power P_{ss} are almost independent of the smoothing window. It is interesting to see that smaller smoothing windows produce higher power deviations. This is due to the extremely short power peaks and the time-shift which is a property of the moving average. Therefore, shorter smoothing windows produce higher power peaks in the resulting

curve which occur entirely after the original peak has passed. Nevertheless, this effect is small and it can be assumed that the power requirement is independent of the smoothing window and strongly dependent on the traffic model configuration. The tendency of the energy capacity E_{ss} is similar to the previous case. The only difference is that the proportionality is even more pronounced.

Table 8: Parameters of storage requirements for different window widths of moving average smoothing.

Smoothing (s)	Pss (MW)	Ess (kWh)	Tss (s)
1	5.2	0.8	0.6
2	4.3	1.0	0.8
5	3.8	1.1	1.0
10	3.8	1.3	1.2
20	3.8	1.8	1.8
30	3.7	2.5	2.4
60	3.8	48.4	45.5

4.4.4. Comparison of storage requirements for different traffic scenarios

Figure 20 shows the storage power requirement P_{ss} depicted as a function of the smoothing window width. As can be seen, traffic models from ICCS and POLITO give coherent results, as power values cover the same range. For comparison, the same curve from POLITO data is added to both the urban and interurban cases. It can be observed that the power level is in between both. As mentioned before, interestingly an intermediate traffic density (iccs_med, urban) produces the highest power peaks. This is due to the fact that with a high traffic density, the demand is higher but also less variable.

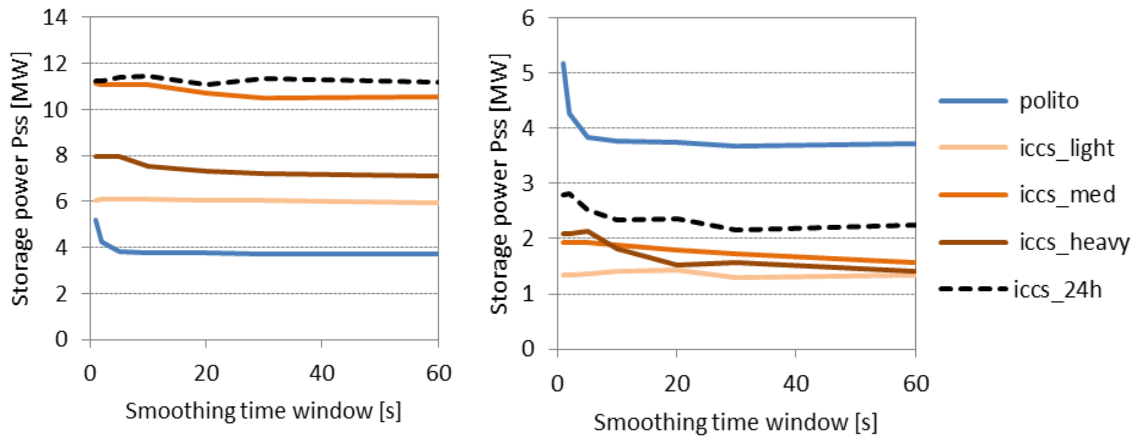


Figure 20: Storage power requirement for low, medium and high traffic for different window widths of moving average smoothing. Urban (left) and inter-urban right) environments.

In Figure 21 storage energy capacity requirements E_{ss} are presented. Here the most striking result is that storage capacity from POLITO data is much lower than that obtained from the ICCS model. This result is due to the fact that the POLITO model produces very short power spikes with low energy content. For the ICCS model, the 24-h data deserves special interest, as it represents best a typical control interval of 1 day. Energy requirements are generally higher for that case, because in addition to very fast fluctuations, slower fluctuations are added due to the daily traffic profile with changing traffic densities.

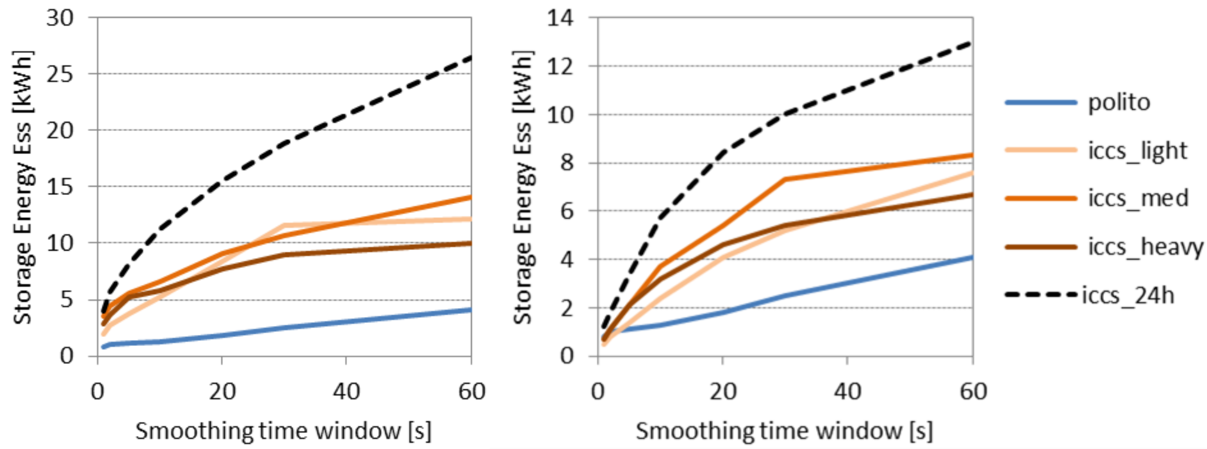


Figure 21: Storage energy capacity requirement for light, medium and heavy traffic for different window widths of moving average smoothing. Urban (left) and inter-urban (right) environments.

In order to illustrate the energy requirement, some examples of the simulated state of charge of the ESS are shown below. In Figure 22, the case of POLITO data is represented. The great variability can be seen clearly and how required energy capacity grows with increased smoothing time intervals.

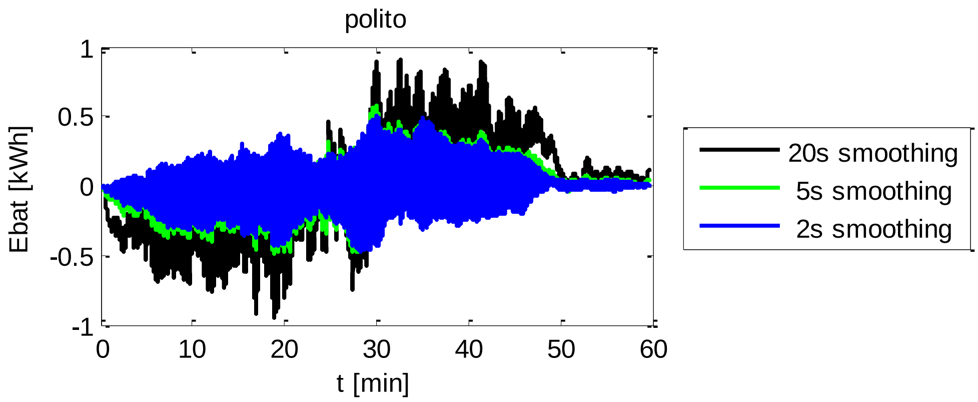


Figure 22: Time series of the state of charge for POLITO model for different window widths of moving average smoothing.

Figure 23 shows the time series of the state of charge for ICCS model in medium traffic. The variation is lower but longer cycles of ESS charging and discharging can be observed which is the reason for the higher energy capacity requirements. Also the lower variation in inter-urban demand (lower graph) can be seen clearly.

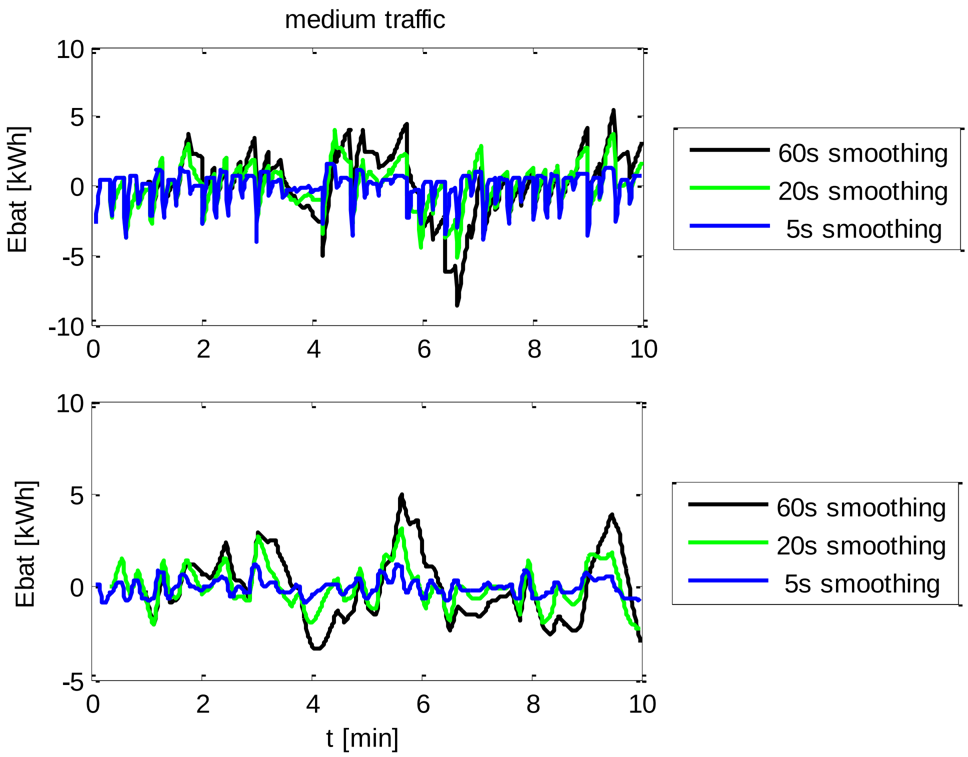


Figure 23: Time series of the state of charge for ICCS model with medium traffic for urban (above) and interurban case (below) for different window widths of moving average smoothing.

Figure 24 shows the typical discharge time T_{ss}. The graphs are similar to the energy capacity; however it also contains the information on the power requirement. As shown all three scenarios of traffic density of the ICCS model produce very similar values for all smoothing windows. As expected, the value of T_{ss} from the POLITO model is much lower, given that power levels were similar and energy levels were much lower.

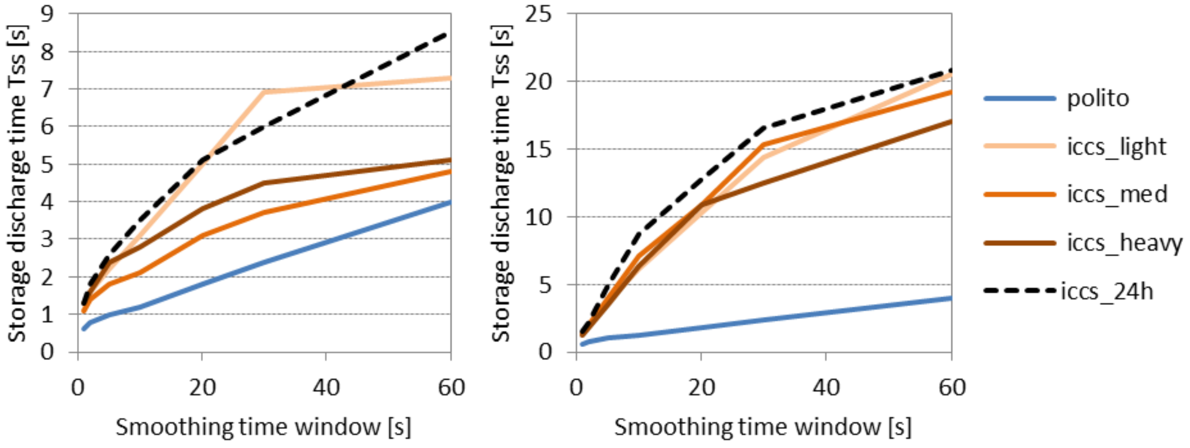


Figure 24: Storage discharge time requirement for light, medium and heavy traffic for different window widths of moving average smoothing. Urban (left) and inter-urban (right) environments.

Figure 25 shows the possible reduction in the peak demand. The changing peak demand is represented as a function of the smoothing window width. In POLITO model and the urban case from ICCS model, a visible reduction in demand peak is obtained. Most of the reduction potential is already covered with smoothing windows below 10s. In the case of POLITO data, a reduction from 8.3 down to 6.1 MW is obtained by applying a 10-s smoothing, which is a considerable reduction of almost 27%. The urban ICCS data shows highest variation for intermediate traffic density, where 28% of reduction is achieved with the same smoothing window. For the daily profile, only 15% of reduction is observed, as variation in high-traffic hours is lower. In the case of inter-urban ICCS case, peak power is only reduced slightly by at most 4%. This can be explained by the low variation in this simulation case.

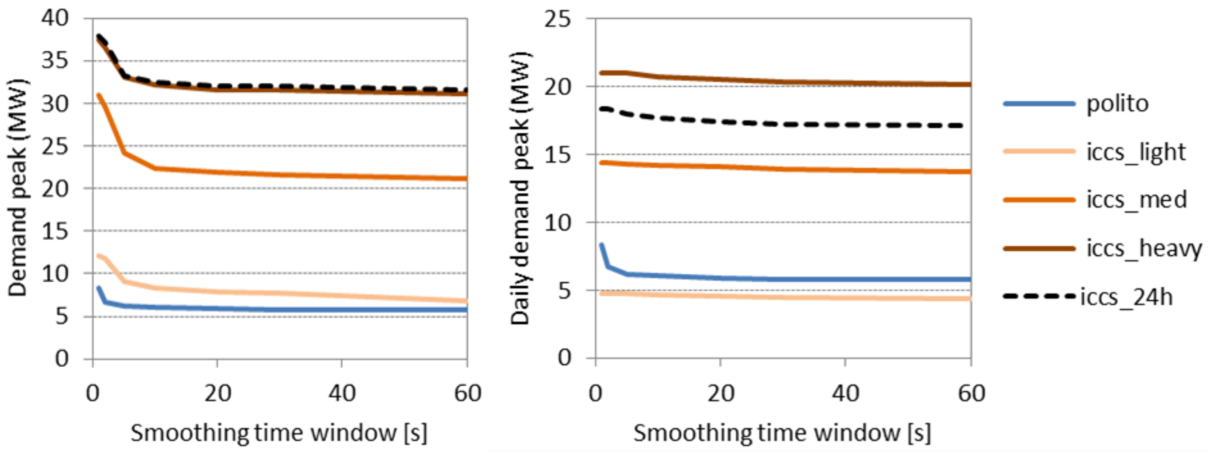


Figure 25: Charging demand peak for light, medium and heavy traffic for different window widths of moving average smoothing. Urban (left) and inter-urban (right) environments.

4.4.5. Concluding remarks

From the storage sizing exercise, it can be concluded that by adopting high-power and low-energy storage systems, a large proportion of power fluctuations can be compensated. Storage duty is obtained by applying a simple moving average model, therefore, the window width of the moving average is an indicator for smoothing strength, and smoothing windows from 1s up to 1min have been studied.

Sensible differences have been observed between urban (slow) and inter-urban (fast) traffic. For the urban case with a smoothing window of 5s, most of the fluctuations were smoothed. The corresponding storage system has to be rated at 11.4 MW and it should have 8.2 kWh of energy capacity, which corresponds to a typical discharge time of 2.6 s. This means that at nominal storage system power of 11.4 MW, the system will be discharged in less than 3 s. In practice, power peaks are expected to be much shorter (less than 1s), but several consecutive peaks can occur.

In the inter-urban traffic case, fluctuations are much lower hence storage requirement for smoothing is lower. On the other hand, a smoothing window of 60s is needed to obtain some smoothing effect. In this case, the required storage system has to be 2 MW with8 kWh of energy capacity, which results in a typical discharge time of 20s approximately.

The power requirement is largely independent from the smoothing scenario, but very sensitive to the traffic model and traffic density. On the other hand, all traffic models give results in the

range of 1 – 12 MW of aggregated power. Keep in mind that storage systems should be distributed to be located very near to the power transfer zones, in order to minimise transmission losses.

Finally, energy capacity is mainly driven by the smoothing requirement. The different traffic scenarios also have impact on the required energy capacity, but the main factor is the required smoothing, represented by the window width of the moving average.

4.4.6. Sizing of a storage system including solar PV power

This section investigates the implications of PV power integration with the power transfer infrastructure. Therefore, high-resolution solar generation data is required in order to observe the possible impacts in short time scales (range of minutes). On the other hand, an approximate estimation is provided on how solar PV generation might contribute in a self-consumption scheme. Daily generation and consumption profiles are studied to provide estimations on the annual consumption and generation balance. Further information on data model and simulation scenario can be found in appendix 9.2.6

Table 9 shows the results for 1 minute smoothing period. It can be seen that if smoothing is applied to remove very fast fluctuations (up to 1 min), the integration of solar generation has no impact on ESS sizing, because, available solar data is given in a 1-min time step. Maximum demand is unaffected in this case, as by 18h no more solar power is available. This is because the selected curve is representative for spring or autumn, when day and night are of similar length. In northern countries in summer there will still be considerable generation available (up to 50% of daily peak power on a sunny day).

Table 9 Daily peak power demand (inter-urban case) and ESS size for 1-min smoothing and different values of installed PV power Pinst (sunny day case).

Pinst (MW)	Pmax (MW)	Pss (MW)	Ess (kWh)
1	17.2	2.24	12.9
2	17.2	2.24	12.9
5	17.2	2.24	12.9
10	17.2	2.24	12.9

20	17.2	2.24	13.0

For PV generation to influence ESS size, smoothing should be considerably increased (order of magnitude: hours). These cases have been widely described in the literature, as the flexibility offered by storage helps to improve the integration of variable distributed sources and loads within power grids. However, large ESS energy capacity and the associated costs are the main drawbacks.

In order to illustrate that situation, for the case of 10 MW installed PV power and fast-traffic scenario, smoothing intervals of 1, 2 and 3 h have been applied. In Figure 26 the smoothing effect can be observed clearly. But it becomes apparent that the evening peak is only reduced slightly (down from 18.4 MW without smoothing to 15.9 MW with 3-h smoothing, which represents a reduction of 14%. Also, reduction in demand slops can be observed from the figure. Nevertheless, storage requirements for this scenario are very high.

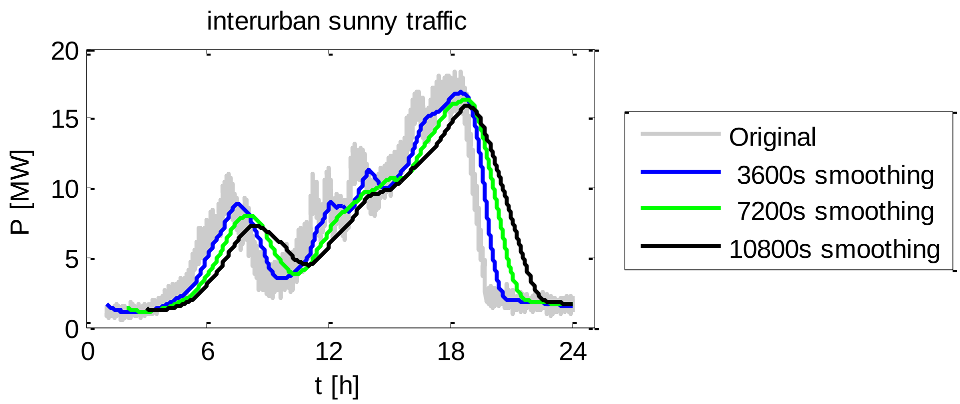


Figure 26: Demand from traffic model (inter-urban traffic: 108 km/h) with solar 10 MW PV and assuming 1, 2 and 3 h of smoothing for storage sizing.

As shown in Table 10, storage power increases with larger smoothing intervals, reaching 12 MW for 3-h smoothing, from 2.2 MW for 1.min smoothing. On the other hand, energy capacity is very high, mainly due to the steep ramps in the demand curve. While for 1-min smoothing only requires 13 kWh capacities, the 3-h smoothing requires up to 23MWh

Table 10: Daily peak power demand (Pmax) and ESS size for different large smoothing intervals, assuming 10 MW of installed PV power.

Smoothing(h)	Pmax (MW)	Pss (MW)	Ess (MWh)
1	16.8	8.0	7.9
2	16.3	11.1	15.5
3	15.9	12.1	22.8

In conclusion, smoothing based on a moving-average strategy is very effective to reduce fast power peaks. However, to reduce the peaks of slower daily profile, this strategy is less effective and the solution requires a large storage system. In order to reduce these requirements, other storage management strategies such as peak shaving (based on thresholds) could be more appropriate. But that study is out of scope of this project.

Table 11 shows the daily solar PV generation and corresponding share of solar energy for different levels of solar resource. The northern countries may reach yields of up to 1000 kWh/kWp while in Spain or Italy, energy generation values are 1500 kWh/kWp. In Spain, solar resources in the south can reach up to 2000 kWh/kWp. The solar share calculations are based on the inter-urban (high speed) scenario on an assumption that throughout the year power transfer demand is same every day.

Table 11 Daily solar PV generation and corresponding share of solar energy for self-consumption.

Pinst (MW)	Mean daily solar energy Epv (MWh)			PV share (%)		
	1000 kWh/kWp	1500 kWh/kWp	2000 kWh/kWp	1000 kWh/kWp	1500 kWh/kWp	2000 kWh/kWp
1	3	4.5	6	1.4	2.1	2.8
5	14	21.0	28	6.8	10.2	13.6
10	27	40.5	54	13.5	20.3	27.0
20	55	82.5	110	27.0	40.5	54.0

The results show that significant amounts of energy can be generated by a well-sized solar PV installation. In this case, 10 MW PV power in Spain can supply 20% of the demand over one year period. This installation does not need additional storage for self-consumption, as generation peaks are below demand levels. If installed power is increased to 20 MW, the solar

share implies some net-metering scheme or additional storage in order to avoid back-feeding of energy to the grid. This makes it viable to include requirements on renewable energy in a dynamic charging application. It is not viable to generate these requirements at this stage as the level of available renewable energy will vary considerably between different locations in the EU.

5. LOCAL AUTHORITIES/ GOVERNANCE REQUIREMENTS

In Work Package 3.2, Task 3.2.3, Local and City Authorities' Requirements for the Installation of On-Road Power transfer Infrastructure for EVs (transport and urban planning), the requirements for integrating on-road power transfer infrastructure for electric vehicles (EVs) with transport and urban planning requirements from a national and local perspective are identified and examined. The aim is to define the requirements and what key stakeholders (especially the industry) expect (and will be required to comply with) from on-road EV power transfer systems in order to fulfil the desired function and be integrated into existing road systems and infrastructure.

Transport and urban planning covers a wide range of issues that may directly or indirectly impact on the provision of on-road power transfer infrastructure for EVs. They are closely interlinked with a wide variety of decisions in one field impacting on the other, and vice versa.

During this task the following key topics relating to on-road power transfer infrastructure for EVs that would need to be addressed from both the transport planning, urban planning perspectives and possible compliance requirements for industry:

- Impacts on other road users.
- Impacts on traffic management.
- Impacts on roads planning and design.
- Impacts on land-use planning.

This report describes the identification of a number of requirements from the perspective of local authorities based on current practice in the UK. In addition, relevant requirements from European regulating bodies and guidance, has also been included. This was achieved by identifying relevant requirements in the following categories:

- Policy documents.
- Statutory legislation.
- Relevant guidance and standards.
- Good practice guidelines.

