This document was prepared for the ETI by third parties under contract to the ETI. The ETI is making these documents and data available to the public to inform the debate on low carbon energy innovation and deployment.

Programme Area: Light Duty Vehicles

Project: Electricity Distribution and Intelligent Infrastructure

Title: Executive Summary

Abstract:

This project was undertaken and delivered prior to 2012, the results of this project were correct at the time of publication and may contain, or be based on, information or assumptions which have subsequently changed. The Electricity Distribution and Intelligent Infrastructure project is comprised of six Work Packages. This Executive Summary covers Work Packages 2.2, 2.3 and 2.5. The purpose of these three Work Packages was to: a) evaluate the different ways in which recharging infrastructure may be provided in the UK and recommend the requirements for the UK deployment; b) evaluate the main cost drivers for plug-in vehicle recharging infrastructure, enabling a realistic forecast to be generated; and c) determine the regulatory, legislative and commercial issues associated with recharging infrastructure and recommend how they should evolve for the UK deployment.

Context:

This project looked at the potential impact of electric vehicles on the UK electricity distribution grid.

Disclaimer:

The Energy Technologies Institute is making this document available to use under the Energy Technologies Institute Open Licence for Materials. Please refer to the Energy Technologies Institute website for the terms and conditions of this licence. The Information is licensed 'as is' and the Energy Technologies Institute excludes all representations, warranties, obligations and liabilities in relation to the Information to the maximum extent permitted by law. The Energy Technologies Institute is not liable for any errors or omissions in the Information and shall not be liable for any loss, injury or damage of any kind caused by its use. This exclusion of liability includes, but is not limited to, any direct, indirect, special, incidental, consequential, punitive, or exemplary damages in each case such as loss of revenue, data, anticipated profits, and lost business. The Energy Technologies Institute does not guarantee the continued supply of the Information. Notwithstanding any statement to the contrary contained on the face of this document, the Energy Technologies Institute confirms that the authors of the document have consented to its publication by the Energy Technologies Institute.

ETI Executive Summary

Programme: Transport – Plug-in Vehicle Economics and Infrastructure

Project: Electricity Distribution and Intelligent Infrastructure (TR1002)

Work Package(s): 2.2, 2.3 and 2.5

Final Deliverable(s): TR1002/SP2/E.ON/04 /05 and /07

Version: *1.0*

Introduction

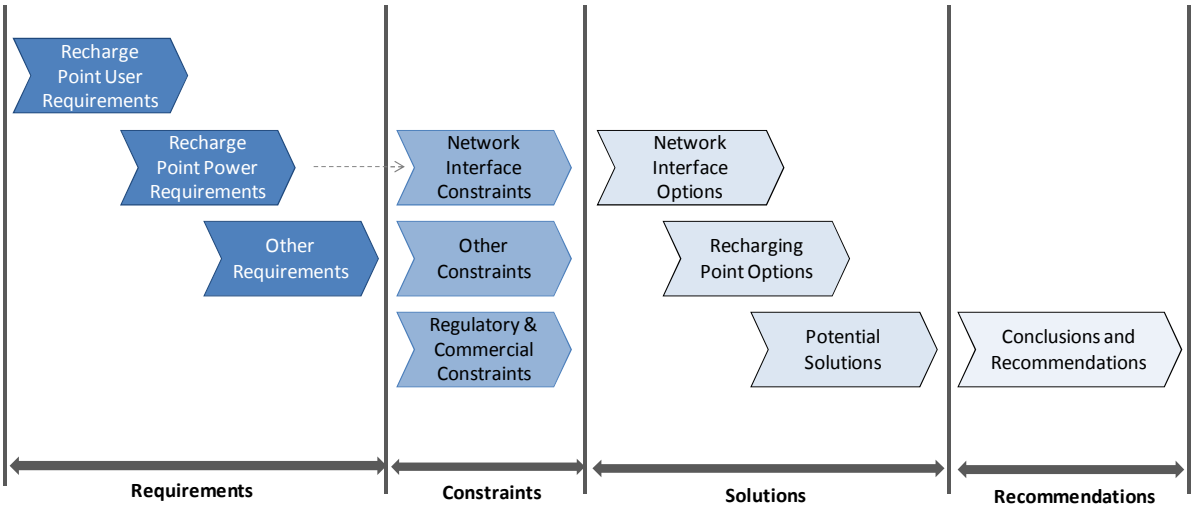
The Electricity Distribution and Intelligent Infrastructure project (TR1002) is comprised of six Work Packages. This Executive Summary covers Work Packages 2.2, 2.3 and 2.5.

2.1	Network Analysis
2.2	Recharging Network Requirements
2.3	Recharging Infrastructure Cost Driver Analysis
2.4	Intelligent Architecture
2.5	Recharging Infrastructure Implementation
2.6	Consumer Testing Framework

The purpose of these three Work Packages was to:

- evaluate the different ways in which recharging infrastructure may be provided in the UK and recommend the requirements for the UK deployment;
- evaluate the main cost drivers for plug-in vehicle recharging infrastructure, enabling a realistic forecast to be generated; and
- determine the regulatory, legislative and commercial issues associated with recharging infrastructure and recommend how they should evolve for the UK deployment.