By identifying state of the art on the positions and understanding of local authorities in the UK, it is proposed that it will be similar across Europe and this information will be useful to understand

more fully what will be required to implement wireless power transfer infrastructure in any European country.

Streets in towns and cities are public assets and there are already a number of competing demands on them which wireless power transfer may well intensify. From our research most local authorities are not yet considering this type of infrastructure and are first looking to understand the installation issues with plug-in power transfer.

It is also possible that the vehicles themselves will have the ability to use both on road and plug in power transfer and that there will be a variety of technologies available. There is little clear guidance or experience that we can draw on in terms of the use of on-road power transfer. We have therefore made no assumptions as to whether the equipment will use inductive or conductive power transfer, nor been able to make any assumptions as the size and dimensions of the equipment, or if it will need to be installed flush with the surface, buried below the surface or might require overhead lines (such as a pantograph system) in determining the requirements for on-road EV power transfer equipment that a local authority may specify.

In our outreach to local authorities there are nonetheless some significant technical aspects that we feel should be highlighted.

5.1. Technical Considerations

In terms of planning, the technology choices made may well affect the number and position of the cables to supply and transmit the electricity to the on-road EV power transfer infrastructure, as well as the requirements for other roadside infrastructure that may be required. However some technologies are developing a standard modular system that can be set into the road in strips, triggered by road side sensors and this may reduce or ease this requirement. Another aspect to consider is the requirement to convert the DC to AC (or vice versa) should this be needed. In addition depending on the voltage and current, it is likely that there will be other unspecified road side equipment that will need to be taken into consideration in terms of planning considerations, such as sub stations[4].

[4] A **substation** is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions.

The overhead or underground supply of electricity presents different planning challenges, especially in urban areas. Presently rules specify that no live wires can be lower than 5.8 metres (or 5.2m in special cases) above the carriageway and all cables must be properly insulated.

There will be many options for how the power transfer system might look like but for the purposes of this report, we have considered three simplified options:

1. The electricity is fed to the power transfer units from overhead (via pylons and wires of some sort).
2. The electricity is fed into the power transfer infrastructure underground and distributed via a wireless system to the vehicles. This is similar to the bus demonstration projects in Milton Keynes, UK and Salt Lake City, Utah.
3. The electricity is fed into the power transfer infrastructure underground or over ground and the vehicles are charged via a conductor such as a rail. An example of this is the tramway in Bordeaux, France which captures its energy from a rail set into the road surface, at grade with the traction rails, rather than the usual overhead catenary. Sensors set into the road and triggered by the tram allow the electricity to flow into the section covered by the tram. The power transfer rail not covered by the tram is not live, and the tram only captures the energy over the section of third rail that is it covering.

Therefore we have assumed that any system will consist of:

1. A primary power transfer unit either installed in the road (flush with the surface or buried), or via overhead lines.
2. With wires connecting these primary modules to
3. Road side equipment.

Between the generating station and consumer, electric power may flow through several substations at different voltage levels. Substations may be owned and operated by an electrical utility, or may be owned by a large industrial or commercial customer. Generally substations are unattended, relying on SCADA for remote supervision and control. **SCADA** (**supervisory control and data acquisition**) is a system operating with coded signals over communication channels (usually wireless) to provide control of remote equipment.

Each option will share but also have different impacts on local planning and design. The following is a short list of these:

- Availability of space under the road surface for the infrastructure.
- Rules and regulations of what can be on the road surface.
- The technical requirements of road side equipment that may be needed for the energy distribution and transmission (such as converters or substations) in terms of their size, distance between them and intrusion into pedestrian areas.
- Technical aspects such as the interference/interaction of the different electrical based technologies (AC/DC current) especially those used today for traffic management such as traffic signals, dynamic signage etc. and how this needs to be integrated with the new infrastructure.
- Communication with road users and pedestrians about the infrastructure and other traffic information.

5.2. Regional and National roles and policy development

The requirements by city and local authorities for on-road EV infrastructure that may be introduced into urban roads will be determined by a range of decisions made at national, regional or European level. In the UK a threefold designation of local authority responsibilities is in place:

- Local Transport Authorities (LTAs): defined as a county council[5], a council of a non-metropolitan district, an area for which there is no county council (i.e. a Unitary Authority), or an Integrated Transport Authority (formerly termed a Passenger Transport Authority (PTA) for passenger transport in the major conurbations).
- Local Highway Authorities (LHAs): designated for all non-trunk roads by the Highways Act 1980 and is the county council or the unitary authority.
- Local Planning Authorities (LPAs): defined by the Town and Country Planning Act 1990[6] as the council of non-metropolitan county, while the council of a district is the district

[5] Transport (including highways and parking), Guidance for Inspectors, Audit Commission, October 2001

[6] http://www.legislation.gov.uk/ukpga/1990/8/section/1

planning authority for the district. The council of a metropolitan district is the local planning authority for the district and the council of a London Borough is the local planning authority for the borough.

- Local Transport Plans The policy set out in the UK's "A New Approach to Transport: A Better Deal for Everyone" White Paper and the 2000 Transport Act, a statutory document, require local transport authorities to prepare Local Transport Plans (LTPs) every 5 years. A LTP is required to cover capital (investment) and revenue (operating) expenditure and are driven by objectives and targets. Annual Progress Reports (APRs) are required annually for monitoring.
- Sustainable Urban Mobility Plans: A similar approach to LTPs has been recommended by the European Commission. The European Commission's Action Plan on Urban Mobility calls for an increase in the take-up of Sustainable Urban Mobility Plans (SUMPs) in Europe. To meet this need, new Guidelines[7] have been produced that explain how to develop and implement a Sustainable Urban Mobility Plan.
- Government Guidance and Advice: this could include policy guidance, process guidance or technical guidance. Guidance should be seen within the wider context of the range of policy instruments available to central government and its relationships with those who manage, affect and use the local transportation system.

Detailed study into regional and national and roles and policy development can be found in appendix 9.3.1.

5.3. Transport and Urban Planning requirements

5.3.1. Introduction

The key purpose of transport planning is to plan, design, deliver, manage and review transport, balancing the needs of society, the economy and the environment[8]. Transport planning is undertaken within the policy context, laws and regulations that are set by legislative, and other,

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7 http://www.mobilityplans.eu/docs/file/guidelines-developing-and-implementing-a-sump_final_web_jan2014b.pdf

8 Developing Urban Transport strategies, Chartered Institution of Highways & Transportation, 1996.

bodies[9]. The process encompasses developing strategic and master plans for transport, designing transport systems, travel planning and the commercial and operational management of transport systems. Transport planning is involved with the siting of transport facilities (for pedestrians, cyclists, public transport users, vehicle users) and the provision of transport services. Various processes may be involved, including data collection and analysis, developing transport models and forecasting, assessment of proposed interventions and stakeholder engagement.

An urban area may be defined as any human settlement, from a small town with a few thousand residents to a large city with hundreds of thousands or even millions of people. In this document we are concerned with authorities that have responsibilities for larger urban areas.

5.3.2. Land-use Planning

Development control is the element of town and country planning through which local authorities regulate land use and new building. It relies on a "plan-led system" whereby development plans are formed (by the local authority) on which the public is consulted. Subsequent development requires planning permission, which is granted or refused with reference to the development plan as a material consideration.

Applications for planning permission must be decided in accordance with relevant policies within the Development Plan prepared and published by the Local Planning Authority, "unless other material considerations indicate otherwise". Planning Control is therefore "policy led" rather than "influence led". The Local Development Framework (LDF) - the spatial planning strategy introduced by the Planning and Compulsory Purchase Act 2004 and given detail in the National Planning Policy

The planning policies expressed in the LDF deal with a wide range of local issues including promoting more energy efficient transport facilities, highway proposals and highway safety, ensuring an adequate supply of land for housing and other uses, safeguarding areas of countryside, and safeguarding important landscapes or sites of historic, ecological or scientific importance. More specific policies usually promote best practice in building design as a

[9] Transport Planning Professional Qualification, http://www.ciht.org.uk/en/tpp/

reflection of local traditions and priorities. Sustainability issues are built into all LDFs, not only in terms of energy efficiency, but also in promoting economic growth, regeneration, and the fostering of strong and inclusive communities. LDFs are a key policy document for all local authorities, enabling them and other local agencies to engage in spatial planning for their local area on an inclusive and "joined up" basis.

Local authorities issue permissions and permits for development, maintenance and road works; so they will set out their own requirements in respect to these for local electric charging infrastructure. These will need to comply with national standards and practices

5.3.3. Infrastructure design, planning and construction

National bodies are usually responsible for the strategic planning of road, and rail, infrastructure. Although this project task focusses on the urban aspects of on-road electric infrastructure power transfer, there will be key points of crossover where the local jurisdiction and organisation will intersect with national ones, such as with major roads (on strategic axes and motorways - tolled or otherwise). The statutory duty for street works operatives / supervisors to hold certain qualifications under NRSWA applies in respect of all street works that involve breaking up or opening the street and adherence to general health and safety duties also apply. The requirements for EV infrastructure may requirement new training.

How EV power transfer infrastructure on the strategic road network will connect seamlessly with local roads needs to be considered. In the UK the main tools used for the design of roads are the:

- Design Manual for Roads and Bridges (DMRB) used for all major roads; and
- The Manual for Streets (MfS), a guidance document for local authorities.

For requirements concerning implementation and installation of on-road power transfer solutions on trunk roads and highways, please refer to the road infrastructure requirements contained in Task 3.2.1: Road Authority/Owner Requirements, UK. Presently there is no particular reference to EV power transfer in these documents.

Planning and constructing new transport infrastructure include many aspects: civil or public works, design and engineering, construction and installation and integration even at local level.

It is not clear if new institutional bodies will be required for the regulation, security and safety arrangements of the EV infrastructure either nationally or locally.

Most local authorities would also conduct a variety of audits and surveys after a major investment. Presently these discrete studies consider issues such as road safety, cycle or pedestrian/walking audits, visual quality etc. It is likely that the new power transfer infrastructure would be included in this process.

Public utilities, safety and supply

Any EV power transfer infrastructure will need to connect to the National Grid for the provision of the electricity. Since the liberalisation of the electricity market there are new players to consider that are not always a public body and local authorities or the private sector may need to interact with several energy providers in order to secure the local distribution and transmission. The requirements for this would also come from those responsible for the National Grid.

In addition, it is also likely that new product approval specifications will be required for the power transfer equipment especially if it will interface with the user. Examples might include such equipment as plates on the road, induction coils, meters, insulation, joining parts etc. which may require new legislation and/ or type approval at European and national levels. Products will certainly need to be tested to ensure safety and may require a CE label before being installed in the public domain. The product ranges that are presently available are considered to be ‘first of a kind’ and there is little competition in the market. Once this occurs the products should be interoperable as possible to limit the possibilities for local authorities to be caught in a vicious circle of procurement from one or few suppliers.

Decisions such as overhead or underground energy provision will be a local decision based on efficiency, cost and aesthetics. Overhead power distribution may be cheaper, and less disruptive to install than excavating the road, but maintenance can be more costly and frequent. In addition, there are environmental and visual intrusion issues to be considered. How the overhead supplies can be connected to provide the charge to the vehicles themselves would need to comply with local planning requirements.

Targets for the density of the power transfer network may well be set nationally, as the take-up of electric vehicles by the public heavily depends on the range of the vehicles. Inspiration could

be taken from the experience on the introduction in the 1970s, that the lack of knowledge of points of sales of lead-free petrol inhibited the take-up of these vehicles, despite the higher policy understanding that this would improve health and local air quality. This could be a similar barrier for electric vehicles. Local authorities will be guided and helped to put infrastructure in place at the rate that they can afford to do so. However, the availability of power supplies will also determine the speed of implementation as presently there is limited roadside power to support the vehicle power transfer and ITS needs of today.

Zoning

Zoning is a tool of land-use planning used by local authorities involving the designation of permitted uses of land based on mapped zones. Zoning may be use-based (regulating the uses to which land may be put), or it may regulate building height, density, and similar characteristics, or a combination of these. The primary purpose of zoning is to segregate uses that are thought to be incompatible. In practice, zoning is used to prevent new development from interfering with existing residents or businesses and to preserve the "character" of a community. Zoning is commonly controlled by local authorities, though the nature of the zoning regime may be determined or limited by state or national planning authorities or through enabling legislation.

Local authorities presently are able to create zones with restricted access for certain types of vehicles such as Low Emission Zones. Policy direction for Low Emission Zoning and congestion charging/urban tolling experience may help provide direction to how local authorities approach on road EV charging. It is conceivable that some areas such as inner cities could be made accessible only to EVs; therefore, it is very likely that the concept of zoning will be used in developing EV charging areas.

Key Design Aspects to be considered

Urban space is at a premium in towns and cities and therefore it is likely that any new EV charging infrastructure will need to cope with significant physical and design constraints. These would typically include:

- Fixed building lines.
- Shallow services and utilities.
- Extensive and unmapped statutory undertakers' equipments (on road and way side locations).

- Conflicts over allocation of space and priority from a wide number of users.
- Variety of compliance and safety standards and local guidelines.
- High cost of remodelling or rehabilitation of streetscapes.
- Maintaining service access.
- Aspiration and requirements in terms of finished design and quality.
- Variety of players, influencers and interested parties.

The UK Manual for Streets (MfS) suggests 15 guiding principles for local authorities to consider for the design and redesign, construction or improvement, use and maintenance of streets. These include (*inter alia):*

- Applying a user hierarchy to the planning process, where street are not categorised by the traffic flow or the number of buildings they serve but rather by their user profile. The needs of pedestrians should be considered as the most, rather than the least, important in the planning considerations.
- Take a collaborative approach. The majority of streets in urban areas, especially those in historic towns and cities, are not standard and a contextual rather than standardised approach is required. Multidisciplinary teams including the planners, users and the industry may be required.
- Promote social inclusiveness. Local authorities have a requirement to recognise and respond to the needs to all ages and abilities. Streets have an important role and function to play in a community. Any charging infrastructure should not impede the use of public space for social interaction, segregate communities or neighbourhoods or benefit any one social group.
- Develop master plans and design codes for larger scale developments, which would clarify the implementation and desired density of EV charging infrastructure. A clear vision and set of objectives for this within the complex mixed-use context of urban areas is important.
- Creating a locally appropriate balance between the needs of different user groups to ensure that traffic capacity is not the primary consideration, but that the street network provides connectivity and permeability across the whole urban area.
- Retaining the local character of the area is considered to be important. Locally distinctive architecture, materials and layouts all add up to the sense of ‘place’, and local authorities are encouraged to respect this unique identity. By moving away from defining a road

only by the traffic flow and developing street types based on weighting the movement function and the place function of streets help to retain the attractiveness and social functions of streets. Any infrastructure for electric vehicles will need to respect this.

- Use a minimum of highway design features to keep the public space uncluttered and retain clear sight lines. A well designed street has only what is necessary to make the street work properly. EV charging infrastructure will need to respect this – and not clutter up the off or on road space with its equipment.
- Create and maintain green living spaces. The streets of cities and towns are also used as important areas for recreation and leisure and the protection of green spaces is an important aspect of city planning. As inner city areas become more congested and polluted there is a growing trend to restrict access to certain zones (according to the environmental performance of vehicles). Low emission zones may also become EV charging zones.
- Take a 'balanced street' concept forward where mixed use and mixed priority of traffic and people are considered. Different approaches will need to be taken according to the different uses and access requirements of streets. This includes the physical constraints associated with the various frontage access to residential, commercial and retail properties as well as on access to and from on-road parking, delivery bays, bus stops and the 'stopping sight distance' (SSD).
- Encourage innovation and adaptability. Local authorities will need to build in options for future growth as well as technological upgrades.

5.3.4. Impact on other road users

The public highway in urban areas is not just a piece of infrastructure but 'a public place which the public may enjoy for any reasonable purpose, provided the activity in question does not amount to a public or private nuisance and does not obstruct the highway by unreasonably impeding the primary right of the public to pass and repass' (Lord Chancellor DPP v Jones 1999).

The EV infrastructure would need to be protected from a variety aspects such as extreme weather conditions especially flooding; spills (from accidents or other sources); and as the opportunities for human interaction with the road is higher in urban areas, vandalism and other human interference (planned or unplanned).

There are a number of physical parameters of roads that the infrastructure will need to comply with, such as the horizontal alignment, radii and dealing with heritage assets. Pedestrian crossings and street furniture will need to be considered in the design and implementation of any on-road charging infrastructure and the placement of equipment on kerbsides and footpaths. Most road crossings today are at grade but sometime raised tables, underpasses or bridges have been built. These may present special challenges for the infrastructure.

Pedestrians have priority over traffic at zebra crossings but there are many types of signalled or informal crossings such as Pelican, Puffin, Toucan and Equestrian[10] crossings that the charging infrastructure will need to adapt to.

Modal prioritisation

There are a number of other road users that need to be considered in relation to this new infrastructure. These include how (urban) freight and deliveries will interact with passenger transport, which includes both private and public entities. This may impact on the present location of delivery bays and bus or tram stops as well as access to major health, shopping, leisure or sports facilities. Most large heavy duty vehicles (HDV) vehicles are banned from entering the urban zones; in addition their height would need to clear any overhead EV charging infrastructure. Access of emergency vehicles as mentioned should not be impeded in any way.

Moreover the interface between different functions of a city may also affect the placement of the any charging infrastructure. Inner city rail hubs where there are large numbers of people and all types of vehicles may be an opportunity on the one hand as there will be large flows of traffic (especially public transport and taxis) but also be a source of technical clashes over electricity supplies especially if the rail facilities (transport and non-transport related) require a large pull on the system.

[10] Pelican crossing features a pair of poles each with a standard set of traffic lights facing oncoming traffic, a push button and two illuminated, coloured pictograms facing the pedestrian from across the road indicate when it is safe to cross. A Puffin crossing has lights controlling the pedestrians on the near side of the road, rather than on the opposite side. The system also utilises sensors which detect the presence of pedestrians waiting at the crossing, and as they are crossing the road. Toucan (two-can) allows both pedestrians and cyclists to cross together and toucan crossings are normally 4 metres wide, instead of the 2.8-metre width of a pelican or puffin crossing. Equestrian – designated crossings for horses.

The different levels of demand according to the local land use may also affect the on-road EV charging infrastructure required. For example an industrial area may have fewer light duty vehicles but greater numbers of heavy duty vehicles, and this might influence the technology chosen and impact the infrastructure. A combination of on-road stationary charging and dynamic charging may also reduce the number of parking places and this may have other knock-on effects to the road system and users.

On-road charging may also impact on speed and its interface with non-motorised transport - pedestrians and cyclists also add another dimension to consider.

Travel Behaviour

The development of smarter travel solutions[11] is a now a key element of transport planning, with smarter travel adopted as mainstream policy across the UK and elsewhere. The aim is to encourage changes in the behaviour of travellers, by providing better alternatives to the use of the private car. In 1998, the (then) Government made a commitment in the White Paper 'A New Deal for Transport' to promote travel planning by the public sector and businesses in order to reduce congestion.

The term smarter travel encompasses a family of 'interventions', 'measures' or 'tools' for influencing travel behaviour towards more sustainable travel options. Key characteristics of these techniques include increased use of public transport, increased walking, increased cycling, reduced single occupancy car use, reduced travel for work, and using technology to help all of the above.

The 'smarter travel' family of techniques includes 4 main types:

- Soft measures (e.g. setting up a car share scheme).
- Promotion and awareness raising (e.g. personalised travel planning).
- Sustainable transport infrastructure (e.g. new walking and cycling routes).
- Monitoring and evaluation (e.g. measuring increased use of infrastructure).

[11] 'Smarter Choices – Changing the Way We Travel', 2004

While smarter travel does not directly affect urban transport planning requirements for EV charging infrastructure, the increasing importance attached throughout Europe to smarter travel initiatives mean that they cannot be ignored.

City and local authorities are, along with other agencies, are responsible for such measures. Smarter travel tools now in place are wide-ranging, dealing not only with work-based trips, but spanning all types of movement of people and goods. The introduction of on-road EV charging infrastructure will support smarter choice interventions. It is important to recognise that the smarter travel tools now in place are much wider-ranging, dealing not only with work-based trips, but spanning all types of movement of people and goods. Whilst smarter travel has traditionally been associated with influencing individual behaviour, and is seen as a 'people focussed' issue, there have been considerable advances in sustainable transport and carbon reduction solutions within the freight and logistics sector.

There may be other considerations in respect to the needs of urban freight and deliveries that may also have an impact on the placement and deployment of EV charging infrastructure. For example, access to and from delivery centres or bays may restrict or constrain its placement.

From our research most local authorities also highlighted that retrofitting any roads with this type of new infrastructure would be complex and expensive and it was not yet clear who would cover this cost. They felt that in the near term future most full charges would still be done at home in the first instance and that the present lack of understanding of the requirements of this type of infrastructure and for the charge to be meaningful as a 'top up' made it difficult to understand.

5.3.5. Transport and traffic management

Transport demand management, traffic demand management or travel demand management (TDM) is the application of strategies and policies to reduce travel demand (specifically that of single-occupancy private vehicles), or to redistribute this demand in space or in time. Traffic management looks at how to manage traffic flows efficiently. Managing demand can be a cost-effective alternative to increasing capacity. TDM generally involves both "push" (to discourage private car use) and "pull" (to encourage reduced travel demand and the use of sustainable transport) elements.

Table 12: TDM Policy Measures That Impact on EV Power transfer Equipment

Type of Policy Instrument	Instrument	Policy examples	Impacts on EV on-road power transfer infrastructure
Planning Instruments	Integration of Land Use and Transport Planning	e.g. Transit-oriented development, “beads-on-a-string”[12] developments, mixed use developments, higher density developments[13]	This measure would determine the location and number of equipment required
	Public Transport Promotion	e.g. Creating public transport networks, giving priority at intersections, promoting the integration of PT modes, promoting (high capacity) mass rapid transit systems	Equipment could be located at bus stops and in bus lanes
	Strategies for Non-Motorised Modes	e.g. Cycling policy and provision, provision for pedestrians	This could restrict potential locations for equipment
Regulatory Instruments	Physical Restraint Measures	e.g. Pedestrian Zones	This could restrict potential locations for equipment
	Traffic Management Measures	e.g. ITS (Intelligent Transport Systems), no stopping areas, highway signage, development of common symbols; traffic signals and other traffic management	Due to the restricted space around urban roads it is likely that there will be conflicts between the existing and planned locations for equipment and other TDM infrastructure in restricted urban zones.
	Regulation of Parking Supply	e.g. Maximum parking limits	This could restrict potential locations for equipment and access to and from parking might cause conflicts

[12] Where development is concentrated around public transport nodes, The Demand for Public Transport, TRL, 2004, (http://www.demandforpublictransport.co.uk/TRL593.pdf) – also called “string-of-pearls”

[13] Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities, Module 3e: Car-free Development

Type of Policy Instrument	Instrument	Policy examples	Impacts on EV on-road power transfer infrastructure
	Low Emission Zone (LEZ)	e.g. in city centre	This could restrict potential locations for equipment but most LEZ zones would benefit from wide scale EV power transfer infrastructure. Indeed local authorities might encourage EV power transfer infrastructure in these zones first. LEZ zones may provide local authorities opportunities to put EV power transfer in place and start excluding higher polluting vehicles
	Speed Restrictions (20 mph)	e.g. in built up areas	Managing the different speeds and stop/start driving will be a technical challenge. could be provided
	Vehicle ownership and use regulations	e.g. obligatory insurance for all vehicles, vehicle emissions control, maximum age for public transport vehicles and taxis, driving licenses for all drivers, etc.	EVs would need to satisfy EU regulations. Asset insurance would need to be allocated.
	Parking Management	e.g. priority allocation of spaces to EVs	This measure could ensure EV power transfer is available
Economic Instruments	Road Pricing, Congestion Power transfer	e.g. during peak hours	EV power transfer equipment could be interoperable with equipment for other services
	Car ownership taxation	e.g. Tax Incentives for cleaner vehicles	This measure encourages the purchase and use of EVs
Information Instruments	Public Awareness Campaigns	e.g. participation in EU Mobility Weeks and other local actions	This measure could promote the use of EVs and the availability of the power transfer infrastructure
	Driver Training/ Eco Driving	e.g. for city drivers	This measure could promote the use of EVs
Infrastructure Improvements	New and improved infrastructure for non-motorised transport	e.g. widening footways and cycle lanes	This could restrict potential locations for equipment
	New and improved infrastructure for other road users (e.g. motorcycles)	e. g. Lane priority for EV vehicles.	Equipment should not hinder other vehicles (e.g. the size/width or surface of the road - motorcycles/ cycle wheels should not be able to get caught between rails)

Type of Policy Instrument	Instrument	Policy examples	Impacts on EV on-road power transfer infrastructure
	Surface and skid resistance	E.g. use of new or different materials; colours etc.	There may be different surfaces / covering materials used for the EV infrastructure and this will need to comply with all existing standards and may need to aesthetically blend with the main road surface.
	Frontage access	e.g. to residential, commercial or leisure property, on or off road parking	Equipment should not hinder the visibility and sight lines

Managing congestion and traffic flow

Urban traffic is very mixed in urban areas with buses, taxis, light duty vehicles and freight, private cars as well as motorised and mechanised two or three wheelers all using the road space. Prioritising one mode over another or driving behaviour change in response to power transfer infrastructure could have a negative influence on the dynamics of such as network.

Installation of infrastructure on different road categories or lanes will also impact effective traffic management. Junctions (signalled or otherwise) are of particular importance as it is here that the majority of accidents and collisions occur. Therefore there will be considerable challenges to manage how to deal with priority at junctions and the interface of the EV power transfer infrastructure with other systems that may be in place to manage traffic. These include the physically existing infrastructure, the alignment of primary utilities and other engineering aspect as well as the present use of intelligent information technologies such as those used to control the traffic signals.

Many junctions in urban areas have traffic and pedestrian signals with adaptive signal control which requires accurate detection 24/7. There are a wide range of technologies used for traffic management: predominantly inductive loops, but magnetometers, video, radar, microwave and other technologies can be used. These technologies are also constantly evolving and being updated. The power transfer infrastructure would therefore need to comply with the requirements of a wide range of needs of other parts of the system that use technology.

Most traffic signals presently rely on induction loops and sensors set into the road to transmit and receive information, typical examples of systems include SCOOT (Split Cycle Offset Optimisation Technique) and MOVA (Microprocessor Optimised Vehicle Actuation). Inductive loops are likely to have problems if placed too close to power transfer infrastructure. This applies to both the loop itself and the full length of feeder cable to the controller cabinet. As magnetometers respond to changes in magnetic field strength and use wireless communication, it is also likely that there will be some important technical issues to address. As there is little information on the different technologies in use or demonstration in this respect it is difficult to gauge the extent of this interference or estimate its impact.

The placement of cables, sensors, ducts and the controller cabinets depend on a variety of locally driven and technical requirements but it is clear that any EV power transfer infrastructure would need to be compatible and not interfere with the existing traffic management system. Presently this would restrict the placement of the EV power transfer infrastructure close to any junction that has traffic signals. Inductive power transfer must not have a negative impact on the performance of signalised junctions as from the local authorities' perspective any failure of the detection system (including data corruption) or other interference caused by the EV power transfer would be unacceptable.

The text box below gives typical distances from the traffic lights for detector loops.

The positioning of detectors varies junction by junction, and according to the control method and the typical speed of vehicles on approach, so there is little specific guidance that can be captured, other than there will almost certainly be detection present close to the stop line near the signal. For a typical SCOOT junction most of the detection and cabling should be within about 20m of the junction (both on approach and exit side). But 'typical' may be only 50% of SCOOT junctions. MOVA will have detection sensors at the stop line, about 30-50m (or ~3.5 sec journey time) from the stop line, and around 80-200m (or 9~18sec) from the stop line. In places where the speed of approach is fast there are longer feeder cables although there will also be plenty of space between the detectors.

The number of detector /inductive loops at a junction varies widely and it is difficult to establish what might be considered 'typical'. In the Netherlands a major intersection or junction can have as many as 70 or 80 loops in place while in a small market town in the UK a junction will have a

lot less. The number of loops required depends on both the complexity of the junction and the type of controller used for the traffic signals.

Buses carry more passengers than any other mode of public transport and services usually use the most densely trafficked urban roads. They tend to receive priority at traffic signals and are able to change the lights as they approach the junction. Bus priority guidance can be found in Local Transport Note 1/97 'Keeping buses moving and 'Bus priority: the way ahead' published by DfT in 2005. This needs accurate detection and predictable journey times from detection to the signals. Tag and beacon detection systems and detection by GPS positioning are also becoming more common. It is likely that these wireless communications for traffic signals and or dynamic signing may face significant challenges with another new wireless based system.

As junctions tend to be the critical points in the network, any reduction in traffic throughput could result in severe congestion. The power transfer infrastructure should not therefore impede or influence driving behaviour at junctions. If there is only one lane with the power transfer infrastructure this could be seen as influencing behaviour as driver tried to change lanes specifically to gain more charge.

In any event, any impact that would reduce traffic flows and interfere with present travel times and speeds was seen as a disadvantage to the introduction of this type of infrastructure.

Information and communications

The communication to users and the availability of on-road EV power transfer infrastructure to help reassure the public that they will be able to find a charge to extend the range of their electric vehicles, without having to plug it in and park it up, will be critical to the success of EV use. The public will need to know where this power transfer infrastructure is to be found and that it is clearly marked. This will require both physical and virtual communication – similar to the way today we can see Wi-Fi hot spots but we can also pick up this information electronically.

This means creating an easily-recognised and widely-used sign taxonomy (including colour coding) and possibly a set of icons that indicate the type of power transfer available. This may be done at European rather than national level, but will need to be locally integrated and respected.

The Convention on Road Signs and Signals, commonly known as the Vienna Convention on Road Signs and Signals, is a multilateral treaty designed to increase road safety and aid international road traffic by standardising the signing system for road traffic (road signs, traffic lights and road markings) in use internationally. This convention was agreed upon by the United Nations Economic and Social Council came into force in June 1978. The Vienna Convention on Road Traffic complements this legislation by standardising international traffic laws.

The Traffic Signs Regulations and General Directions (commonly abbreviated to TSRGD) is the law that sets out the design and conditions of use of official traffic signs that can be lawfully placed on or near roads in England, Scotland, Wales, and the Isle of Man. It is a duty of the local authority (usually) to place appropriate traffic signs, and in doing so to comply with the 'Safety at street works and road works code of practice[14]', and also a duty to keep records of apparatus in the street.

The same convention also specifies road markings. All such markings must be less than 6 mm high, with cat's eye reflectors[15] no more than 15 mm above the road surface. The length and width of markings varies according to purpose, and no exact figures for size are stated. However all words painted on the road surface should be either of place names, or of words recognisable in most languages, such as "Stop" or "Taxi".

New, clear and easily recognisable icons or symbols will need to be developed that can be understood by all European citizens wherever they are. In addition, it is likely that there will be many opportunities for dynamic communications to users indicating the availability of the power transfer infrastructure – however this also implies that there will need to be more signs, cluttering up the streetscape. Many road signs are static and the introduction of any new signs and changing them to dynamic technologies will also increase the cost of the EV infrastructure. This could be offset in part by improved communications and traffic management options but it will also require the physical management of these installations by those responsible for road signs currently and in the future.

[14] https://www.gov.uk/government/publications/safety-at-street-works-and-road-works

[15] The cat's eye is a retro-reflective safety device used in road marking.

In today's planning environment, EV power transfer communications will need to comply with the present trends to reduce rather than increase the number of signs and this will need to be integrated into the present road signs and their placement. The use of dynamic or static signs and their impact on driving behaviours will also need to be more thoroughly investigated. It is also unclear who will organise and or fund the provision of information to drivers and how it will be nationally and locally coordinated. An added complication will be the communication on how payment for the charge will be made.

It is envisaged that this will be seen as a commercial opportunity for mobile phones and that smart phones and 'apps' will play a defining role in both the communication to the public and act as a method of payment.

In addition several local authorities suggested that there might need to be some new indications on the vehicle itself that it was being charged. This would require new additional type approvals for the industry.

Over and above the physical communication there will need to be some investment in public outreach and media relations to reassure the public of the safety of the system, the cost and transparency of the payment and to help build trust between the public and the authorities that this is in their interest and that there are real and tangible benefits.

6. VEHICLE MANUFACTURER REQUIREMENTS

In this task the requirements for integration of on-road power transfer solutions with vehicle platforms and architecture requirements will be examined and identified.

Vehicles are designed to carefully balance safety, performance, range and weight. Integration of a power transfer system on-board may affect one more of these vehicle architecture parameters.

6.1. Power transfer modes and identification of the technical domains addressed

The possible power transfer modes for the wireless and conductive power transfer solutions are described below:

- **Static power transfer** - vehicle parked (garage, paring slot, bus terminal…), typically no driver or passenger on board [time > 5 min].
- **Stationary en-route power transfer** - vehicle not in motion (car waiting at the traffic light, bus at a stop), typically driver and passengers on board) [time < 5 min].
- **Dynamic en-route power transfer** - vehicle at constant or variable speed typically in a devoted lane, driver and passengers always on board.

All task partners confirmed the combination of vehicle classes/power transfer mode/partner leader for vehicle manufacturer requirements as shown in Table 14 and Table 13

The following technical domains have been identified and need to be analysed below:

- Relevant standards.
- Vehicle drive train power requirements.
- On-board energy storage and range.
- Size, Weight and weight distribution.
- Interface (physical, electrical, mechanical, control).

Table 13 Wireless power transfer case

Wireless power transfer		Vehicle Classes		
		Cars (VeDeCom)	LDV (CRF)	HDV (Scania)
Power transfer modes	Static	X	X	X
	Stationary / en-route	X	X	X
	Dynamic en-route	X	X	X

Table 14 Conductive power transfer case

Conductive power transfer		Vehicle Classes		
		Cars (VeDeCom)	LDV (CRF)	HDV (Volvo)
Power transfer modes	Static			X
	Stationary / en-route			X
	Dynamic en-route			X

6.2. Wireless power transfer standards

This section lists all relevant standards or on-going standardization activities regarding wireless power transfer, currently, the following standards are under development:

a) **ISO 19363 (Stage AWI, scheduled for 10-2016 PAS Public Available Specification)** - Electrically propelled road vehicles - Inductive wireless connection to an external electric power supply - Interoperability and Safety requirements.

b) **IEC 61980 - Electric vehicle wireless power transfer (WPT) systems**

- Part 1 General requirements (Stage CDV).
- Part 2 Specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems (Stage WD, scheduled for 2014 as TS).
- Part 3 Specific requirements for the magnetic field power transfer systems (Stage: WD, scheduled for 2014 as TS).

c) **SAE J2954 Wireless Charging of Electric and Plug-in Hybrid Vehicles** (Guideline scheduled for 06/2014)

6.2.1. HDV standards

There are ongoing discussion for all of the above mentioned passenger car standards (ISO 19363, IEC 61980, SAE J2954) to make extensions that would incorporate applications for HDV. So far there are no available schedules.

6.3. Vehicle drive train power requirements

6.3.1. Power level

Vehicle power requirement at various speeds were measured in order to assess the power demand of the vehicle during the dynamic en-route power transfer mode (both constant and variable).As shown in Figure 27, when the maximum speed is limited up to 70-80 km/h then the average power transfer power rate is between 20 and 30 KW. This should be enough for the drive train supplying and the battery power transfer in the case of private cars and LDV. HDV require 125KW for traction at 90km/h therefore some 150KW is required from the power transfer infrastructure, taking into account transfer efficiency, although a greater headroom will be required if the infrastructure is to be used for traction as well as battery replenishment..

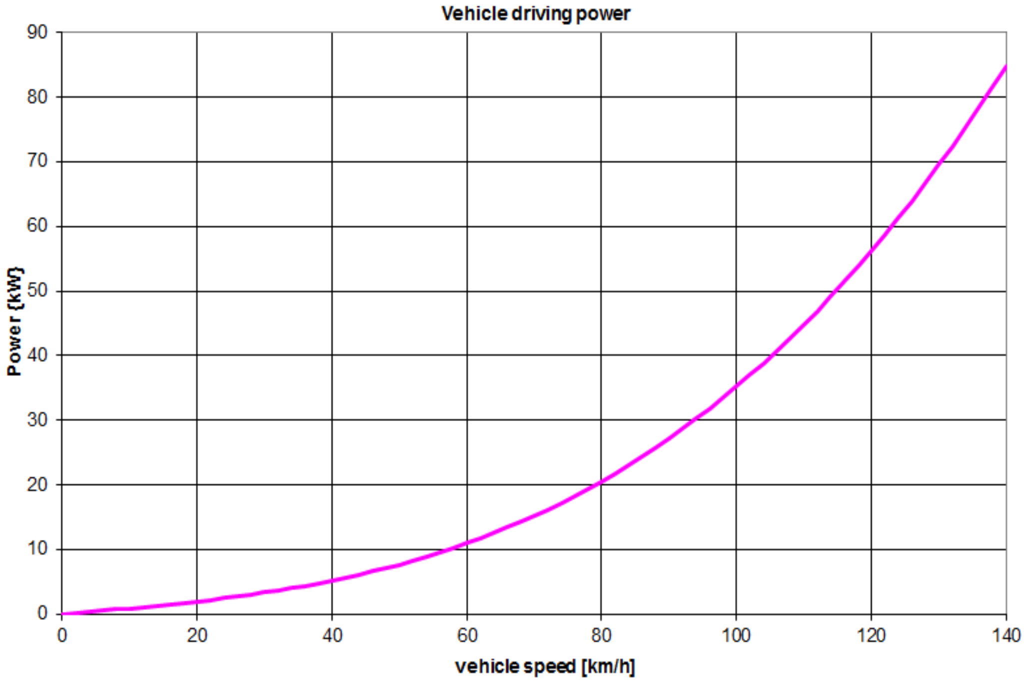

Figure 27 LDV driving power vs. speed curve

6.3.2. Efficiency

The power transfer efficiency, defined from AC grid side to the vehicle DC side, shall be higher than 85% for the private cars and LDV. For the HDV a lower efficiency (80%) could be considered given the higher power value (>200kW).

6.3.3. Power transfer frequency

The power transfer frequency influences the main electrical windings parameters: voltage, current, apparent power, efficiency and power factor. The selection of the operating frequency results in a trade-off between the limited values of these parameters and other constraints. Ideally the frequency should:

- Be the highest possible, for efficiency reasons
- Be lower than 150 kHz, for safety reasons
- Not interfere with reserved bandwidth, for integrity reasons
- Be unique, for interoperability reasons

For health aspect, the frequency used for power transmission should be in the induction band: 10 kHz to 150 kHz. For magnetism optimisation, the frequency should be as high as possible.

Regarding the vehicle compatibility, Keyless entry system and tyre pressure monitoring are in the range of 125 kHz, so this frequency should be avoided.

6.3.4. Voltage Level

The vehicle DC side voltage level is strictly linked with the voltage of battery pack installed on the vehicle. Levels can be very different depending on category of vehicle (light vehicle, cars, trucks, bus, etc.) and on application (hybrid, full electric, etc.). It is possible to identify two main categories related to the nominal voltage:

- Voltage comprised between 150V and 400V: typical voltage range for passenger car and LDV
- Voltage higher than 400V: typical voltage range for HDV

6.4. On-board energy storage and range

The electric energy storage capability is the key technology for electrification. Energy and/or power density of the storage system define the range, weight and power as well as the customer acceptance. In previous decades, the electric vehicle take-up failed due to the lack of a suitable electric energy storage technology that was able to fulfil the automotive requirements. On-board battery requirements for the automotive applications are listed below:

- **Safety:** The battery system behaviour with its related safety mechanism must be guaranteed in normal use, in case of an accident during maintenance, variable weather conditions etc.
- **Specific Energy [Wh/kg]:** Higher values are better for integration of the battery into the vehicle. Higher energy density also means longer range for a given weight; this has huge impact on EV take-up.
- **Specific Power [W/kg]:** It is important to guarantee vehicle performance (also for hybrid application) with limited weight.
- **Cycle Life:** This is defined as the number of charge/discharge cycles a battery can perform before reaching its end of life without letting some features go outside acceptable limits. (Features mainly depend on type, usage, producer of battery, etc.).
- **Calendar Life:** This is the elapsed time before a battery becomes unusable whether it is in active use or inactive.

- **Cost:** The price of the battery, this is usually quoted in cost per kWh. The high cost of batteries is one of the major issues with the current slow electric vehicle take-up.
- **Fast Charge:** This presents the opportunity to the electric vehicles to reach standard ICE vehicle's fast refuelling capability.
- **Temperature Range:** This is the ambient temperature range that a battery should operate in; higher temperatures results in faster chemical reactions hence higher SOC reduction.

It is necessary to install an adequate battery pack that will provide sufficient range and minimise "range anxiety" but at same time the weight of the vehicle should be at its optimum and the price of the vehicle should be affordable for its target market.

It is important to highlight the factors that can influence battery ageing, the battery parameters should be considered when designing the power transfer equipment and drivetrain. The factors that affect battery ageing are listed below:

- **Cycling:** Desired chemical reactions are usually accompanied by unwanted ones which consume some of the active chemicals or impede their reactions, hence battery capacity reduces with the number of charge-discharge cycles a battery is subjected to.
- **Depth of discharge:** The cycling life of batteries is reduced if they are repeatedly subjected to deep discharges.
- **Temperature:** Higher temperature leads to faster chemical reactions and higher SOC reduction, hence reduced battery life.
- **Overvoltage:** Exceeding maximum allowable voltage reduces batteries' life. The overvoltage can be due to overpower transfer conditions
- **Type of cycle:** Cycles having a high energy throughput (charge or discharge) reduces battery life; high power cycles particularly stress the batteries when operating near the voltage limits. This is particularly relevant in stationary and dynamic charging environments where energy is likely to be supplied in short intense bursts.
- **Undercharge:** if SOC goes below the minimum defined threshold, large crystals tend to form and number of dendrites increases. These crystal modifications can lead to higher auto-discharge and even lead to internal short-circuits during repower transfer. Most batteries are protected against undercharge.

In the case of dynamic power transfer using a coil based system, the coil size and the space between them will introduce a speed-dependent pulsating character to the vehicle power transfer with potential negative effects on the battery life.

The limitations related to batteries ageing could be minimised by using combination of batteries and supercapacitors as a power buffer. The supercapacitors would operate during the peak power periods, by a supporting battery during the en-route power transfer (stationary or dynamic) or during regenerative braking. Ideally, the dynamic charging system should be developed in conjunction with the rest of the on-board power electronics and battery system to ensure that the characteristics of the various subsystems are compatible.

Current electric cars typically have an installed battery pack energy capacity between 20 and 30kWh which provides a real world range of some 100 to 150km, depending on driving conditions.

For light commercial vehicles a shorter range could be acceptable for specific missions. For example, for urban goods delivery within a limited area, a range of less than 100 km could be considered sufficient. Furthermore, the adoption of modular battery packs can allow customer to choose the desired range. Generally, for light commercial vehicles with a cargo compartment (up to total mass of 3.5 ton), energy capacity should be at least 40 kWh. This value can be reduced if stationary en-route (at traffic lights, stops) and dynamic en-route power transfer points are considered.

The aim for dynamic power transfer of HGVs is to limit the size of batteries to a minimum. Although depending of type of operation, weight, speed, topology and the availability of power transfer along the route different vehicles will require different size of battery.

The required battery capacity for heavy duty trucks is, as for cars, highly dependent on charging opportunities but it is also very dependent on application (weight and transport mission), and so there is no simple requirement for battery size. The energy requirements of heavy duty vehicles are such that only when significant proportion of the roads used for most of the heavy duty truck driving cycle are equipped with dynamic charging, that it will be possible to replace the ICE size and weight, with an increased size of high voltage battery.

For example, a heavy vehicle travelling at 90km/h requires 125kW traction power, so a 20kWh battery will only have a range of 14km. If 50% of the road infrastructure were to be equipped

with charging infrastructure, this would need to provide 250kW of transfer power capability to keep these vehicles operational.

Much larger batteries than in the example above would not be practical since the trailer load capacity would be reduced, and the maximum bogey weight limitation of the truck would be exceeded. For trucks and buses with lower goods weight, one could equip vehicles with a battery that can extend the electrical range. For heavy duty trucks that only drive at steady state conditions Volvo currently recommend that vehicles should be equipped with a significant powered ICE so as not to disturb transportation needs, while electrical road infrastructure is not available. In the first applications, the battery may only be used to facilitate smooth transitions between ICE drive and electrical motor drive.

6.5. Size, Weight and weight distribution

6.5.1. Secondary device dimensions

In the current standard developments for the wireless power transfer (IEC 61980) the maximum mechanical size of the secondary device are defined as function of the power transfer classes as shown in the table below:

Table 15: Mechanical size of the secondary device

Power class / Direction	MF-WPT1 (<3.7kW)	MF-WPT2 (3.7 to 7.7kW)	MF-WPT3 (7.7 to 22kW)
X(direction of travel)	350mm	600mm	750mm
Y (transverse)	300mm	450mm	600mm
Z (height)	22mm	22mm	35mm

6.5.2. Secondary coil placement

For the choice of the coil placement, some issues have to be considered for each vehicle class:

- Coil dimension.
- Number of coils.
- Placement of the AC/DC converter system.

- Placement of the cooling system, control unit and/or other auxiliaries.
- Presence of sensitive LV and HV systems near to the placement region, which can suffer EMI issues.
- Proximity to the battery to be charged, in order to optimize the layout and reduce length of electrical connections.
- Wiring harness topology considerations taking into account connectors for easy connection/disconnection of the system (both for power and signals connections).
- Interactions with possible conductive power transfer system already present on vehicle (investigation on power connections management).
- Weight repartition and effects on vehicle dynamic behaviour.
- Air gap variations in different vehicle load conditions (key-factor for a light truck).
- Points of mechanical installation and easy removable connections.
- Layout of charging bays (for static and stationary cases)

6.5.3. Light duty vehicle case

The Iveco Daily Electric can have different layouts according to the desired range of autonomy and load capacity. For this reason different modular battery packs (from 2 to 4) can be installed to fit different mission range (from 90 to 130 km).

The following hypotheses of underbody coil installation can be considered as described below and in the Figure 28:

- Front part of vehicle (in place of the front battery pack): this region contains many different devices, related to the LV and HV systems (HV traction batteries, LV systems, cooling systems, and other ancillary systems); due to the high complexity already present in such a region, it is not recommended to place another system, which provides additional EMI risks and requires possibly consistent re-packaging.
- Central part of vehicle (between the electric motor and the central battery pack): In this part of the vehicle is located the transmission to the rear wheels (together with the traction electric motor). Due to the presence of moving mechanical parts, the coil placement in this region could be acceptable only where there are no moving parts, in order to avoid safety issues; in this case the placement is probably feasible.
- Rear part of vehicle (behind the rear axle, on the rear overhang): The presence only of the optional battery pack makes this region the most acceptable for the coil placement,

since there are no moving parts, nor other electrical/electronic (E/E) systems that could be in conflict with the new system.