A high-level overview of the analysis is shown below.



Requirements

Analysis of underlying recharging point user requirements (deliverable SP2/E.ON/04) was used to derive power requirements for recharging points. In summary:

ID	Charge Point Usage Requirements	ID	Power Requirements
CP1.0	Energy supplied to the vehicle should be sufficient to meet the intended range of the user (or maximum capacity of the battery) and this must be transferred during recharging within an acceptable timescale.	PR1.0	Energy supplied to the vehicle should be sufficient to meet the intended range of the user (or maximum capacity of the battery) and this must be transferred during recharging within an acceptable timescale.
CP1.1	Domestic recharging infrastructure must support the full re-charge of a passenger car within 8 hours.	PR1.1	Domestic recharging infrastructure must support a minimum of 13Amp (3kWh) recharging.
CP1.2	Some domestic users will require faster recharging times, typically around 4 hours for a full recharge (e.g. to charge up visiting relative's vehicles).	PR1.2	Some domestic users will require infrastructure to support 32Amp charging.
CP1.3	Some domestic users may require multiple vehicles to be recharged simultaneously at home.	PR1.3	Some domestic users will require infrastructure to support 2 or more 13Amp or 32Amp recharging points.
CP1.4	Commercial recharging infrastructure must support the full charging of light vehicles within 8 hours, to support employee commutes or the recharging of company vehicles overnight. Faster recharge times may be required in some cases.	PR1.4	Commercial recharging must support 13Amp recharging of a number of vehicles at the same time. Recharge rates of 32Amp are likely to be desirable.
CP1.5	Commercial recharging infrastructure may need to support the full recharging of heavier vehicles within 8 hours (overnight recharge).	PR1.5	Commercial recharging may need to support charging at greater than 50Amp; higher rates are likely to be desirable.
CP16	On street public charging will probably be used to partly recharge vehicles and therefore must be able to top up 50% of the battery of a typical passenger vehicle within a maximum of 4 hours.	PR1.6	On street public recharging must support 13Amp recharging.
CP1.7	On street public charging will probably be used to partly recharge vehicles and therefore will *ideally* be able to top up 50% of the battery of a typical passenger vehicle within a maximum of 2 hours.	PR1.7	It is desirable for on street public recharging to support 32Amp or three phase recharging.
CP1.8	Public rapid charging (e.g. at motorway service stations) will need to provide a passenger vehicle with a full charge in approximately 30 minutes, ideally less.	PR1.8	Public rapid chargers (e.g. at motorway service stations) will require a minimum of a three phase supply for DC charging.

Other requirements have been defined (also in deliverable SP2/E.ON/04), covering:

- Usability and operational requirements
- Business requirements
- Safety requirements
- Electrical safety regulations
- Distribution network interface requirements

Constraints

Against each of the Power Requirements summarised above, the constraints on potential solutions have been evaluated; primarily these are distribution network interface constraints. The table below provides a summary of the detail in deliverable SP2/E.ON/04.

ID	Power Requirements	ID	Low Voltage Network Constraint
PR1.1	Domestic recharging infrastructure must support a minimum of 13Amp (3kWh) recharging.	NC1.1	For electrically heated properties, standard design procedure indicates that no more than a single 13Amp charger may be facilitated with the existing standard service cables and cut-out fuses. However, practical experience considering thermal cycles, indicates that a single 32Amp charger can be facilitated. Most domestic premises (those with a 100Amp supply) are able to meet this requirement without upgrading their supply. Those with an 80Amp fuse and electric heating will not be able to support vehicle recharging.
PR1.2	Some domestic users will require infrastructure to support 32Amp recharging.	NC1.2	Those properties with at least a 100Amp supply and without electrical heating are currently able to meet this requirement. (However the DNO must be notified of loads >7 kW so they must be informed of a 32Amp charger installation). Those properties with electric heating or an 80Amp fuse will not be able to support fast (32Amp) charging.

ID	Power Requirements	ID	Low Voltage Network Constraint
PR1.3	Some domestic users will require infrastructure to support 2 or more 13Amp or 32Amp recharging points.	NC1.3	Most domestic premises (those with a 100Amp supply) and no electric heating can currently support either two 13Amp charge points or one 32Amp charge point. Other types of properties or those with more vehicles cannot currently be supported.
PR1.4	Commercial recharging must support 13Amp recharging of a number of vehicles at the same time. Recharge rates of 32Amp are likely to be desirable.	NC1.4	Commercial premises with a low baseload and therefore supply (100Amp, single phase) will be constrained by the number of vehicle recharging bays (similar to domestic). Larger premises with higher capacity supplies will be able to accommodate multi-vehicle recharging; however, baseload must be considered.
PR1.5	Commercial recharging may need to support charging at greater than 50Amp; higher rates are likely to be desirable.	NC1.5	A three phase supply is required for this level of recharge. Vehicle recharging must consider the baseload.
PR1.6	On street public recharging must support 13Amp recharging.	NC1.6	Low Voltage (LV) supplies are common in streets. Capacity may only be restricted by the distribution network infrastructure.
PR1.7	It is desirable for on street public recharging to support 32Amp or three phase recharging	NC1.7	LV supplies are common in streets. Capacity may only be restricted by the distribution infrastructure.
PR1.8	Public rapid chargers (e.g. at motorway service stations) will require a minimum of a three phase supply for DC recharging.	NC1.8	Any significant number of public rapid chargers at motorway services it likely to increase the load beyond that available. Availability of a high capacity connection may be costly due service station remoteness.