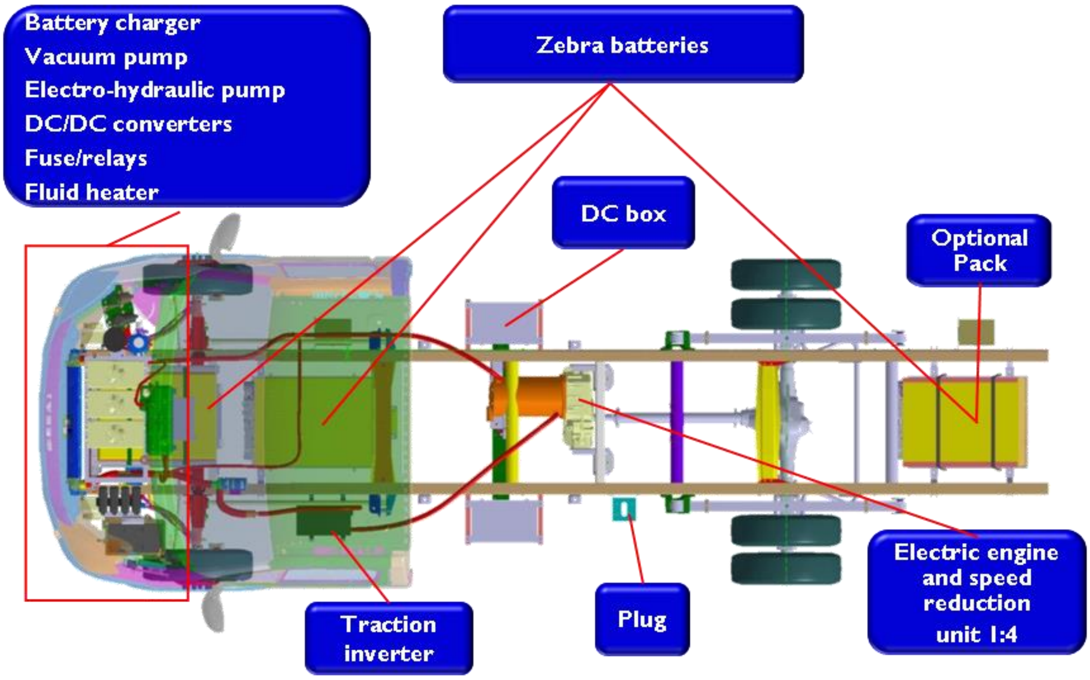

Figure 28: System layout of Iveco electric Daily, as a basis for secondary device installation.

While the rear overhang is the most convenient place for charging coils for this vehicle, in the general case for all vehicles this may not be the most suitable location. For dynamic charging, coils can be placed anywhere on the centreline of the vehicle, but for static and stationary cases a standardised charging coil location within a charging bay will need to be defined, suitable for the greatest number of vehicles. Work on this subject is in progress in standardisation bodies, so no requirement can be created at this stage.

6.5.4. Heavy duty vehicle case – Scania Wireless Power Transfer

Scania has set the following high-level requirements for an HGV charging system:

- 200mm ground clearance.
- 120kW continuous power.
- Speed: 90km/h.
- Standardized interfaces for all different suppliers.

- A standard bus frame is 900mm (all EU OEMs).

With these in mind, Scania has developed a prototype wireless power using inductive power transfer.

The pick-up coils are mounted beneath the centre of the chassis, with substantial shielding. The layout of the installation is shown in Figure 29.

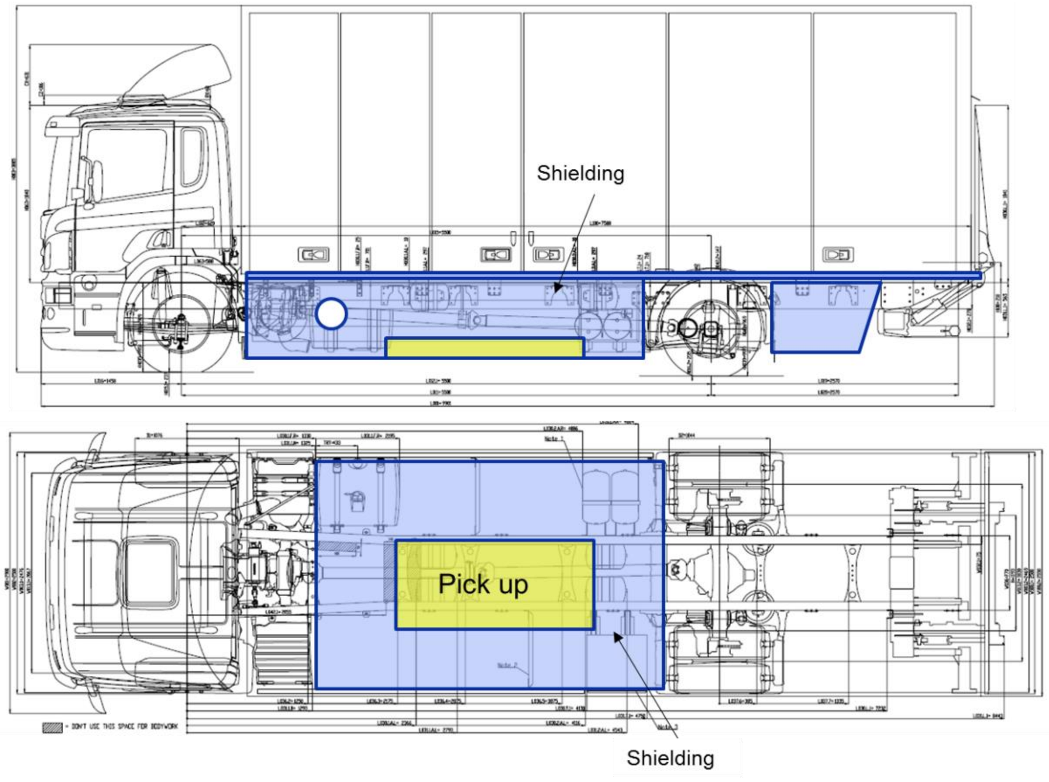

Figure 29: Scania wireless power transfer installation

A photograph of the installation is shown in Figure 30.

Figure 30: Pickup coil mounted under chassis rails

As before, the location of charging coils needs to take into account different vehicle types and charging bay designs. As there is a great variation in the size and layout of heavy vehicles, it may not be possible to define a single standardised coil position on the vehicle.

6.5.5. *Heavy duty vehicle case – Volvo ERS conductive system*

The Volvo Electrical Road System (ERS) is a conductive power transfer system, where two power lines have been built into the surface of the road. The power line is built in sections and each section is only live as the truck passes. Power is transferred to the truck via a current collector located under the vehicle.

The pick-up hardware has a target weight of 50kg/unit, including actuators and structure. A significant proportion of this weight is the actuators and the collector shoes.

Different pickup structures have been evaluated, and shown in Figure 31 is a packaging solution that has been proposed by Volvo for a FH truck. The blue boxes illustrate the available space for new components, and the size of these can be modified as a function of size of the fuel tanks. This space would be needed for power electronics, such as high voltage battery, and converter component between the grid voltage and the battery traction voltage (on-board) system.

The main requirements and study has found that the pickup can be mounted next to the prop shaft, and that it can be lifted up from this position to a home position. This will not impact the ground clearance of the vehicle, when driving with pickup, off the ERS system. Figure 32 shows that the collector shoes of the pickup are well above the minimum required ground clearance for

a FH truck. For a Volvo hybrid truck, the main enabler (ICE + transmission), would be rebuilt, where an electrical motor would be merged in this main propulsion component (see brown component in Figure 31).

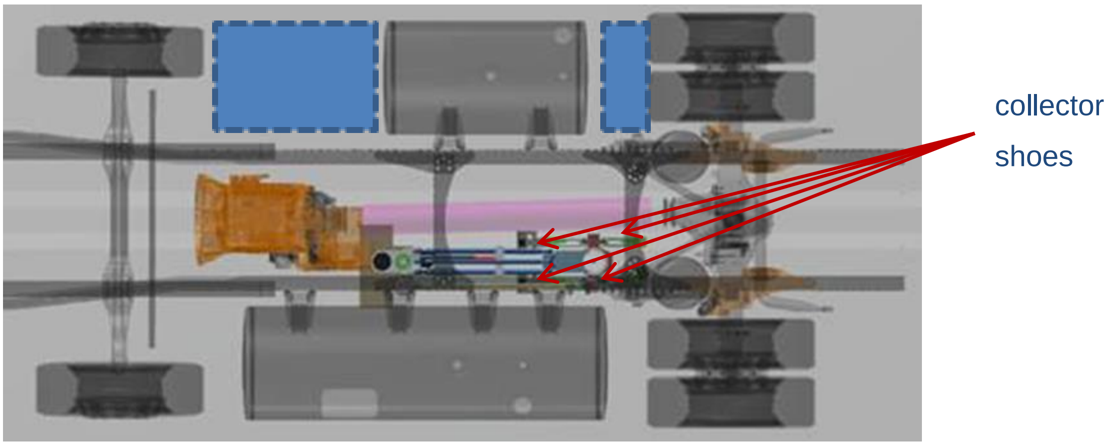

Figure 31: FH truck layout

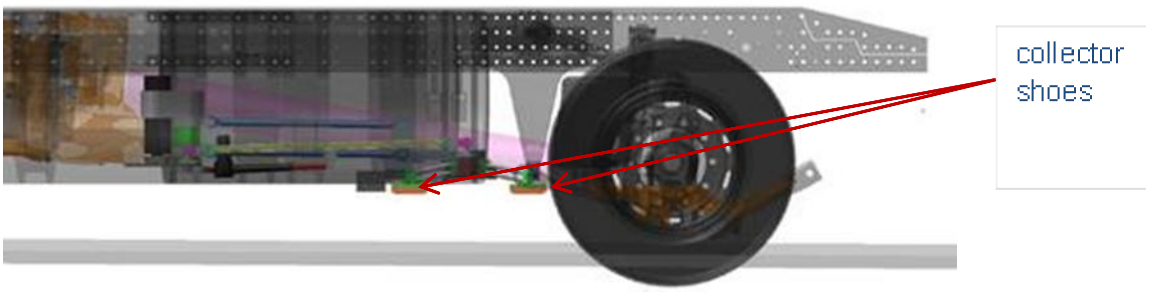

Figure 32: FH truck side view

6.6. Interface (physical, electrical, mechanical, control)

The following minimum set off parameters need to be taken into account when considering the various interfaces on the vehicle:

- Environment
  - Temperature operating limits.
  - Cooling requirements.

    - Vibration.
    - IP-classification.
- Electrical installation
    - Electrical Operating Range.
    - Electromagnetic Compatibility.
    - Inputs.
    - Outputs.
    - Supply and Fuses.
    - Cable harness, power and signal connectors.
    - Insulation resistance.
- Control
    - CAN communication with in vehicle ECUs (internal status, measurements, fault codes, enable/disable command, power/current request/limits, etc.).
    - Wireless communication with the primary on-road power transfer device (status, received power/energy, operating frequency etc.).
    - Current source behaviour with closed loop current control done by the in-vehicle secondary device (AC/DC).
    - Variable current/power regulation.

At this stage of the project, interface requirements cannot be determined as the interface points are still to be defined. This will be done in WP34, at which point interface requirements will be defined.

7. SAFETY – EM ENVIRONMENT

7.1. Introduction

The purpose of this section is to provide a high-level overview regarding the standardization activities related to the wireless and conductive power transfer with focus on the safety and EMC aspects for the on-board and off-board devices.

The following technical domains have been identified and need to be analysed:

- Protection from electro-magnetic field EMF - human health and safety (H&S)
- EMC requirements:
  - Immunity requirements.
  - Emission requirements (conducted and radiated emissions).
- Electrical safety:
  - Protection against electric shock.
  - Protection against thermal incidents.
  - Detection of foreign object debris.

7.2. Identification of the existing standards or in progress standardization activities

At the international level, standardization is mainly dealt with by two institutions: the International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO). Electric vehicle charging infrastructure standardization is the responsibility of IEC-TC69, while the ISO Technical Committee (TC) which deals with the aspects related to electric vehicles is TC22 (Road Vehicles). Inside TC22, subcommittees involved in the Wireless Charging standardization activities are SC3 (Electrical and electronic equipment) and SC21 (Electrically propelled road vehicles). Usually IEC performs work related to electric components, devices and electric supply infrastructures for the vehicle while ISO follows the work related to the vehicle as a whole.

In the United States, standardization is organized on a sectoral basis. For the automotive sector, the Society of Automotive Engineers (SAE) develops standards. These standards are named with letter "J" before the code.

List of relevant standards or ongoing standardization activities regarding wireless charging for cars and LDV, currently, the following standards are under development:

7.2.1. ISO 19363 - Electrically propelled road vehicles - Inductive wireless connection to an external electric power supply - Interoperability and Safety requirements.

This standard, which is at stage AWI, scheduled for publication in Oct 2016, specifies electric safety requirements for inductive wireless connection of electrically propelled road vehicles to an external electric power supply. It applies to electrically propelled road vehicles with voltage class B electric circuits. The requirements when not connected to off-board equipment of the external electric power supply are specified in ISO 6469-3.

NOTE 1 Requirements for off-board equipment of the external electric power supply are specified in IEC 61980-3.

NOTE 2 Requirement for bidirectional power flow is under consideration.

7.2.2. IEC 61980 - Electric vehicle wireless power transfer (WPT) systems

This standard consists of three parts:

- Part 1 General requirements (Stage ADIS – Approved for FDIS Circulation).
- Part 2 Specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems (Stage ANW – Approved New Work, scheduled for 2016 as TS).
- Part 3 Specific requirements for the magnetic field power transfer systems (Stage: ANW, scheduled for 2017 as TS).

IEC 61980 Part 1 scope:

This standard applies to the equipment for the wireless transfer of electric power from the supply network to electric road vehicles for purposes of supplying electric energy to the RESS (Rechargeable energy storage system) and/or other on-board electrical systems in an

operational state when connected to the supply network, at standard a.c. supply voltages per IEC 60038 up to 1000V a.c. and up to 1500 V d.c. This standard also applies to Wireless Power Transfer (WPT) equipment supplied from on-site storage systems (e.g. buffer batteries etc.).

The aspects covered in this standard include:

- The characteristics and operating conditions of the **off-board supply equipment**.
- The specification for required level of electrical safety for the **off-board supply equipment**.
- Requirements for basic communication for safety and process matters if required by a WPT system.
- Requirements for basic positioning for efficiency and process matters if required by a WPT system.
- Requirements for two- and three-wheel vehicles are under consideration.
- Requirements for **WPT system while driving** are under consideration.
- Requirements for **bidirectional power transfer** are under consideration.
- The connection to installations according to IEC 60364-7-722.
- **Specific EMC requirements for WPT systems** to the extent not covered by IEC 61851-21-2.

This standard does not apply to:

- Safety aspects related to maintenance.
- **Trolley buses, rail vehicles and vehicles designed** primarily for use off –road.
- **WPT vehicle power supply circuit**, which is covered by ISO 6469.
- **EMC requirements for on-board equipmen**t while connected, which is covered in IEC 61851-21-1.

IEC 61980 parts 2 and 3 are not yet in draft stage.

7.2.3. SAE J2954 Wireless Charging of Electric and Plug-in Hybrid Vehicles (Guideline scheduled for 06/2014)

The objective of the taskforce is initially to create a guideline for demonstration projects and design verification and later standardize in 2015 with field confirmation. Basically, the work in SAE J2954 has the following objectives:

- Determine Minimum Performance Criteria for power transfer (Efficiency) through team consensus with input from industry studies.
- Develop Safety Criteria also by coordinating with data gathering.
- Develop Testing Protocol for Safety and Performance of wireless power transfer.
- Create a Matrix of available wireless power transfer technologies also through supplier presentations.
- Develop a common interface for vehicle side power transfer to assist in interoperability of wireless power transfer.
- Develop protocol and determine means of communication.

7.3. Protection from electro-magnetic field EMF - human health and safety (H&S) for on-board and off-board devices

The safety limits for human exposure to electromagnetic fields are determined by on-going reviews of scientific evidence of the impact of electromagnetic fields on human health most national regulations reference recommend the human exposure guidelines determined by the Institute of Electrical and Electronic Engineers (IEEE) and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). In their most recent reviews of the accumulated scientific literature, both the IEEE and ICNIRP groups have concluded that: there is no established evidence showing that human exposure to radio frequency (RF) electromagnetic fields causes cancer, there is established evidence showing that RF electromagnetic fields may increase a person’s body temperature or may heat body tissues and may stimulate nerve and muscle tissues.

The main standard/guidelines are listed below:

- IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz”, IEEE Std. C95.1-2005.
- “Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (Up to 300 GHz)”, ICNIRP Guidelines, International Commission.
- Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz - 100 kHz). Health Physics 99(6):818-836; 2010.
- IEC62311: Assessment of electronic and electrical equipment related to human exposure restriction for electromagnetic fields (0Hz 0 300 GHz).

-Measurement procedures with regard to public exposure

- IEC62233: Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure.
- 1999/519/EC, "Council Recommendation of 12th July 1999 on the limitation of exposure of the general public to electromagnetic fields (0hz to 300Ghz), Official Journal if the European Communities No. L 199, 30th July 1999, pp. 59–70.

7.4. Electromagnetic Compatibility (EMC) Requirements

7.4.1. On-board vehicle devices

EMC requirements for on-board equipment are under consideration in IEC 61851-21-1. The device under specification shall conform to the applicable component level EMC requirements. EMC requirements for installation of E/E components in vehicles can be classified in two categories, referring to tests and requirements at component level and at vehicle level.

EMC requirements and tests at component level (E/E components)

- RF emissions (emitted disturbances)
    - CISPR-25 Conducted RF Emissions - (Voltage on Supply Lines).
    - CISPR-25 Conducted RF Emissions - (Current on all Lines in Harness).
    - CISPR-25 Radiated Emissions.
    - Conducted Transient Emissions.
- RF immunity ISO 11452-x, consisting of 10 parts:
    1. General principles and terminology
    2. Absorber-lined shielded enclosure
    3. Transverse electromagnetic mode (TEM) cell
    4. Bulk current injection (BCI)
    5. Stripline
    6. (Withdrawn)
    7. Direct radio frequency (RF) power injection
    8. Immunity to magnetic fields
    9. Portable transmitters
    10. Conducted immunity in the Extended Audio Frequency Range (30Hz to 250Hz)
    11. Radiated immunity test method using a reverberation chamber.

EMC requirements and tests at vehicle level (E/E components)

- RF emissions
  - On-Vehicle Antenna Measurements (CISPR 25).
  - Listening Tests.
  - Off-Vehicle Antenna Emission Measurements (CISPR-12).
  - Magnetic Field Emission (MFE-Test) (CISPR-12).
- RF immunity ISO 11451
  - Immunity to Electromagnetic Fields from Off-Board Sources.
  - Immunity against Transmitters Installed on the Vehicle (OBT-Test).
  - Immunity against Portable Transmitters (PT-Test).
- Voltage transients
  - Conducted Vehicle Transient Sources (**ISO 7637**).
  - Electrostatic Discharges (ESD) (ISO 10605).

7.4.2. Off-board devices

IEC 61980-1 EMC related requirements.

The main standard for electric vehicle inductive power transfer is IEC 61980 which outputted IEC 61980-1 (with current status: circulated as committee draft with vote) that among others includes a chapter regarding EMC of the off-board WPT module with analysis of two fundamental EMC considerations namely, electromagnetic immunity and emission limits. According to (HEMIS, 2012) the draft includes among other definitions of the following immunity requirements:

- Electricity grid sourced disturbances:
  - Off-board power transfer equipment should resist common mode conducted disturbances caused by switching of small inductive loads, relay switching, and distribution level switch equipment function. (Fast transient bursts). (Immunity could be assessed with respect to the following standard: EN 61000-4).
  - Off board equipment should resist voltage surges caused by faults on the power system, lightning and power system switching operations. (Immunity could be assessed with respect to the following standard: EN 61000-4).

  - Off board power transfer infrastructure should resist dc components caused by asymmetrical grid loads. (Immunity could be assessed with respect to the following standard: EN 61000-4).
  - Off board power transfer infrastructure should resist supply voltage variations and interruptions (Immunity could be assessed with respect to the following standard: EN 61000-4).
  - Off board power transfer equipment should resist low frequency harmonics caused by non-linear loads connected to the network. (Immunity could be assessed with respect to the following standard: EN 61000-4).
  - Off board power transfer equipment should resist electrostatic discharge (Immunity could be assessed with respect to the following standard: EN 61000-4).
- Electromagnetic field sourced disturbances
  - Off-board power transfer equipment should resist electromagnetic field exposure while the system is used to charge the battery load at rated power (Immunity could be assessed with respect to the following standard: EN 61000-4-3, EN 61000-6-1/2/3).

The following inductive power transfer system emissions are considered in the standard:

- Emissions towards the electricity grid
  - Emissions due to the operation of the inductive power transfer system on the ac supply system (Emission limits could be assessed with respect to the following standard: EN 61000-3).
- Electromagnetic field emissions
  - Magnetic fields 25 KHz to 30Mhz. (Emission limits could be asserted with respect to the following standards: EN-55011, EN 55014-1 and EN-50121-2, EN 300 330-1).
- Emissions of the inductive system to internal power transfer equipment control signalling.

7.5. Electrical safety requirements

7.5.1. On-board devices

All voltage class B circuits shall be protected against direct and indirect contact. For this reason, the requirements in this section shall apply only to systems belonging to Class B family (according to classification in ISO 6469 and ISO 17409 (under development).

NOTE: Class B circuits refer to working voltages between 25 V AC and 1000 V AC, or 60 V DC and 1500 V DC.

Protection against Direct Contact with Live Parts

The degree of protection and the means of protection requirements are specified below.

- Degree of Protection: HV part shall be protected by an enclosure with a protection degree that meets or exceeds regulation and industry standards (ECE R100 and ISO 20653); the protection degree shall be specified and certified by the supplier.
- Means of Protection: HV component shall have insulation, enclosures or protective covers that prevent direct contact with HV. These protective means shall be securely fastened and shall withstand mechanical strain for design life. These protective devices shall not be opened, disassembled or removed without use of special tools. Protective means of insulation shall fully cover live parts with insulation and shall be removable only through destruction. The insulation material shall be suitable for the voltage and temperature ranges of the HV component. The insulation shall have sufficient insulation resistance and fulfil the requirements of the dielectric strength test. Protective means shall comply with ECE R100, ISO 6469-3 and ISO 23273-3 as applicable.

Protection against Indirect Contact to HV

Protection against indirect contact shall be ensured by using insulation and galvanically connecting the exposed conductive parts of the device with the rest of the HV system. All components that contain HV shall comply with ECE R100, SAE J2344 and SAE J2578 as applicable.

- Insulation: The HV circuits shall be insulated from electric ground, chassis ground and other LV and HV circuits. Insulation of cables, connection systems, bus bars and circuit boards shall meet or exceed the Dielectric Strength requirements.
- Equipotential Bonding: The outer frame of the HV component shall be connected to chassis ground with a maximum electrical resistance of the contact of 20 mΩ. All components that contain HV shall comply with ECE R100, ISO 6469-3, ISO 23273-3 as applicable.

LV Power Net Protection

HV and LV lines shall not, in any case, come in contact with each other, by means of galvanic separation (mechanical separation between these circuits). All components that contain HV shall comply, as applicable, with ISO 6469-2.

High Voltage Interlock Loop (HVIL)

All HV components with HV access covers shall provide HVIL protection to attempts to access live parts. The Loop of the HVIL is implemented in wiring and connectors, and it shall not be routed in parallel to HV cable.

7.5.2. Off-board devices

General requirements

- Hazardous live parts shall not be accessible.
- Protection measures against electric shock under single faults conditions shall be implemented.
- For EV supply equipment intended for fixed installation, the requirements are specified in IEC 60364-7-726.
- It is recommended to use independent protection means (overcurrent and fault current) for each connecting point to the vehicles that can be used simultaneously in order to ensure a better availability of power.

Protection against direct contact

- Degrees of protection against access to hazardous parts: IP ratings for enclosures shall be at least IPXX:

- IP ratings for enclosures: the minimum IP ratings for the enclosures of the off-board power components shall be IP21 for indoor use and IP44 for outdoor use. The environments of use shall be indicated in the manual.
- IP ratings for primary device: the IP degrees for the primary device shall be as follows:
  - The minimum IP degrees shall be IP 65.
  - The minimum IP degrees in public road installation: IP 69K (ISO20653) as installed.

Protection against thermal incidents

The requirements are intended to prevent:

- Accessible parts of the WPT system from exceeding certain temperatures to prevent skin burns when touched accidentally or intentionally IEC Guide 117.
- Components, parts, insulation and plastic materials of the WPT system from exceeding certain temperatures which may degrade the electrical, mechanical, or other properties of the WPT system during normal use over the expected life of the equipment IEC 61439-1.
- Foreign objects in the air space between primary and secondary device from exceeding temperatures which could become a touch hazard. Depending on the WPT technology, a set of daily life test objects that may be exposed to the energy of the WPT system, has to be defined.

For the defined test objects the following maximum temperature limits, based on IEC 60364-4-42:2010-05 and IEC Guideline 117, shall not be exceeded when accessible:

- Metal parts with bare metallic surface: 80 °C.
- Parts with non-metallic surface: 90 °C.

7.6. Dynamic conductive power transfer for HDV

The standard dealing with the dynamic conductive power transfer is: CLC/TS 50502 Technical specification. Electric equipment in trolley buses – Safety requirements and connection systems.

For dynamic conductive power transfer there are some added safety requirements for high-voltage components on-board devices:

- Extra sealing, casing, or electrical monitor of physical compartment(s) with high-voltage components.
- Special precaution in case of hazards, incidents.
- For conductive dynamical power transfer, similar to trolley-buses, components need to be isolated with an extra isolation.

8. CONCLUSIONS

8.1. Road authority/owner requirements

This section investigated the requirements for integration of on-road electrical power transfer solutions with existing road infrastructure. The work in this task was primarily carried out by SANEF and TRL and therefore, the majority of the requirements are based on the information available in France and the UK. However, in order to make sure that the outputs from this work are useful and applicable across Europe as much as possible, feedback was sought from other European countries' Road Authorities / Owners on the identified requirements.

Due to the limited number of current on-road charging equipment installations, when determining the requirements for such equipment, no assumptions were made as to whether the equipment will use inductive or conductive power transfer, nor were any assumptions made as the size of the equipment, whether it will need to be installed flush with the surface, can be buried below the surface or could be a pantograph system, with overhead lines.

Five varieties of on-road power transfer solution installations were considered:

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.

First the physical requirements of the road owner were considered. These included Size, Weight, Components (Material), 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. As the road is a very harsh environment, and the cost of road maintenance is substantial, any equipment installed in or on the road must not compromise the longevity of the road or increase maintenance requirements.

The consequences of operation of the systems were also considered. Likely requirements are:

- The system must not affect the non-electric vehicles or the non-charging vehicles travelling on the road (especially their electronic components).

- The system, on-line or off-line, must not affect the driving abilities of the drivers (for all types of vehicles: electric or not, charging or not, motorbikes, bikes).
- The system, on-line or off-line, must not affect the health of the passengers of the vehicles (for all types of vehicles: electric or not, charging or not).
- The system, on-line or off-line, must not affect the health of the pedestrians walking on the road and near the road. (On motorways, pedestrians may be passengers from a vehicle stopped after an incident or maintenance staff or emergency staff).

The consequences of the magnetic fields were considered, identifying where legislation and standards exist. In the UK for example, no legislation exists governing emissions within pavement structures, although health and safety legislation will be relevant. The ICNIRP has developed guidelines on exposure to EMFs.

When considering the performance of charging systems, it is noted that these must not adversely affect the traffic condition. Hence systems need to work at prevailing traffic speeds, and should not change traffic behaviour so as 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. The UK in common with other EU countries has a wide range of regulation covering the installation and maintenance of roads and road-side infrastructure. These are designed to ensure that roads are built to sufficient quality and safety standards. These will include requirements on 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 will need to be generated.

The legal and regulatory requirements relating to road operators were examined, including overhead clearance, trench reinstatements, road installations, maintenance of strategic and non-strategic roads, roadside and in-road equipment and equipments safety.

The concept of the Forever Open Road (FOR) was considered. This is an initiative of the Forum of European Highway research Laboratories (FEHRL), which aims to create the next generation

of adaptable, automated and resilient roads. The integration of power transfer infrastructure into the FOR will place significant requirements on the FOR.

Finally Weigh-In-Motion systems were considered for their effect on road operations.

8.2. Grid/distribution requirements

This section of the deliverable studied the grid requirements for the installation of dynamic power transfer systems in different environments, urban streets or interurban roads.

The study has listed general high level grid requirements. Numerous international standards have been found, focusing on different topics such as safety, reliability, voltage regulation and monitoring RES, as well as magnetic field and communications requirements. The grid requirements have been studied in more detail in two countries – Spain and France –These regulations specify the way in which the connection of the charging systems must be designed in order to avoid unwanted effects on the grid.

This study included an investigation into expected demand under two scenarios; coordinated and uncoordinated traffic. In the first case, demand power has a smooth variation that could be supported by the grid. However, in the uncoordinated case, power fluctuations were very high, especially in the medium traffic density scenario. It is concluded that traffic coordination is an interesting option in order to reduce fluctuations at a low cost, although it could be technically very difficult to implement in real world drive environments.

Different models have been assessed, in order to analyse the impact of power transfer infrastructure design on power fluctuations. It is concluded that gaps between power transfer pads should be avoided, in order to obtain a more continuous overall demand.

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. For the urban case with a smoothing window of 5s, most of the fluctuations were smoothed. The corresponding storage system has to be rated at 11.4 MW and it should have 8.2 kWh of energy capacity. In the inter-urban traffic case, fluctuations are much lower hence storage requirement for smoothing is lower. On the other hand, a smoothing

window of 60s is needed to obtain some smoothing effect. In this case, the required storage system has to be 2 MW with 8 kWh of energy capacity.

Finally, the integration of solar PV has been studied. It could be shown that daily profiles of solar generation and demand from on-road charging are very similar, which opens a great opportunity for self-consumption schemes even without a storage support. 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. No impact has been observed for smoothing periods up to 1 min (fast fluctuations). Therefore, larger smoothing periods of up to 3 h have been applied, when the smoothing intervals are extended to hours. Discharge times increase from seconds to hours, which mean that a storage system with 7 MW of nominal power will have 7 MWh of energy capacity for a discharge time of 1h. Such large systems has be managed in a more sophisticated way (not just smoothing based on moving averages), in order to justify the installation cost.

Overall, the requirements on the grid are such that a highly variable demand is likely due to the short power pulses a charging system would create, and hence local smoothing would need to be considered to ensure load on the grid are manageable.

8.3. Local authorities/city governance requirements

In Work Package 3.2, Task 3.2.3, Local and City Authorities' Requirements for the Installation of On-Road Power transfer Infrastructure for EVs (transport and urban planning), the requirements for integrating on-road power transfer infrastructure for electric vehicles (EVs) with transport and urban planning requirements from a national and local perspective are identified and examined.

The technical considerations section investigates the requirements for power distribution and how electrical power may be delivered to the charging infrastructure within existing regulations. Examples from existing inductive power demonstration projects are noted, as well as a tram project in France. The potential impacts of these distribution systems on local planning regulations are identified.

The requirements by city and local authorities for on-road EV infrastructure that may be introduced into urban roads will be determined by a range of decisions made at national, regional or European level. How the various local planning bodies operate in this environment

are considered, and includes a detailed study into regional and national and roles and policy development.

Finally transport and urban planning requirements are considered. The key purpose of transport planning is to plan, design, deliver, manage and review transport, balancing the needs of society, the economy and the environment. A detailed description of the planning process operates in the UK is given. This includes:

- Land use planning which considers how land is allocated and used.
- Infrastructure design, planning and construction which considers the strategic and operational planning of road and rail infrastructure. Various planning guidelines and standards will need to be taken into account when implementing EV power transfer infrastructure.
- Impact on other road users, particularly in urban areas where roads are not just infrastructure, but are considered a public place. Hence any infrastructure should take into account how the public use the road space, and planning needs to take this into account. Multi-modality and other travel behaviour issues need to be taken into account.
- Transport and traffic management can make use of policies and strategies to reduce travel demand during peak periods, and effective use of planning policies can assist in this.

8.4. Vehicle manufacturer requirements

This chapter concentrated on vehicle manufacturer's needs and requirements. There are existing standards for electrical/electronic devices, electrical vehicles and general vehicle requirements. IEC and SAE are also developing standards specifically designed to address dynamic or wireless power transfer methods, such as IEC 61980 and SAE J2954 which addresses electric vehicle wireless power transfer systems.

The power demand for a car moving at speed of 80km/h is between 20-30 KW, for HDV power demand is approximately 125KW at 80km/h. It can be concluded that the efficiency of the system should be higher than 85% for a car and 80% for a HDV. However efficiency is dependent on number of factor one of which is the power transfer frequency. The frequency has to be high enough to provide efficient power but at same time it should not interfere with other systems and it should be safe for humans, so there is a trade-off between efficiency and safety.

It is anticipated the frequency of the power transfer systems should be between 10-150 kHz for safety reasons.

The typical voltage range for a car is dependent on the battery pack, for a car this value is normally 150-400V, however voltage range can be higher than 400V for HDVs. The size of the secondary coils are defined in IEC61980, according to the standards the dimensions of the secondary

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

The systems must be designed to consider the environmental factors, operational power range, cooling requirements and good level of safety and protection precautions should be taking into account.

8.5. Safety- EM environment

This chapter investigated the safety and EMC aspects in relation to the dynamic power transfer. The study covered human health and safety, electrical safety and EMC requirements.

There are list of standards with regards to electrically propelled vehicles, these are:

- **ISO19363:** This standard specifies electric safety requirements for inductive wireless connection of electrically propelled road vehicles to an external electric power supply.
- **IEC61980:** Electric vehicle wireless power transfer (WPT) systems
    - Part 1 General requirements (Stage CDV).
    - Part 2 Specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems (Stage WD, scheduled for 2014 as TS).
    - Part 3 Specific requirements for the magnetic field power transfer systems (Stage: WD, scheduled for 2014 as TS).
- **SAE J2954:** Wireless Charging of Electric and Plug-in Hybrid Vehicles, The objective of the taskforce is initially to create a guideline for demonstration projects and design verification and later standardize in 2015 with field confirmation.

The safety limits for human exposure to electromagnetic fields are determined by on-going reviews of scientific evidence on the impact of electromagnetic fields on human health most national regulations reference recommend the human exposure guidelines determined by the Institute of Electrical and Electronic Engineers (IEEE) and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

EMC requirements for on-board equipment are under consideration in IEC 61851-21-1. The device under specification shall conform to the applicable component level EMC requirements. EMC requirements for installation of E/E components in vehicles can be classified in two categories, referring to tests and requirements at component level and at vehicle level.

- EMC requirements and tests at component level (E/E components).
- EMC requirements and tests at vehicle level (E/E components).

Electrical safety requirements for on and off board devices are based on protection, bonding, insulation, and temperature of the accessible parts.

9. APPENDIX

9.1. Road authority / owner requirements

9.1.1. Physical Characteristics

Technical domain	Sub domain	Requirements	Applicability[16]	Origin / Importance rating	Country Applicability
Physical characteristics	Size	The size of the system must weaken neither the strength of the structure of the pavement nor the wearing course.	1,2,3,4	Standard	All
		Minimum static clearance between live conductors must be maintained	5	Regulations and guidance	All
		The size of the system must be compliant with the clearance of the bridges or the tunnels, and must allow the safe traffic of extra-large trucks when authorised on the road.	5	Standard	All
		Where there are bridges over the tramway the parapets should deny access to the overhead electric system. No live electrical part may be lower than a set minimum above the surface of any carriageway at the maximum temperature of the	5	Regulations and guidance	UK

[16] Applicability to types of charging solution installations: (1) – Wireless / under the road, (2) – Wireless / flush with road. (3) – Wireless / on the road, (4) – Conductive / flush with road, (5) – Conductive / overhead

Technical domain	Sub domain	Requirements	Applicability[16]	Origin / Importance rating	Country Applicability
		wire			
		Live wires must not be "within reach" from a nearby building or structure and must be supported on insulators or covered by insulation	5	Good Practice	All
	Weight	The weight of the system must not accelerate the ageing of the structure of the pavement The acceleration of the ageing of the structure of the pavement results in the increase of frequency of maintenance operation and consequently significant costs.	1,2,3,4	Good Practice	All
	Components (material)	The material composing the system must not chemically interact with the components of the pavement The chemical interaction with the components of the pavement results in the increase of frequency of maintenance operation and consequently significant costs	1,2,3,4	Good Practice	All
	Components (material)	The material composing the system must be able to withstand chemical and mechanical interaction of substances expected on the road, e.g. salt and gritting substances Troubles on the pavement, generated by chemical or mechanical actions result in the increase of frequency of maintenance operation and consequently significant costs	1,2,3, 4	Good Practice	All
	Strength	The system must be strong enough to withstand (weight, vibrations) • The passage and possible stop of heavy vehicles of 44 tons, with a limit from 10 tons to 13,5 tons per axle,	1,2,3,4	Standard	All

Technical domain	**Sub domain**	**Requirements**	**Applicability[16]**	**Origin / Importance rating**	**Country Applicability**
		depending on the country • The passage and possible stop of the construction vehicles (finisher, compacter) during the implementation of the pavement layers. • The passage and possible stop of extra-large vehicles when authorised on the road.			
	Robustness, heat resistance, fire resistance	The system must withstand weather impacts : humidity, rain, frost, heat, snow, UVA, UVB, at least to the same standard as the road	1,2,3,4	Standard	All
		The system must withstand the heat of the mix (120-200°C) during the laying of the upper layers of the pavement. Use of low-temperature asphalt mix could also be possible.	1,2,3,4	Good Practice	All
		The system must withstand the impact of the de-icing salt: corrosion and thermal shock generated by their applications (for information: the temperature gradient is around 60°C in 3 minutes. Normal pavement of a motorway is able to withstand a gradient from -25°C to 60°C over a few minutes). Troubles on the pavement, generated by the corrosion and thermal shock of de-icing salt result in the increase of frequency of maintenance operation and consequently significant costs	1,2,3 and 4	Good Practice	All
		The system should be able to resist a fire on the road or a spill of hazardous material	All	Good Practice	All

9.1.2. Consequences of the operation of the system

Technical domain	Sub domain	Requirements	Applicability[17]	Origin / Importance rating	Country Applicability
Consequences of the operation of the system	Temperature	The temperature generated by the operation of the system must not alter the structure of the pavement. The temperature of the system combined with the natural temperature of pavement must be under 40°C. Troubles generated by an abnormal raise of temperature result in the increase of frequency of maintenance operation and consequently significant costs	1,2,3,4	Good Practice	All
	Magnetic field	The magnetic field generated by the system must not interact with the roadside equipment such as variable message signs, optical fibre, optical and magnetic sensors (including inductive loops), traffic lights, ITS transceivers and so on.	All	Safety	All
		The magnetic field generated by the system must not interact with communications devices used by emergency teams and maintenance teams.	All	Safety	All
		Use of alternative materials in pavements to meet requirements of charging systems: Local regulations may allow the substitution of materials subject to performance specifications.	1,2,3 and 4	Regulations	All

[17] Applicability to types of charging solution installations: (1) – Wireless / under the road, (2) – Wireless / flush with road. (3) – Wireless / on the road, (4) – Conductive / flush with road, (5) – Conductive / overhead

Technical domain	Sub domain	Requirements	Applicability[17]	Origin / Importance rating	Country Applicability
	Electric field	The electric field generated by the system must not interact with the roadside equipment such as variable message signs, optical fibre, optical and magnetic sensors (including inductive loops), traffic lights, ITS transceivers and so on.	All	Safety	All
		The electric field generated by the system must not interact with communications devices used by emergency teams and maintenance teams.	All	Safety	All

9.1.3. Performance of the services

Technical domain	Sub domain	Requirements	Applicability[18]	Origin / Importance rating	Country Applicability
Performance of the services	Speed of vehicles	The speed of the vehicles using the system must be compliant with the average speed of the flow of vehicles.	All	Safety	All

[18] Applicability to types of charging solution installations: (1) – Wireless / under the road, (2) – Wireless / flush with road. (3) – Wireless / on the road, (4) – Conductive / flush with road, (5) – Conductive / overhead

Technical domain	Sub domain	Requirements	Applicability[18]	Origin / Importance rating	Country Applicability
	Speed of vehicles	The speed of the vehicles using the system must be compliant with the average speed of the flow of vehicles. On motorways, the average speed is at least 100 km/h for light vehicles not mixed with trucks, 80 km/h for trucks. On trunk roads (outside urban areas), the average speed is at least 70km/h	All	Good Practise/ Safety - Medium	France
	Speed of vehicles	The speed of the vehicles using the system must be compliant with the average speed of vehicles in the charging lane(s). On UK motorways, average speeds in the three running lanes are 95, 115 and 130 km/h. Note that highest average speed is actually above the UK national speed limit of approximately 113km/h.	All	Good Practice/ Safety - Medium	UK
	Speed of vehicles	If Smart Motorways technology is in use, then the average speed of all lanes will be controlled (e.g. in UK: controlled at either 80 or 95 km/h). Charging solutions should not impeded the use of additional lanes or obeying of speed limits. E.g. the hard shoulder might be used as a running lane, either dynamically or permanently.	All	Good Practice/ Safety - Medium	UK
	Communications	If Smart Motorways technology is in use, this will be setting speed limits automatically. The charging system should be able to communicate with the Smart Motorways system to select the most appropriate operational regime	All	Good Practice - Low	All
	Mix of vehicles (electric and non-electric/ in charge	In case there is no dedicated lane for the charging system, the flow of the non-charging vehicles must not be affected by the charging ones.	All	Safety	All

Technical domain	Sub domain	Requirements	Applicability[18]	Origin / Importance rating	Country Applicability
	or not	In case there is no dedicated lane for the charging system, the flow of the non-electric vehicles must not be affected by the electric ones The traffic flow must not be affected by vehicles wanting to change their lane to use the system on the charging lane.			
	Mix of vehicles (electric and non-electric/ in charge or not	The number of charging vehicles must not exceed the capacity of the available charging lane(s)	All	Good Practice - Low	All
	Vehicle headway	The system must be able to cope with vehicles travelling within a 4m of each other	All	Good Practice - Low	All
	Efficiency	The system must be efficient through a wearing course of at least 4 cm thick.	1	Good Practice	All
		The system must be efficient if the wearing course is soaked with water (especially in case of porous asphalt)	1,2,3 and 4	Good Practice	All
		The system should be able to cope with the expected vehicle deviations from the centre line in each lane, e.g. efficiency should be maintained. Driving simulator studies show that in the UK, a car on the highways is within 5cm of the lane centre line for XX% of time and within 15cm XX% of time.	All	Good practice / Medium	All
	Switch on/off	The system can be switched off remotely as soon as required by the traffic management (e.g. in case of an incident on the zone) or the road maintenance.	All	Good practice - Safety	All

Technical domain	Sub domain	Requirements	Applicability[18]	Origin / Importance rating	Country Applicability
		Stopping the system must not generate an abrupt decrease of the speed of the charging vehicles.	All	Good practice - Safety	All
		Emergency stopping spots must be locally implemented to be activated in case of emergency	All	Good practice - Safety	All
		The system must stop automatically as soon as an abnormal hot spot is detected (fire).	All	Good practice - Safety	All
		Individual charging lanes can be switched on/off remotely according to traffic conditions and/or speed limits and/or whether the hard shoulder is in use as a running lane	All	Good Practice - Low	All
		Responsibility for switch on/off should be clearly defined. A dedicated charging operator might be required	All	Good Practice / Safety - Medium	All
	Other sensors	In-road charging solutions are unlikely to be placed in conjunction with existing inductive loop sensors buried in the road surface. Therefore, either the systems should be placed in locations where they will not impede the operation of such sensors or the charging systems could emulate current data collection methods, e.g. inductive loops. Traffic data would be collected, packaged and transmitted in the same way as existing loop data	1,2,3,4	Good Practice - Low	All

9.1.4. *Installation and the maintenance*

This section makes extensive use of UK regulations as an example. Equivalent local law, possibly with different specific requirements, will apply in other countries.

Technical domain	Sub domain	Requirements	Applicability[19]	Origin / Importance rating	Country Applicability
Installation and Maintenance	Positioning	The lane on which the system is implemented must be chosen according to the kind of road traffic expected to use the system	All	Good Practice	All
	Positioning	Installation of systems in traffic bottlenecks should be avoided where these systems adversely affect driver behaviours to avoid increasing congestion in bottleneck areas.	All	Good Practice - Low	UK
	Positioning	The positioning of the system in the pavement must not weaken the structure. Especially, it must not generate cracks or other distortions of the upper pavement layers (wearing course and binding course) Ideally the system will be positioned in the binder, under	1	Good Practice	All

[19] Applicability to types of charging solution installations: (1) – Wireless / under the road, (2) – Wireless / flush with road. (3) – Wireless / on the road, (4) – Conductive / flush with road, (5) – Conductive / overhead

Technical domain	Sub domain	Requirements	Applicability[19]	Origin / Importance rating	Country Applicability
		the wearing course. This allows the system to be protected by the upper course of the pavement from the friction of the wheels and from the weather impacts. Furthermore, it is compliant with the maintenance practises (de-icing, snowplough) and allows a suitable transverse flow of water on the wearing course.			
		If the cumulative settlement of a reinstatement exceeds the limits shown in Table S2.4 of the SROH at any time within the guarantee period, an agreed engineering investigation shall be carried out, jointly with the Authority.	1,2,3 and 4	Law - New Roads and Street Works Act, 1991 - High	UK
	Structural integrity	A reinstatement of 1000mm depth or less requires an intervention if the cumulative settlement is greater than 30mm or 1.5% of the unbound layer thickness (whichever is greater)	1,2,3 and 4	Law – SROH. 210 - High	UK
	Structural integrity	Rutting - Requirements for allowable rutting are described in Annex 2A, for e.g., intervention level of concern for rutting is 20mm. Cracking - Requirements for allowable cracking are described in Annex 2A. Ride Quality - Requirements for ride quality are described in Annex 2A, for e.g., intervention level of concern for 30m variance for 100m reporting lengths is 110mm^2	1,2,3 and 4	Standard – DMRB 7.3.2 - Medium	UK
	Structural integrity	The reinstatement of any surface shall be as flat and flush as possible with the surrounding adjacent surfaces. There should be no significant depression or crowning in the	1,2,3 and 4	Law – SROH. 210 - High	UK

Technical domain	Sub domain	Requirements	Applicability[19]	Origin / Importance rating	Country Applicability
		surface. Construction tolerances at the edges of the reinstatement shall not exceed ± 6mm.			
	Trench reinstate-ments	Edge depression intervention shall be required where the depth of any edge depression exceeds 10 mm over a continuous length of more than 100 mm in any direction	1,2,3 and 4	Law – SROH. 210 - High	UK
	Trench reinstate-ments	Surface depression intervention shall be required where the depth of any area of surface depression spanning more than 100 mm in any plan dimension exceeds the intervention limit X shown in Table S2.1. of SROH	1,2,3 and 4	Law – SROH. 210 - High	UK
	Trench reinstate-ments	Surface crowning intervention shall be required where the height of any area of surface crowning spanning more than 100 mm in any plan dimension exceeds the intervention limit Z shown in Table S2.2 of SROH	1,2,3 and 4	Law – SROH. 210 - High	UK
	Trench reinstate-ments	All fixed features, such as edgings, channel blocks, drainage fixtures, surface boxes and ironware etc., should be as level and flush as possible with the adjacent surfaces.	1,2,3 and 4	Law – SROH. 210 - High	UK
	Fixed Features	The positioning of the system on the pavement must not affect the skid resistance of the surface (esp. for motorcycles), the evenness, and the waterproofing of the wearing course. The system must allow the transverse flow of water on the wearing course.	2,3,4	Standard	All

Technical domain	Sub domain	Requirements	Applicability[19]	Origin / Importance rating	Country Applicability
	Structural integrity	Rutting – requirements for allowable rutting are described in NFP98-150-1 standard Skid resistance – requirement for allowable skid resistance are described in NFP98-150- 1 standard	1,2,3,4	Standard – NFP98-150-1	France
	Structural integrity	Evenness – requirements for allowable measures of evenness are described in DGR n°200-36 (22nd may 2000)	1,2,3,4	Standard – circulaire DGRn°200-36	France
	Structural integrity	Requirements for texture depth, Polished Stone Value (PSV), or Aggregate Abrasion Value (AAV) can be found in Section 2.6 of the SROH There is no requirement to provide a texture depth, PSV, or AAV that is superior to that of the surrounding surface.	1,2,3 and 4	Law – SROH. 210 - High	UK
	Skid Resistance	Chamber tops subject to trafficking are selected based on their ability to provide an adequate level of skid resistance. Measurement of in-service skid resistance potential shall be by means of a Polished Skid Resistance Value (PSRV). There is no requirement to provide a texture depth, PSV, or AAV that is superior to that of the surrounding surface.	1,2,3 and 4	Standard UK : BS 9124 - Medium	All
	Skid Resistance	Surface and sub-surface drainage arrangements should be designed to prevent water entering the lower pavement layers, either from the surface or from the sides.	1,2,3,4	Standard UK : Design Manual for Roads and Bridges 4.2 and 7.2.3 - Medium	All

Technical domain	**Sub domain**	**Requirements**	**Applicability[19]**	**Origin / Importance rating**	**Country Applicability**
	Drainage	Charging system and maintenance design must ensure continuity of drainage, both in and below the pavement layers and across the carriageway. Care must be taken during the resurfacing schemes, where the existing layer beneath the new surfacing has to provide a near impermeable layer or else be replaced.	1,2,3,4	Standard UK : Design Manual for Roads and Bridges 4.2 and 7.2.3 - Medium	All
	Roadside equipment – safety	The roadside equipment must be installed behind the guard rail on motorways if there is one. The safety distance between the edge of the pavement and the roadside unit must be respected. Outside urban areas, the distance depends on the type of the roads: 10m for motorways, 7 for other new roads, 4m for other existing roads.	All	Practice Technical guide “Traitement des obstacles latéraux”(SETRA-2002)	France
	Roadside equipment – safety	For highways: Passively safe furniture placed a minimum of 600mm from the back of the safety barrier with larger objects placed at a minimum of 2m from the back of the safety barrier.	All	Standard - DMRB 2.2.8 - Road Restraint System (RRS) - Medium	UK
	Roadside equipment – safety	Care shall be taken to ensure that no substantial fixed obstructions obstruct the user sightlines when driving.	All	Standard DMRB 6.1.1	All
	Roadside equipment – safety	Installation of road side equipment and the cables connecting the primary module to road side equipment should not disrupt the existing drainage at the edge of the road (e.g. gulleys, ditches).	All	DMRB 4.2	UK

Technical domain	Sub domain	Requirements	Applicability[19]	Origin / Importance rating	Country Applicability
	Roadside equipment - Drainage	There are no legal requirements governing road side equipment on non-SRN roads, and local authorities implement their own requirements based on risk assessments, with the option of following the HA requirements as guidelines for good practice.	All	Guidance / Good practice - Local authority requirements - DMRB 4.2 - Low	UK
	Roadside equipment – wires	The wires connecting the charging unit to the roadside equipment must not prevent the traffic of the vehicles for winter maintenance (snow removal) and the traffic of the vehicles for the maintenance of the shoulder (sweepers, mowers, trimmers…). The wires must be buried in the pavement and under the flush drainage devices along the road (such as gutters, ditches…) and under the optical fibres.	All	Practice	All
	Binding	The system must be firmly attached to the road in order not to be torn by the traffic of construction vehicles (finisher, compacter) during the implementation of the upper layers of pavement.	1	Practice	All
	Binding	The system must be firmly attached to the road in order not to be torn by the traffic of vehicles (regular traffic flow, acceleration, braking) and by the vehicles of winter maintenance (esp. with a blade for snow removal).	2,3,4	Practice	All
	Procedure Time schedule for installation Dealing with seams	Implementation inside the pavement of an existing road should be carried out jointly with a maintenance operation (that occurs every 12-15 years on intercity motorways). Maintenance operation consists in scarifying the upper layers and the re-gravelling them.	1	Practice	All

Technical domain	Sub domain	Requirements	Applicability[19]	Origin / Importance rating	Country Applicability
		The installation of a charging unit has to be integrated upstream in the overall road infrastructure construction / maintenance regime to ensure that the effects of the implementation of such a system are taken into account in the studies and in the definition of the procedure of roadworks.			
	Procedure Time schedule for installation Dealing with seams	In case the time schedule is not compliant with a maintenance operation, a dedicated procedure for implementation must be defined to guarantee that : • The mechanical characteristics of the road are not affected by the implementation (strength, evenness, skid resistance, waterproofing (esp. if the implementation generates seams on the pavement) • The safety and the traffic flow are well-managed during the implementation • All the roadside equipment are not damaged by the works • The roadwork are conducted in a period when the traffic flow allows it (it may be restricted to the night between 22h and 5h for the most circulated road) And more generally, required roadwork is performed according to the state-of the art for the kind of road	1,2,3,4	Standard	All
	Procedure Time schedule for installation	A dedicated procedure for implementation must be defined to guarantee that : • The engineering structures (bridges, tunnels)	5	Standard	All

Technical domain	Sub domain	Requirements	Applicability[19]	Origin / Importance rating	Country Applicability
		adjacent to the road are not damaged • The safety and the traffic flow are well-managed during the implementation • All the roadside equipment are not damaged by the works • The roadwork are conducted in a period when the traffic flow allows it (it may be restricted to the night between 22h and 5h for the most circulated road) And more generally, required roadwork is performed according to the state-of the art for the kind of road			
	Procedure Time schedule for installation	In case implementation is conducted jointly with a road maintenance operation, the time schedule for the installation of the system must fit with the global schedule of the maintenance operation. (for information, losses generated by one night of delay in the laying of mix are around €150k)	All	Practice	All
	Dealing with seams	The installation of the system should be carried out in one go (i.e. single roadwork's site). If not possible and if seams are required, a dedicated procedure must be defined to guarantee the quality of the seams.	All	Practice	All
	Maintenance	There should be no need to access the components buried into the road, except during the major maintenance operation on the pavement. That means that the system should be robust enough to work for a period of 12-15 years without having to change or fix the buried	1	Practice	All

Technical domain	Sub domain	Requirements	Applicability[19]	Origin / Importance rating	Country Applicability
		components. • In case there is a need to access the buried components outside the periods of major pavement maintenance operations, a dedicated procedure must be defined (cf. installation).			
	Maintenance	The frequency of maintenance of the component should not affect the level of service of traffic flow (i.e. the frequency should be low if the average traffic is high). A dedicated procedure must be defined (cf. installation)	1,2,3,4	Practice	All
	Waste of components	Scarification and planning of the pavement layer in which the components are installed result in the destruction of these components. Debris resulting from the planning of the pavement must not require a special treatment before landfilling or recycling (unlike asbestos or PAH)	1,2,3,4	Practice	France
	Visual integration	Good integration of visible equipment in the landscape is crucial for the social acceptability of the charging solution. Attention has to be focused on urban areas, when a lot of various equipment is already installed in a narrow space, and where the residents may be very reluctant with every new installation that may modify or alter their usual landscape.	All	Practice	All

9.1.5. Safety

Technical domain	Sub domain	Requirements	Applicability[20]	Origin / Importance rating	Country Applicability
Safety	Vehicles	The system must not affect the non-electric vehicles or the non-charging vehicles travelling on the road (especially their electronic components).	All	Practice	All
	Vehicle passengers	The system off-line must not affect the driving abilities of the drivers (for all types of vehicles : electric or not, charging or not, motorbikes, bikes) The system on-line must not affect the driving abilities of the drivers (for all types of vehicles : electric or not, charging or not, motorbikes, bikes) The system off-line must not affect the health of the passengers of the vehicles (for all types of vehicles : electric or not, charging or not) The system on-line must not affect the health of the passengers of the vehicles (for all types of vehicles : electric or not, charging or not)	All	Legal	All
	Pedestrians	The system off-line must not affect the health of the pedestrians walking on the road and near the road. The system on-line must not affect the health of the pedestrians walking on the road and near the road. (On motorways, pedestrians may be passengers from a vehicle	All	Legal	All

[20] Applicability to types of charging solution installations: (1) – Wireless / under the road, (2) – Wireless / flush with road. (3) – Wireless / on the road, (4) – Conductive / flush with road, (5) – Conductive / overhead

Technical domain	Sub domain	Requirements	Applicability[20]	Origin / Importance rating	Country Applicability
		stopped after an incident or maintenance staff or emergency staff)			

9.1.6. Legal and Regulatory

Technical domain	Sub domain	Requirements	Applicability[21]	Origin / Importance rating	Country Applicability
Legal and Regulatory	Installation	Installation by equipment owners on public roads must respect the local regulation regarding the occupancy of the public domain. (e.g. signature of formal agreement or licence or contract)	All	Low	All
	Road Installation	Excavations in the public highway by non-statutory undertakers for the purpose of laying new apparatus, requires the issue of a licence by the Highway Authority	All	Law - Section 220 of the Highways Act (1980) - High	UK
	Maintenance - SRN	Highways Act imposes a legal requirement for a road owner to maintain their road network; it does not state how this should be achieved. Therefore, in England, a standard that defines when maintenance should be carried out was	All	Standard - Design Manual for Roads and Bridges (DMRB) - Medium	UK

[21] Applicability to types of charging solution installations: (1) – Wireless / under the road, (2) – Wireless / flush with road. (3) – Wireless / on the road, (4) – Conductive / flush with road, (5) – Conductive / overhead

Technical domain	Sub domain	Requirements	Applicability[21]	Origin / Importance rating	Country Applicability
		developed.			
	Maintenance – Non SRN	Local Authorities have a duty of care similar to the HA, mostly covered by the Highways Act 1980, but supplemented by case law, to establish what reasonable levels of maintenance are.	All	Good Practice - Well Maintained Highways – a Code of Practice - Low	UK
	Trench reinstatements	The Undertaker shall guarantee the performance of the reinstatement to the relevant standards, for the relevant guarantee period. Once the guarantee period is passed, the duty of care falls on the Highway authority to maintain the performance of the pavement.	1, 2, 3 and 4	Law – NRSWA - High	UK
	Overhead clearance	There is a continuous duty on operators to maintain safe clearance from live wires to any tree, building or other structure where people may be present.	5	Guidance - Electricity Association’s Standard 43-8 Overhead Line Clearances (ENA 2004) - Low	UK

9.2. Grid/Distribution networks requirement

9.2.1. Spanish Low Voltage Code

Connection

As a general rule, the connection must follow the indications included in Complementary technical instruction 11, ITC-BT-11 (Electric energy distribution grids – Connections) of the low voltage electrotechnical regulations. Conductors will be isolated aluminium, and the materials used and the installation conditions will comply with prescriptions shown in ITC- ITC-BT-07 for underground electric energy distribution lines.

The connection will be dimensioned taking into account the following aspects:

- Maximum expected load, according to ITC-BT-10.
- Supply voltage
- Maximum allowed currents for the conductor type and installation conditions.
- Maximum allowed voltage drop. This voltage drops will be the one established by the distribution company, on its voltage drop sharing in the elements that constitute the grid, so that in the general protection box it is within the limits established by the Electric Verification and Energy Supply Regularity Regulation

Connections should always comply with the general conditions for crossing, proximity and parallelism set by ITC-BT-7. Design aspects of the charging infrastructure, such as minimum power transfer pad distance are not affected by these general conditions for the grid connection of the charger (converter). Expected power fluctuations are not included in that regulation.

Circuit Breaker Panel (CBP)

As a general rule, CBP must comply with the indications shown in ITC-BT-13 (Connection installations. Circuit Breaker Panels are the boxes where protection elements for the main supply lines are placed, and they signal the beginning of the part of the installation own by the client.

CBP will be preferably placed on the exterior facades of the buildings, in places with free and permanent access. Their location will be set in agreement between the property and the supplying company. If the connection is underground, it will always be installed a niche in the wall, which will be closed with a door, preferably metallic, with IK 10 protection level according to UNE-EN 50.102, externally covered following the environmental characteristics and protected

against corrosion, having a standardized lock. The lower part of the door will be located at a minimum of 30 cm from the ground. If the facade is not public, the CBP will be placed in the limit between public and private properties.

Only two boxes can be located in the same niche, having a box for every general supply line. If more than two boxes are required, other technical solutions could be used, with prior agreement between the property and the supply company.

CBPs to be used will belong to one of the types included in the technic specifications of the supply company that have been approved by the competent public administration. Inside them, there must be fuses in all the phase conductors, with breaking power at least equal to the expected short-circuit current at the point of installation. The neutral conductor will consist of a mobile connection located to the left of the phases, being the CBP in service position, and will also have a grounding terminal if required.

CBPs will comply with all the points indicated in regulation UNE-EN 60439 -1, will have flammability degree according to UNE-EN 60439 -3, once installed will have protection level IP43 according to UNE 20324 and IK 08 according to UNE-EN 50102 and must be sealable.

General feeding line (GFL)

The GFL links the CBP to the meters. Isolated wires and protection wires and tubes will follow ITC-BT-07 and ITC-BT-21.

Wires will made of copper or aluminium and its isolation level will be 0.6/1 kV. The minimum section of the wires will be 10 mm^2 for copper and 16 mm^2. The GFL will be dimensioned taking into account the following aspects:

- Supply voltage
- Maximum allowed currents for the conductor type and installation conditions.
- Maximum allowed voltage drop.

Protection and measurement box

If supplying a single client, CBP and measurement devices can be concentrated in a single element. This element is called Protection and measurement box (PMB) and it is also analysed in ITC-BT-13 (Connection installation CBPs).

In the installation of the PMB the same indication must be followed as in the CBPs, except no superficial installation will be allowed. Besides, reading devices from the measurement equipment must be located at a height between 0.7 and 1.80 m. PMBs will comply with all the applicable points of UNE-EN 60439 -1, will have flammability degree according to UNE-EN 60439 -3, once installed will have protection level IP43 according to UNE 20324 and IK 08 according to UNE-EN 50102 and must be sealable.

Meters

Meters and other devices used to measure the energy consumed by the EV fast charge point should comply with the indications of ITC-BT-16 (Linkage installations. Meters: Location and installation systems). Meters and other devices used to measure the electric energy could be located in:

- modules (boxes with sealed lids)
- panels
- electric cabinets

All of them will constitute groups that should comply with regulation UNE-EN 60.439 parts 1, 2 and 3. The minimum protection level that those groups have to possess, according to UNE 20.324 and UNE-EN 50.102, respectively are:

- Indoors installations: IP40; IK 09
- Outdoors installations: IP43; IK 09

They must allow the direct reading of the meters and time switches, and to the rest of metering devices when needed. Transparent parts allowing those direct readings must be UV resistant. When modules or cabinets are used, they must have inner ventilation to avoid condensation without diminishing their protection level.

Meters will be installed in outdoors modules or cabinets, having free and permanent access. Those cabinets will be embedded in civil work, and their walls should be at least 15 cm thick; or in a prefabricated concrete box, having walls 5 cm thick. The box will be closed with a door, preferable metallic, with IK 10 protection level according to UNE-EN 50102, externally covered following the environmental characteristics and protected against corrosion, having a

standardized lock. It will be located at such a height that metering devices are located between 0.7 m and 1.8 m from the ground.

Cables should have a rated voltage of 450/750 V , made of copper, class 2 according to UNE 21.022, with dry insulation, extruded based on thermostable or thermoplastic mixtures, identified according to the colours described in ITC MIE-BT-26. Cables should be non-fire propagators, with low opacity and smoke generation. Cables with characteristics similar to UNE 21.027 –9 (thermostable mixtures) or UNE 21.1002 (thermoplastic mixtures) comply with this description. Moreover, it must have the required wiring for control circuits in order to satisfy current tariff conditions. The cable should have the aforementioned characteristics, its identification colour will be red and it will have a 1.5 mm2 section. Connection will be direct and conductors will not require special preparation or terminals.

Meters recommended by the supplier companies on their particular technical regulations should be used.

Individual derivations

The ID links the GFL to user facilities. The wires used will be always isolated (457/750 V) and will be made of copper or aluminium. If the wires are underground its isolation will be 0.6/1 kV. The minimum section of the wires will be 6 mm^2. The Id will be dimensioned taking into account the following aspects:

- Supply voltage
- Maximum allowed currents for the conductor type and installation conditions.
- Maximum allowed voltage drop.

Concentration of control and protection devices

The concentration of control and protection devices of the installation must comply with the indications reflected in ITC 17, 22, 23 and 24. The housings will comply with UNE 20.451 and UNE-EN 60.439 -3, with a minimum IP 30 protection level according to UNE 20.324 and IK07 according to UNE-EN 50.102. The housing for the power control switch should be sealable and its dimensions will be adequate to the supply type and the applicable tariff. Its characteristics and type correspond to an officially approved model. Control and protection devices will be, at least:

One power control switch (PCS). It must be substituted by programmable current switches, maximeters or integrators added to the meters if the contracted current is larger than 63 A.

One automatic general switch (AGS) breaking all poles, having manual operation and provided with overload and short-circuit protection. This switch should be independent from the power control switch.

One general differential switch, destined to the protection from indirect contacts in all circuits, except if this protection is achieved using other devices, according to ITC-BT-24.

All-pole breakers, destined to the protection from overloads and short circuits of every inner circuit. One overvoltage protection device, according to ITC-BT 23, if required.

Due to operative and safety reasons, it is convenient to install the charging points in independent circuits where the only load is the charging point itself. Thus, every circuit and every charge point will be protected by a specific automatic switch and a differential switch, besides the general PCS and AGS. Differential switches for the charge point circuit should have a sensitivity of 30 mA. Both automatic and differential switches can be implemented in the same device.

For installations connected to aerial low voltage lines, placed on pole or facade, or with thunderbolt risk is advisable the use of atmospheric discharge overvoltage protection (lightning). These protections systems will be overvoltage dischargers.

Conductors of the inner installation

Conductors feeding the charging point in the inner installation must comply with the indications of voltage drop and maximum current reflected in REBT ITC-BT-19 (Inner or receiving installations. General Prescriptions) or ITC-BT-29 (Particular prescriptions for electric installations in places with fire or explosion risk), if being placed in such a place. Conductor section will be such that the voltage drop from the origin of the inner installation to the consumption point is below 5%. This value will be assessed considering the maximum power of the charging point.

Conductors feeding the charging point must be RV-K 0.6/1 kV. The feeding circuit should have grounding/protection conductor. The section of the protection conductors is shown in Table 16:

Table 16: Minimum recommended sections for protection conductors in the LV supply circuit

Section of phase or polar conductors of the installation (mm^2)	Minimum section of the protection conductors (mm^2)
S ≤ 16 16< S ≤ 35 S > 35	S (*) 16 S/2
(*) With a minimum of: 2.5 mm^2 if protection conductors are not part of the supply wiring and have mechanic protection. 4 mm^2 if protection conductors are not part of the supply wiring and do not have mechanic protection.	

Protection tubes and envelopes

Tubes used to protect the conductors feeding the EV fast charge point must comply with the indications established in ITC-BT-21 (Interior or receiving installations. Tubes and protecting envelopes as a general rule, and ITC-BT-29 if they cross areas classified as having fire or explosion risk. If the conductors are located underground, protection tubes must comply with regulation UNE-EN 50086 2 – 4.

As a general rule, it will be used tubes having a diameter allowing an easy placement and extraction of the cables and conductors. Table 17 indicates the diameters allowed by REBT:

Table 17: Diameters of the protection tubes recommended in low voltage installations

Nominal section of the unipolar conductors (mm^2)	Tube external diameter (mm)				
	Conductor number				
	≤ 6	7	8	9	10
1,5	25	32	32	32	32
2,5	32	32	40	40	40
4	40	40	40	40	50

6	50	50	50	63	63
10	63	63	63	75	75
16	63	75	75	75	90
25	90	90	90	110	110
35	90	110	110	110	125
50	110	110	125	125	140
70	125	125	140	160	160
95	140	140	160	160	180
120	160	160	180	180	200
150	180	180	200	200	225
185	180	200	225	225	250
240	225	225	250	250	--

Particular Technical Regulations (NTP)

Besides the compliance with the requirements in REBT, fast inductive charge installations must meet those related to the particular technical regulations (NTP) of the DSO in the area. The NTPs are the documents through which the DSOs standardize their distribution grids and their components. These NTPs always follow the REBT indications while adapting them to the characteristics of the DSO, reducing for example the types of wires so its storage materials are reduced.

In Spain, there are more than 350 energy distributors, 5 big DSOs and about 350 small companies. Two of the main DSOs in Spain are ENDESA and GAS NATURAL FENOSA, which is the reason why next paragraphs are focused on these companies, showing only the most remarkable aspects.

ENDESA

Figure 33 represents the components of an inductive charger installation according to the particular technical regulations of ENDESA following the configuration with disconnection box.

Disconnection box

If the supply is performed from an underground grid, the installation of a disconnection box is mandatory. The boxes will be embedded or leaned against the wall, just below the CBP of the charging point. They will be installed in those lines where, according to the exploitation, it is considered necessary to include disconnection points.

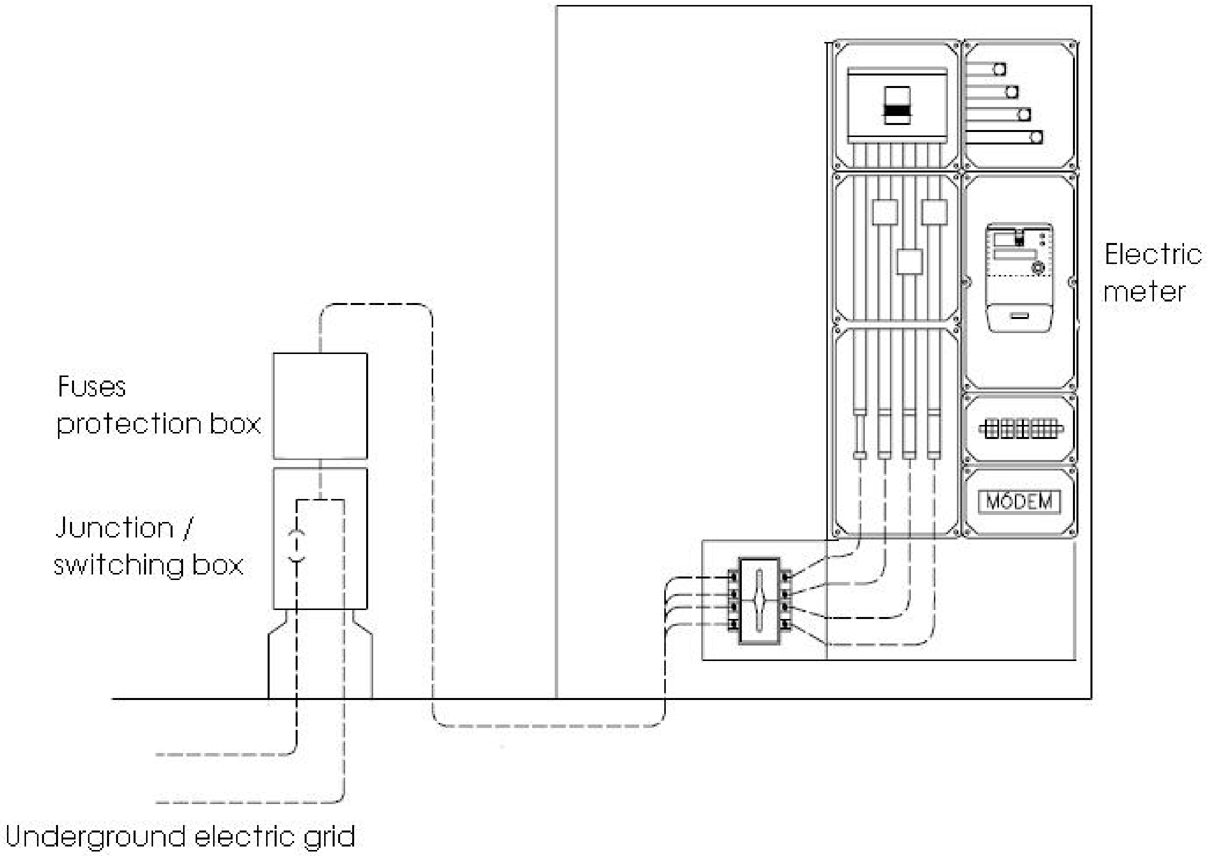

Figure 33: Electrical installation for inductive fast chargers

Connection

Connection circuits will start in disconnection boxes as a general rule. In underground connections conductors to be used will be aluminium, single-pole, type RV, rated voltage 0.6/1

kV, with reticulate polyethylene insulation (XLPE) and PVC cover. Connection conductors will be the ones shown in Table 18 and Table 19. Protection tubes must follow ITC-BT-11 characteristics.

Table 18: Conductors for the construction of LV underground connections

Conductor (mm^2)	Maximum admissible current at 25°C		Resistance □/km	Reactance □ /km
	Buried	Under tube	25°C	
4x1x50 Al	180	144	0.64	0.09
3x1x95+1x50 Al	260	208	0.32	0.08
4x1x50+1x95 Al	330	264	0.21	0.08
4x1x50+1x150 Al	430	344	0.13	0.08

Table 19: Maximum admissible currents

Conductor section (mm^2 in Al)	Maximum current at 25ºC		Current at 40ºC
	Buried	Under tube	In the air
50	180	144	140
95	260	208	220
150	330	264	300

Circuit breaker panel (CBP)

The main characteristics of CBPs to be used in these installations are summarized in Table 20. It is important to consider that the maximum current determines the power of the charger to be connected.

Table 20: Recommended CBPs for the LV connection circuit

CGP CODE	POWER FUSES		
	SOCKETS		FUSES
	NUMBER	SIZE	I_{max} (A)
CGP-1-100	1	0	100
CGP-7-100	3	0	100
CGP-7-160	3	0	160
CGP-7-250	3	1	250
CGP-7-400	3	2	400
CGP-9-160	3	0	160
CGP-9-250	3	1	250
CGP-9-400	3	2	400

Besides, for CBPs at a height ranging from 0.50 m to 3 m, the CBP will be built-in, as an underground connection.

Protection and Measurement Box (PMB)

In feedings for one or two customers, the metering devices can be joined to the CPB, creating the PMB. Protection and measurement box will be used mainly in underground feedings, being not used in aerial ones. The conductors used in PMBs must meet the following requirements:

- The minimum section of conductors connecting the distribution grid to fuse-carrier contacts will be 25 mm^2 (copper)
- The minimum section of conductors connecting fuse-carrier contacts to the metering devices will be 16 mm^2 (copper)
- These conductors will be V 750 according to UNE 21031

Meters

The meters that can be used in ENDESA installations must be included in the ENDESA approved meters list. Meters must be protected against external agents and shock: IP40 and IK09 for indoor and IP43 and IK09 for outdoor facilities. The meters cabinets should allow the reading of the energy consumption.

In individual meters with current higher than 80 A, the use of indirect metering devices will be mandatory. These elements will be:

- 3 current transformers
- 1 static multifunction combined meter
- 1 verification multiple socket, able to test and/or substitute meters without interrupting the supply
- 1 set of conductors linking the secondary sides of current transformers and the meter
- Enclosures for indirect individual metering devices

The standardized powers to be contracted with less than 63 A are summarized in Table 21, characteristics of the metering current transformer calibres:

Table 21: Relation between current transformation relation, supply voltage and power.

CT calibre (A)	Feeding voltage (V)	Power to contract (W)	
		Minimum Power	Maximum Power
100/5	3 x 133/230	17.926	59.754
	3 x 230/400	31.176	103.920
200/5	3 x 133/230	35.852	119.508
	3 x 230/400	62.352	207.840
500/5	3 x 133/230	89.631	298.770
	3 x 230/400	155.880	519.600
1000/5	3 x 133/230	179.262	597.540
	3 x 230/400	311.760	1.039.200
2000/5	3 x 133/230	358.524	1.195.080.
	3 x 230/400	623.520	2.078.400

Concentration of control and protection devices

Protection devices to avoid permanent overvoltages will be installed mandatorily. About transitory over voltages, ITC-BT-23 will establish the need for protections. The power control switch (PCS) will not be programmable if the current is lower or equal to 63 A. If current is greater than 63 A, the power control will be done with a maximeter.

In contracts with maximeter, the installation of a PCS is not necessary and the AGS will be enough to protect the installation.

Protection tubes

The technical characteristics for underground tubes are described in NTP CNL00200: Polyethylene tubes (without halogens) for underground wiring. The standardized diameters are shown in Table 22:

Table 22: Standardized diameters for tubes in underground wiring

GE designation	Diameter	
	Minimum external (mm)	Minimum internal (mm)
PE tube 63 mm	63	47
PE tube 160 mm	160	120
PE tube 200 mm	200	150

GAS NATURAL - FENOSA

Connection

Connections feeding EV charging stations will not go through protection, switching or measurements cabinets from other installations.

The part of the cabinet for protection and measurements must be double isolated, and independent of that for switching or other functions, complying also with the characteristics required to the PMB. The access door of the PMB will be independent and with standardized lock.

Circuit Breaker Panel (CBP)

The assigned voltage will be 5000 V. The current will fit with some of the following values, in amperes: 100 – 160 – 250 – 400. As a general rule, only CBP with fuses up to 250 A will be installed. CBPs with fuses of 400 or 630 A will be installed only in the case that one GFL feeding a derivation box.

The fuses will have reduced losses, being conditioned by the maximum dissipated power summarized in Table 23.

If the installation, due to singularity, complexity or high power requirements, is different to those described in the Particular Technical Regulations, Union Fenosa and the owner will establish different conditions, always complying with the REBT.

Table 23: Type of CBP and maximum power dissipation in fuses

CGP CODE	POWER FUSES			
	SOCKETS		FUSES	
	NUMBER	SIZE	I_{max} (A)	Dissipated power (W)
CGP-1-100	1	0	100	7
CGP-7-160	3	0	100 – 160	7 - 12
CGP-7-250	3	1	250	20
CGP-7-400	3	2	400	30
CGP-9-250	3	1	250	20
CGP-9-400	3	2	400	30
CGP-10-400	3	2	400	30
CGP-11-250/250/400	3/3	1/1	250/250	20/20
CGP-12-250/250/400	3/3	1/1	250/250	20/20
CGP-14-250/400	3	1	250	20
CGP-14-400/400	3	2	400	30

Protection and measurement box

The different types of PMB to be used are gathered in Table 24.

Table 24: Codes of PMB for Unión Fenosa installations

Código CPM	Denominación
CPM-1ME-UF	CPM monofásico con P≤14490W
CPM-1TE-UF	CPM trifásico con P≤15kW
A-(2)M-EP-UF	Armario 2 monofásicos P≤15kW
A-(2)M/T-EP-UF	Armario 2 monofásicos/trifásicos P≤15kW
AR-(2)M/T-EP-UF	Armario reparto, 2 monofásicos/trifásicos P≤15kW
A-TEIP.UF	Armario trifásico P>15kW ÷I≤63A W
AR-TEIP-UF	Armario reparto trifásicos P>15kW I≤63A
A-(2)TEIP-UF	Armario 2 trifásicos P>15kW ÷ I≤63A
AR-(2)TEIP-UF	Armario reparto 2 trifásicos P>15kW ÷ I≤63A
A-TtEI-UF	Armario trifásicos P>15kW ÷ I>63A trafos de intensidad
AR-TtEI-UF	Armario reparto trifásicos P>15kW ÷ I>63A trafos de intensidad

Meters

Meters will comply with ES.130.ES.RE.EMA: Particular Specifications for Energy Metering Installations in installations with less than 20 kV.

In the case of a power higher than 43.5 kW, an indirect metering device will be installed. The characteristics of the necessary current transformers are summarized in Table 25.

Table 25: Characteristics of the current transformers in relation to the demanded power

POTENCIA DEMANDADA (kW)	TRAFOS DE INTENSIDAD	
	RELACION	TIPO
Entre 15 y 33 kW (*)	50/5	Primario Bobinado
Entre 33 y 55 kW	100/5	
Entre 55 y 110 kW	200/5	
Entre 110 y 220 kW	400/5	
Entre 220 y 330 kW	600/5	Primario Pasante
Entre 330 y 415 kW	750/5	
Entre 415 y 450 kW	1500/5	
(*) Exclusivamente previo acuerdo entre Propiedad y UF Distribución		

9.2.2. Modelling of charging requests

Evaluation of charging demand patterns

In this part of the deliverable, an assessment of the overall demand that occurs on a charging lane due to electric vehicle traffic is made. Initially the model used for simulation is presented, followed by an analysis of the scenarios executed and discussion on the results of simulations.

Two different simulation models are presented. The first one has been developed at ICCS and the second one at POLITO.

Simulation model overview

A simulation engine has been developed in order to model the transmission of charging requests from vehicles passing over wireless power transfer pads to the charging system operator and in order to simulate the charging profiles dispatched by the charging infrastructure controller. By logging the cumulative power dispatched at each timeslot of the simulation interval estimations regarding the aggregated demand can be produced.

The simulation mechanism consists of two basic components; the charging request generator and the power dispatch core which responds to a request with a proposed charging profile. The image below depicts these two mechanisms in the charging infrastructure ecosystem.

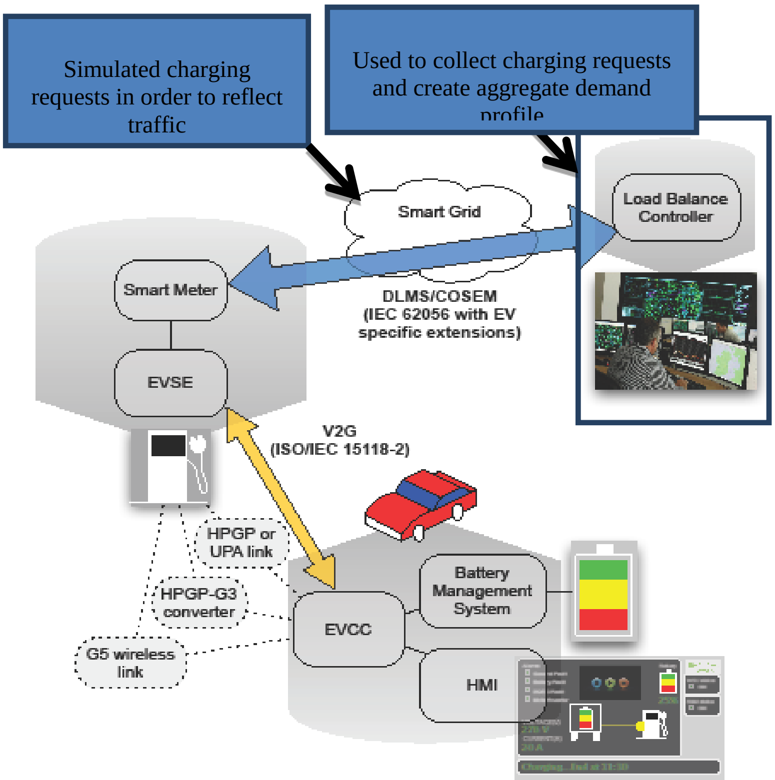

Figure 34: Simulation ecosystem

Simulation parameters

The following charging related parameters have been modelled in the simulation framework.

- Power transfer request
- Nr of power transfer pads
- Probability of occupying a power transfer pad
- Nr of simulation timeslots

A charging request consists of the following parameters

- Maximum power transfer power
- Requested energy amount
- Charging duration

9.2.3. Simulation model from POLITO

In Figure 35, the power transfer lane layout employed in the POLITO model is shown. The length of power transfer pads (LCZ) is the same as in the model of ICCS. But while the ICCS model assumes zero distance between power transfer pads, in the POLITO model a considerable interdistance l of 30m is assumed. Important differences in the fluctuations are expected, due to this difference.

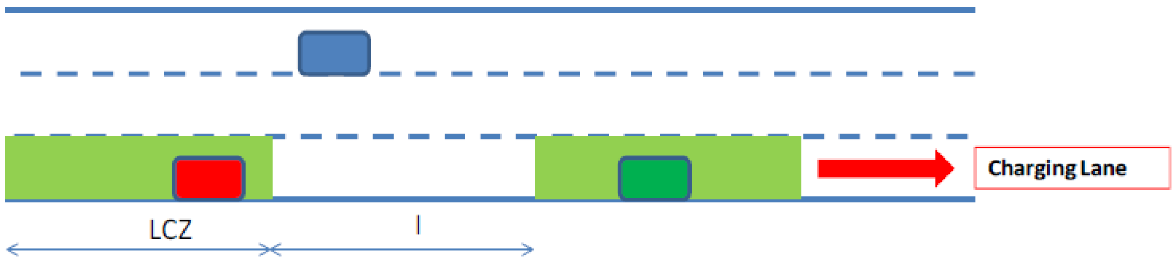

Figure 35: Power transfer lane layout employed in the POLITO model

The critical density value of 30 veh/km/lane has been assumed based on the generally adopted values for freeways under basic conditions (Daganzo, 1997)[22]. Values for minimum traffic headway are chosen between 1.5 and 2.5 s in order to consider the use of ADAS (Yannis, 2004)[23]. Some car manufacturers use adaptive cruise control (ACC) to give the drivers the opportunity to manually choose the minimal headway, but the absolute minimum headway is set at 0.9 s (Hegeman, 2005)[24]. In this study, a more prudent value of 1.5 s has been assumed

Charging demand data obtained from POLITO model is represented in Figure 36. Large and fast fluctuations can be observed. Power ramps of several MW/s are obtained.

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[22] Daganzo C.F., (1997), "Fundamentals of Transportation and Traffic Operations". Pergamon.

[23] Yannis G, Golias J.,Antoniu C., 2004. “Combining traffic simulation and driving simulator analyses for Advanced Cruise Control system impact identification”. Proceedings of the 83rd Annual Meeting of the Transportation Research Board, January 2004, Washington D.C.

[24] Hegeman G., Brookhuis K, Hoogendoorn S. (2005). Opportunities of advanced driver assistance systems towards overtaking. European Journal of Transport and Infrastructure Research-EJTIR, 5, no. 4 (2005), pp. 281-296

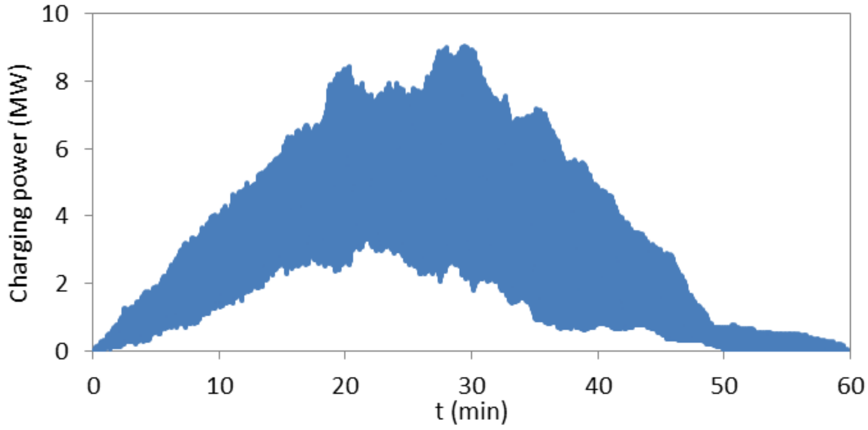

Figure 36: Charging demand from POLITO traffic model

9.2.4. Storage Sizing

In order to estimate the requirements for energy storage which would be necessary to mitigate power peaks from the charging infrastructure, a sizing method. Essential parameters of any electrical energy storage system (ESS) are the nominal power P_{ss} (MW) and the energy capacity E_{ss} (kWh). In addition, a typical discharge time T_{ss} can be defined as follows:

$$T_{ss}[s] = 3.6 \frac{E_{ss}[kWh]}{P_{ss}[MW]}$$

The units of energy and power are based the results which are expected. Very short power peaks in the MW range will require high-power and low-energy ESS. Therefore, typical discharge times are expected to be best measured in seconds.

In order to obtain the required storage parameters, a simple method is applied in order to obtain the duty cycle of the ESS. As the ESS is introduced in order to smooth the demand, a moving average is applied to that time series in order to obtain the desired (smoothed) output signal. The duty power of the ESS is then defined as the difference between charging demand and desired output, as shown in the equation below.

$$P_s(t) = P_{MA}(t) - P_{ch}(t)$$

Where $P_s(t)$ is the time series of the duty power of the ESS, $P_{out}(t)$ is the smoothed output obtained from the moving average and $P_{ch}(t)$ is the charging demand obtained from the traffic model.

The moving average is defined as follows:

$$P_{MA}(t) = \frac{1}{n}\sum_{i=1}^{n} P_{ch}(t-i)$$

The smoothing window width n is defined by the number of time steps which are used to calculate the average. For the present study, the window width is expressed in seconds. The study will be carried out for smoothing windows from 1s up to 60s. Values of 1, 2, 5, 10, 20, 30 and 60s are used in order to calculate the storage requirements.

The analysis of traffic data shows that there is a typical daily cycle, with a steep increase in the morning and another steep decrease in the evening. These traffic ramps, converted in demand ramps produce a temporal bias in the storage duty. This is due to the typical time lag of moving averages. During the morning ramp-up, the moving average will produce a negative bias, causing a continuous storage discharging, while in the evening, the bias is inverted and the storage is recharging until the initial state of charge is reached at the end. This daily charging cycle is an artefact of the smoothing technique. It can be widely removed with another moving average applied on the storage duty power[25]. As a first guess, a smoothing window of 1 min has been found for that temporal bias correction.

From the time series of storage duty $P_s(t)$ power and energy requirements are obtained, assuming storage efficiency of 100% (no losses). The storage power is defined as the maximum absolute power of the time series. It is assumed here, that the ESS can be charged and discharged at nominal power.

$$P_{ss} = \max|P_s(t)|$$

[25] H. Bludszuweit, “Reduction of the uncertainty of wind power predictions using energy storage”, PhD Thesis, Universidad de Zaragoza, 2009

The energy storage capacity E_{ss} is obtained by integrating the power over time. The result of the integration is another time series $E_s(t)$ which represents the state of charge of the ESS relative to the starting level. The required storage capacity E_{ss} is finally the difference between the highest and the lowest state of charge registered in the period of time under study.

$$E_s(t) = E_s(t-1) + P_s(t)\Delta t$$
$$E_{ss}(t) = \max\big(E_s(t)\big) - \min\big(E_s(t)\big)$$

In the following sub-sections, results are presented for the different simulation scenarios and traffic models which have been developed so far.

9.2.5. Storage sizing with ICCS Traffic model

From the ICCS model, scenarios of low, medium and high traffic have been considered for urban and inter-urban roads (see section 9.2.2).

Urban case: 36 km/h

In Figure 37 the original urban charging demand has been represented together with the results from smoothing with moving averages. As can be observed, already with a smoothing window of 5s a considerable reduction of power peaks is achieved. Further improvements with 20s and 60s can be observed, but the improvement is much less.

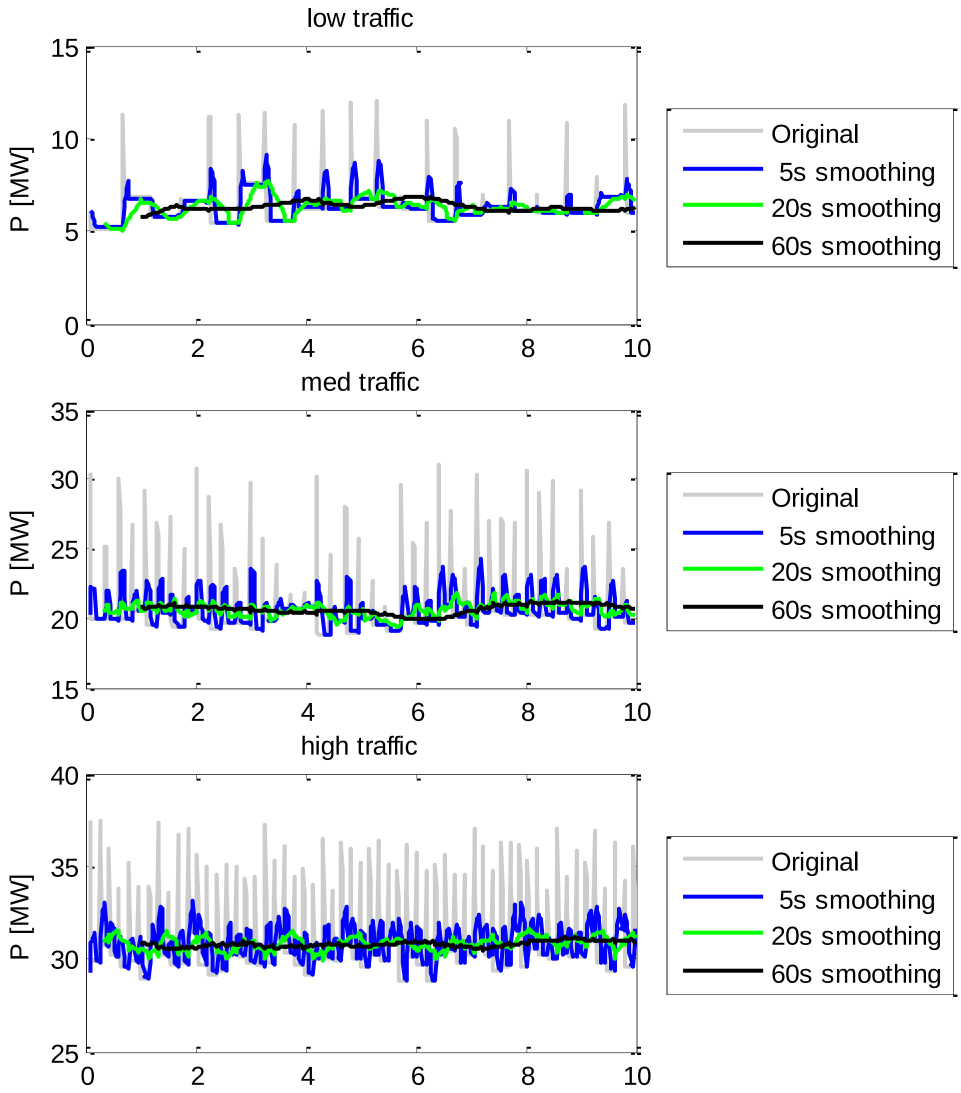

Figure 37: Charging power demand for urban case (36 km/h) with low, medium and high traffic for different window widths of moving average smoothing

Inter-urban case: 108 km/h

In Figure 38 the inter-urban case is represented. It can be observed that at high traffic speed, the variability is much lower and power spikes are wider. This is surprising, as the opposite may be expected. The reason can be found in the way traffic is modelled. At high speed, the distance between cars is longer and each power transfer pad can only carry one car. During the simulation time step of 1s, each car leaves a power transfer pad and enters a new one. No overlap occurs which may cause power peaks. In the urban scenario, distances are shorter and

two cars may enter one power transfer pad. Due to the statistical modelling approach, that circumstance may add up to high and very short power peaks.

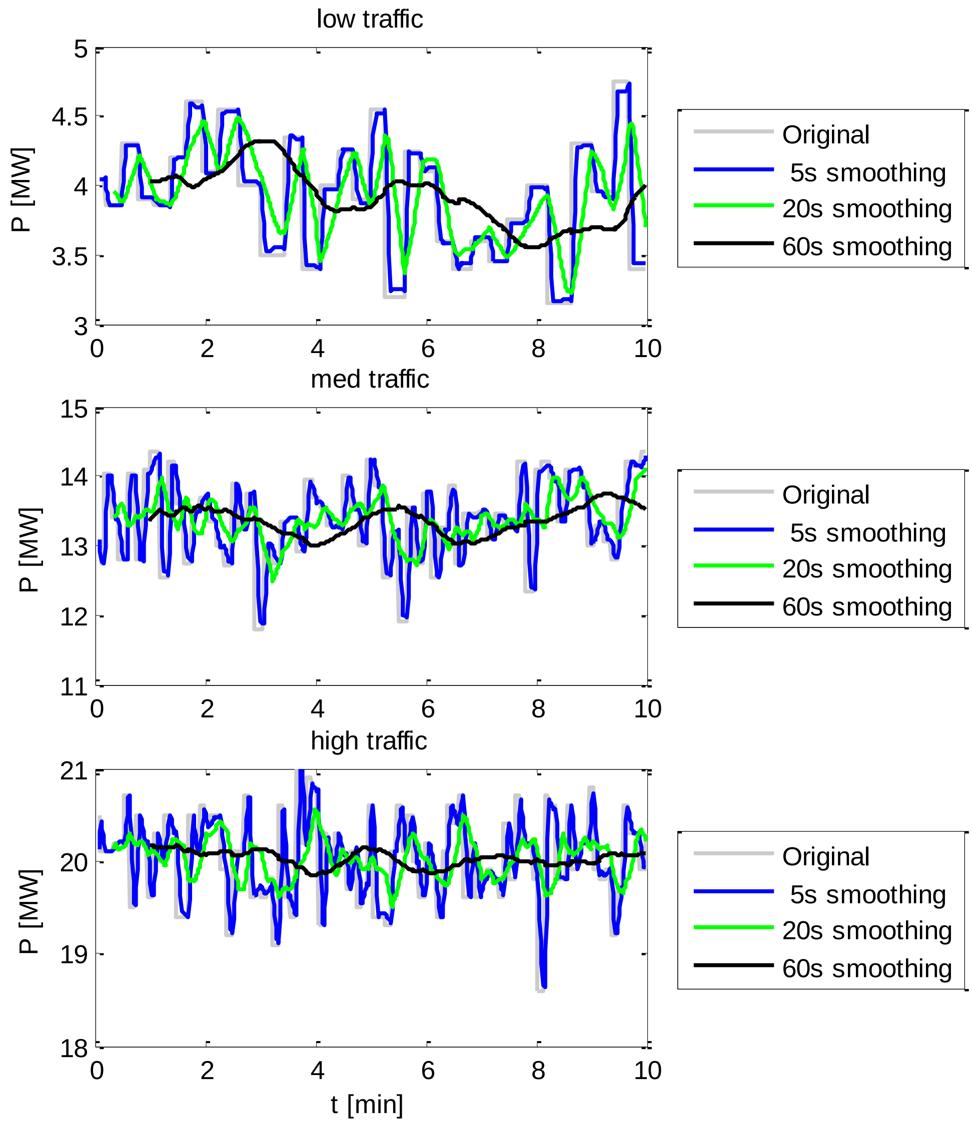

Figure 38: Charging power demand for inter-urban case (108 km/h) with low, medium and high traffic for different window widths of moving average smoothing

Regarding the smoothing, it can be observed that contrary to the urban case, much larger smoothing intervals are necessary and the reduction of power fluctuations is smaller. Even with 20-s smoothing, almost no effect is observed and 60-s smoothing is needed.

9.2.6. *Sizing of a storage system including solar PV power*

In order to study the influence of photovoltaic (PV) production on the sizing of a storage system, PV data have been collected. These data come from actual irradiation data measured in a PV plant in France. Data have been normalized and therefore can be adapted to any PV plant assigned power. Time step is 1 min. Figure 39 shows the first 7 days of the data.

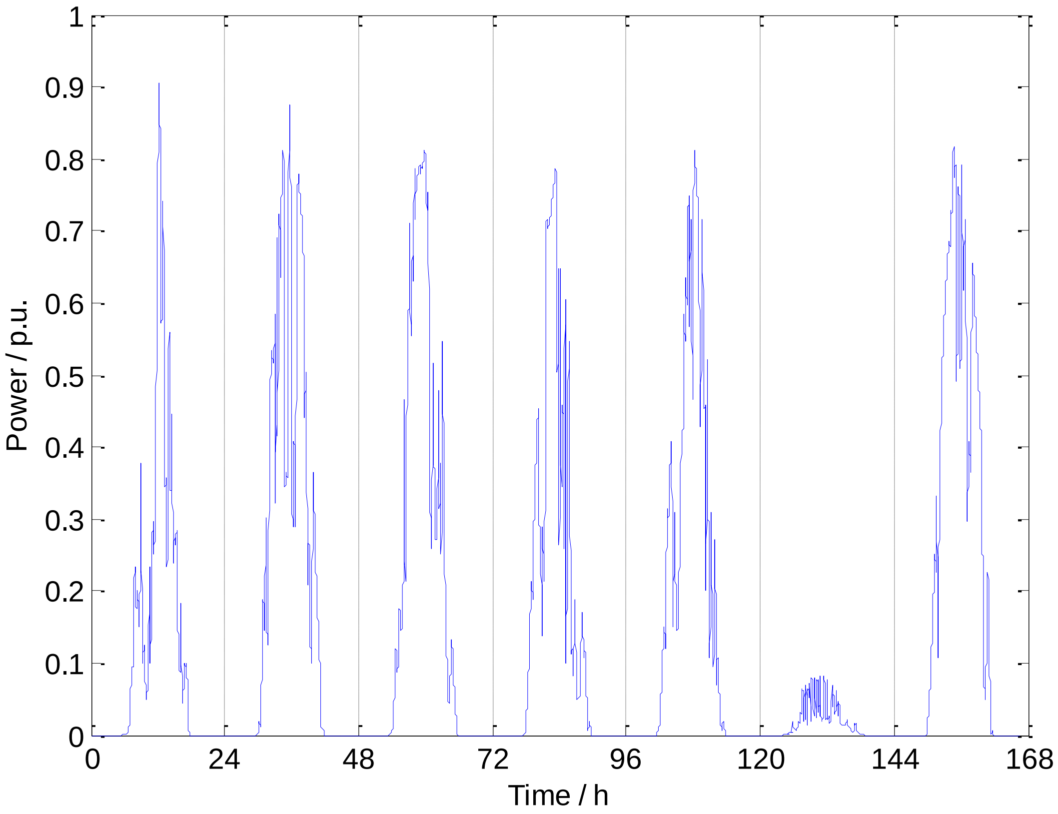

Figure 39: Normalized PV data

To keep the simulation simple but still pertinent, two scenarios of power solar production have been defined: a sunny day and a cloudy day. Two days that correspond to the defined scenarios have then been chosen among the PV data. Figure 40 shows solar PV generation for the selected days assuming an arbitrary installed PV power of 10 MWp. A large difference can be observed between sunny and cloudy days. In the presented example, peak power varies from 1 MW for a cloudy day to 8 MW on a sunny day. For the first part of the study an installed power of 10 MWp is considered. Later, the variation of that power is also evaluated.

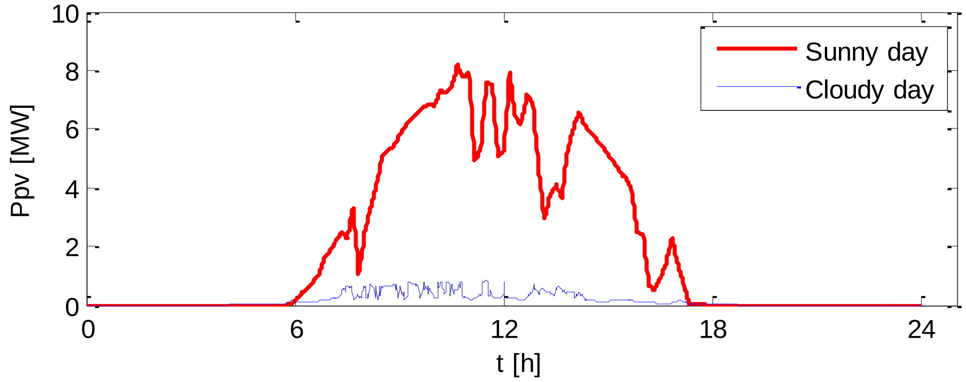

Figure 40: Sunny day and cloudy day PV generation scenarios

Influence of PV generation on power demand

In order to study the daily balance of demand and solar PV generation, 24-h data from the traffic model detailed in previous sections is used here. For the studies of the impact of solar PV integration, the fast-traffic scenario (108 km/h) has been chosen, representing traffic over inter-urban high-speed roads. Similar results are expected regarding the integration of solar PV generation in the low-speed case.

PV generation combined with charging demand

Results are shown in Figure 41, where it can be seen that PV generation might help to reduce the overall energy demand over the day as part of the energy produced is consumed locally. However, simulations show that the daily morning and evening peaks remain almost the same as they occur before or after PV generation is significant.

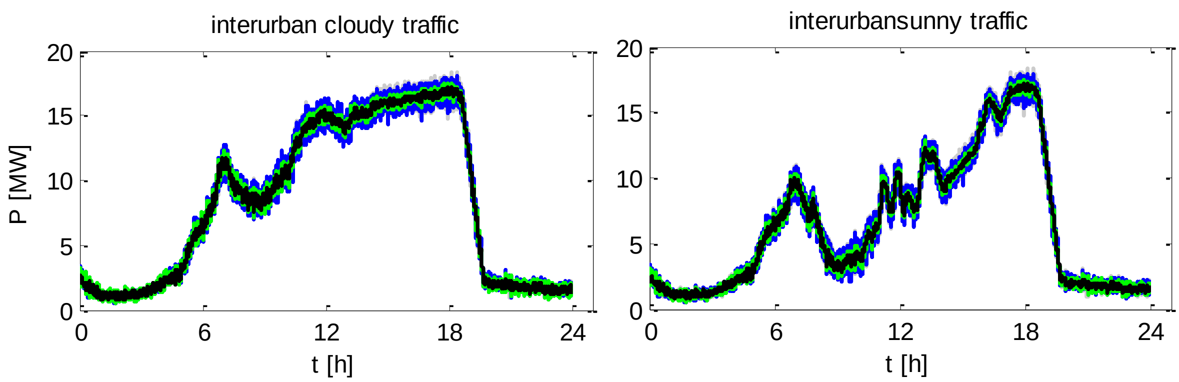

Figure 41: Demand from traffic model (fast traffic: 108 km/h) with 10 MW installed solar PV power

This results shows that PV generation only, is not efficient for decreasing the power demand. The use of storage might help to increase self-consumption ratio and then decrease power and energy demand over the power grid. One can also notice the effect of the variability of PV production: cloudy days reduce considerably the effect of PV generation. Therefore, local climate and latitude of the PV plant has a strong influence on its ability to reduce the power and energy demand over the power grid.

PV generation and storage sizing

In order to study the impact of solar integration on the demand and storage sizing, 4 different solar power levels are considered: 1, 5, 10 and 20 MWp of installed PV power. For the case of fast traffic and sunny day, the resulting daily demand profile is shown in Figure 42. As can be observed, only the 20-MW installation produces more power than demand in the central hours of the day.

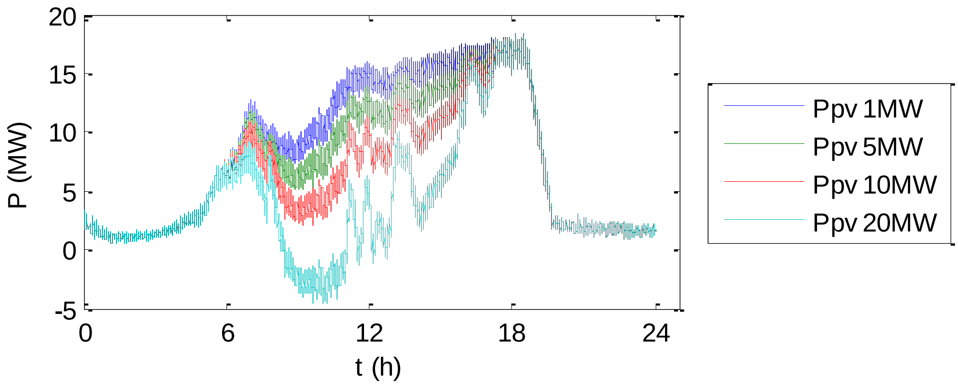

Figure 42: Demand from traffic model (fast traffic: 108 km/h) over PV peak power

9.3. Local Authorities and City Governance requirements

9.3.1. Policy development

Policy Instruments

"Policy instruments" is the term used to describe methods used by governments to achieve a desired effect. The two basic types of policy instruments are regulatory and economic instruments. Regulatory instruments, specifically laws and regulations, are the most commonly used policy instruments. For example, to achieve the desired effect of fewer traffic accidents, governments pass laws which regulate driving. Economic instruments, such as tax credits for certain types of investment or subsidies/ financial incentives to stimulate the purchase of certain products, are also used as a way of influencing the actions of individuals and the private sector.

A range of policy instruments are available to central government in its relationships with those who manage, affect and use the local transport system – including local and city authorities, local transport authorities, highways agencies, etc. It is usual that the policies of central government set out the framework for action and may set targets, while the implementation is delivered by regional, metropolitan or local levels of government. Each policy instruments has a different role and possibly audience (see Table 26).

There are a variety of policy instruments and these influence legislation and regulation and implementation aspects of transport in various ways at European, national and local levels. The table below outlines a selection of the most important ones.

Table 26: Policy Instruments

Instrument	Responsibility	Impact on Local Authorities/ City authorities
Policy (for example European Directives, White Papers, Ministerial policy statements and speeches)	European Union/ UNECE/ Central or National government/ Regional or Provincial government/ Local government	Outlines government policies and possible overall target levels related to EV on-road charging; facilities that authorities are expected to pursue albeit with the potential for local variations and/or interpretation; and the levels of security and safety that will be required.

Legislation (laws passed by Parliament or local bodies that are legally binding)	European Union/ Central government	Authorities are obliged to abide by any legislation in respect to EV on-road charging (this may not be specifically in place presently and therefore may need to be interpreted from other relevant legislation).
Regulation[26] (the set of rules on how the law will be implemented)	European Union/ Central government	Authorities are obliged to abide by the rules of the law (the regulations) and therefore new regulatory bodies that are charged with ensuring that towns and cities are compliant and also deal with conflicts of a legal nature will be required
Financial allocations	Central government/ regional government/ local government	Financial allocation determines levels of expenditure by authorities and priorities for investment, including for EV on-road charging. Today most major infrastructure is usually paid (entirely or partially) by central government via a variety of competitive and non-competitive mechanisms. How the funds are spent is a local decision. It is likely that this model will continue.
Plan approval	Central government/ regional government/ local government	The need for plan approval centrally can limit or delay an authority's plans and restrict investment in EV on-road charging facilities. It is not clear at this moment the roles and responsibilities for national and local planning and how these will intersect. In any case the more levels of approval required almost always adds cost and time delays to any project
Target setting	Central government/ regional	Target setting can require an

[26] Legislation is basically an act of law passed by a legislative body such as the government so that it becomes a law. A regulation is a set of rules on how the law will be implemented. Regulations are imposed by the regulatory body.

	government/ local government	authority to achieve specified goals, e.g. a certain number/coverage of EV on-road charging facilities/units within a time period. In respect to technology choices and their affordability this can pose challenges at local level.
Standards[27]	Central government	Standards would require authorities to keep to, for example, specified materials, maximum and minimum dimensions, locations of EV on-road charging facilities, signage etc. They also need to keep abreast of any changes.
Inspection	Central government/ regional government/ local government	Central government could require inspections of authorities to ensure maintenance of EV on-road charging equipment. Local governments or specially accredited bodies would need to ensure that any maintenance or public works by third parties that might disrupt the EV infrastructure do not compromise safety.
Guidance	Central government/ regional government/ local government	Guidance provides advice to authorities regarding the design, layout, location EV on-road charging equipment. There is no such guidance available specifically for on-road EV charging infrastructure.

The aim is to ensure that city and local authorities correctly interpret and implement government policies in respect of the facilities that they are expected to provide. There would need to be significant communication and stakeholder consultation to local citizens about the local implantation of EV on-road charging facilities being put in place in towns and cities.

[27] A *standard* is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products and services are provided to a common, agreed level of quality.

Standards and guidance sit towards the middle of the continuum – they convey policy, procedural and technical advice that may be based on legislation, but equally may be to do with the ways in which local and city authorities are encouraged to exercise their discretion.

As transport is an activity of priority concern to all governments the strategic importance of international transport also requires intergovernmental cooperation. The overall objective of such cooperation is to facilitate and develop international transport while improving its safety and environmental performance. The UNECE Transport Division and the Inland Transport Committee (ITC) covers a large number and a great variety of issues, including those pertaining to specific infrastructures, vehicles and operational procedures of road, rail and inland waterways transport, as well as of multi-modal and combined transport. Their work includes specific issues of passenger and goods transport, as well as the transport of special cargoes.

The transport of dangerous goods requires specific, particularly stringent, internationally recognised safety regulations that would need to be adhered to. In the field of vehicle regulation there is no other equivalent international organisation for vehicle type-approval, their mutual recognition and conformity. The UNECE helps to achieve practical results through international agreements, particularly concerning the regulation of technical aspects of various transport policy challenges and they will also play a role in the development of common standards for electric mobility.

How the rules are interpreted should follow international and national guidance permitting a certain degree of innovation by authorities. The regulation of the rules may be local or nationally organised depending on the country involved. A common understanding and interpretation of the rules would need to be also adopted by industry, fitting in with national and local requirements. At present national government is focussing on plug-in charging infrastructure and there is little understanding of the potential for on-road EV charging at local levels by local authorities. National level grants and funding schemes are their main focus presently.

9.3.2. Local Transport Plans

The policy set out in the UK's "A New Approach to Transport: A Better Deal for Everyone" White Paper and the 2000 Transport Act, a statutory document, require local transport authorities to prepare Local Transport Plans (LTPs) every 5 years. A LTP is required to cover capital (investment) and revenue (operating) expenditure and are driven by objectives and targets.

Annual Progress Reports (APRs) are required annually for monitoring. The third LTP (LTP3) series covers the period 2011-16 and LTAs must demonstrate their support for following five national goals:

- Supporting economic growth;
- Reducing carbon emissions;
- Promoting an equality of opportunity;
- Contributing to better safety, security & health; and
- Improving the Quality of Life and a healthy natural environment.

LTP3 comprises two parts: a Strategy (setting out local policy) and an Implementation Plan (describing what measures will be implemented) but LTAs have significant flexibility in the interventions proposed and how they will be delivered. The DfT's 2009 Guidance on Local Transport Plans (LTP3)[28] specifically sets out the importance of smarter travel and the need for local authorities to consider the opportunities for smarter travel first, ahead of infrastructure based solutions.

In terms of EV charging infrastructure nothing is yet mentioned at national level. However European Parliament has set the ambitious target of 456,000 electric vehicle charging points by 2020 in a draft agreement (to be finalised in Spring 2014). The UK has ambitions to have one of Europe's largest electric vehicle charging point networks by 2020, with at least 70,000 public access charging points for electric vehicles across the UK - a 14-fold increase. This will form part of network of the 456,000 units spread across Europe, including 86,000 in Germany, 72,000 in Italy and 55,000 in France, and supplied by green energy where possible.

9.3.3. Sustainable Urban Mobility Plans in Europe

A similar approach to LTPs has been recommended by the European Commission. The European Commission's Action Plan on Urban Mobility calls for an increase in the take-up of Sustainable Urban Mobility Plans (SUMPs) in Europe. To meet this need, new Guidelines[29]

[28] http://webarchive.nationalarchives.gov.uk/20110509101621/http:/www.dft.gov.uk/adobepdf/165237/ltp-guidance.pdf

[29] http://www.mobilityplans.eu/docs/file/guidelines-developing-and-implementing-a-sump_final_web_jan2014b.pdf

have been produced that explain how to develop and implement a Sustainable Urban Mobility Plan.

Other than encouraging the use of clean vehicles and fuels it does not presently require consideration of any issues relating to EVs or the charging infrastructure but this is likely to change in the future as more EVs come onto Europe's roads.

9.3.4. Government guidance and advice

Government guidance that addresses transport and urban planning may be of three types[30]:

- Policy guidance (outlining what needs to be achieved), for example the previous series of PPG (Planning Policy Guidance) Notes;
- Process guidance (outlining how to deliver policy), for example the Guidance on Local Transport Plans or the Manual for streets; and.
- Technical guidance (the detailed requirements of what needs to be realised), for example the series of Transport Advisory Leaflets and Local Transport Notes.

[30] Decision-Making in Local Transport Planning, Department for Transport, May 2003