In addition to technical constraints, there are a number of regulatory and commercial issues that require compliance. These are detailed in deliverable SP2/E.ON/07, although they are not anticipated to be substantial constraints on potential solutions in the longer term. However, clarification and/or amendment would be beneficial in a number of areas, including:

- The responsibilities and rules for distribution network operators (DNOs) to invest in network reinforcement and/or the deployment of recharging points and allocate the costs to electricity consumers.

- Whether a single organisation can perform the installation of a recharging point, rather than separate activities by recharge point installer, DNO and meter owner.

Solutions

The tables on the following pages summarise a range of scenarios for each of the Power Requirements outlined above and the associated constraints, together with a recommended solution for each. The final charts present the anticipated costs for each solution. The cost for installing recharging points is comprised of:

- Recharging point hardware procurement and commissioning (shown below);
- Where required, new/upgraded connections to the distribution network (also shown below); and
- Where required, 'upstream' upgrades to the distribution network (covered in deliverable SP2/EFEN/04 and summarised separately) or system 'intelligence'.

Conductive or Inductive Vehicle/Recharging Point Interfaces

There are two primary options for the interface between the vehicle and the recharging point: conductive and inductive. Conductive connections are low risk and the 'installed cost' for recharging points presented in the chart below are based on this option.

Data from preliminary testing by the development company HaloIPT indicates that inductive recharging could yield losses of only around 2% greater than conductive connections. The key benefits would be substantial improvements in consumer experience, reduced exposure to the environment for recharging points and avoiding trip hazards from trailing cables.

Such systems are estimated to be significantly more expensive though, as shown below.

However, there is no independent test data giving a transparent evaluation of inductive recharging. It is recommended that this is trialled in the ETI follow-on project to gather performance data and test the impact on consumer attitudes.

Cost of Recharging Point Hardware Procurement

There are significant opportunities for cost reduction in recharging points, much of which is in the next decade due to strong competition in the global supply chain. The costs for recharging point hardware procurement include connectors, appropriately ruggedized encloses, electrical safety systems, power electronics and control circuitry.

Solution	Current Price[1]	2020 Price[1]	2050 Price[1]
Wall box (e.g. for domestic or workplace)	891	221	190
Public charge post (e.g. for use on street)	2,827	1,265	1,074
DC charger (for very high power transfer)	29,401	16,520	13,286
Inductive charger (avoiding physical connection)	3,375	2,813	2,250

[1] *In British Pound, 2010 real cost*

Solutions for Domestic Environments

Req. ID	PR1.1	PR1.1	PR1.2	PR1.3	PR1.3	PR1.3
Power Requirements	**Domestic recharging infrastructure must support a minimum of 13A (3kWh) charging.**	**Domestic recharging infrastructure must support a minimum of 13A (3kWh) charging.**	**Some Domestic users will require infrastructure to support 32A charging.**	**Some Domestic users will require infrastructure to support 2 or more 13A or 32A recharging points.**	**Some Domestic users will require infrastructure to support 2 or more 13A or 32A recharging points.**	**Some Domestic users will require infrastructure to support 2 or more 13A or 32A recharging points.**
Constraint	100A fuse	80A fuse and Electric Heating	100A fuse, no electric heating	100A fuse, no electric heating	100A fuse, electric heating	100A fuse, electric heating
Solution Title	13A or 32A recharging	Supply Constrained	No electric heating, 13A or 32A recharging	No electric heating, 2 vehicle recharging	Electric Heating: 2 vehicles: Load Management	Electric Heating: 2 vehicles: Supply Upgrade
Supply Upgrade - single phase		Y				Y
Supply Upgrade - three phase						Y - depending on required load
Local Load Management					Y	
Energy Storage	Too expensive					
AC conductive Charging (13A or 32A)	Y (or inductive)					
Inductive Charging	Option					
DC Rapid Charging	Too expensive					
Wall Box	Y					
Charge Post	Too expensive					
Recommendation(s)	13A or 32A Mode 3 Wall Box			Twin socket 13A Mode 3 Wall Box	Twin socket 13A or 32A Mode 3 Wall Box, depending on load management system.	Supply upgrade and twin socket 32A Mode 3 Wall Box
Recharge rate – miles per hour	~10-25mi/hr x1 vhcl			~10mi/hr x2 vhcls	~10-25mi/hr x2 vhcls	~25mi/hr x2 vhcls
Solution Cost	B			C	D	

Solutions for Commercial Environments

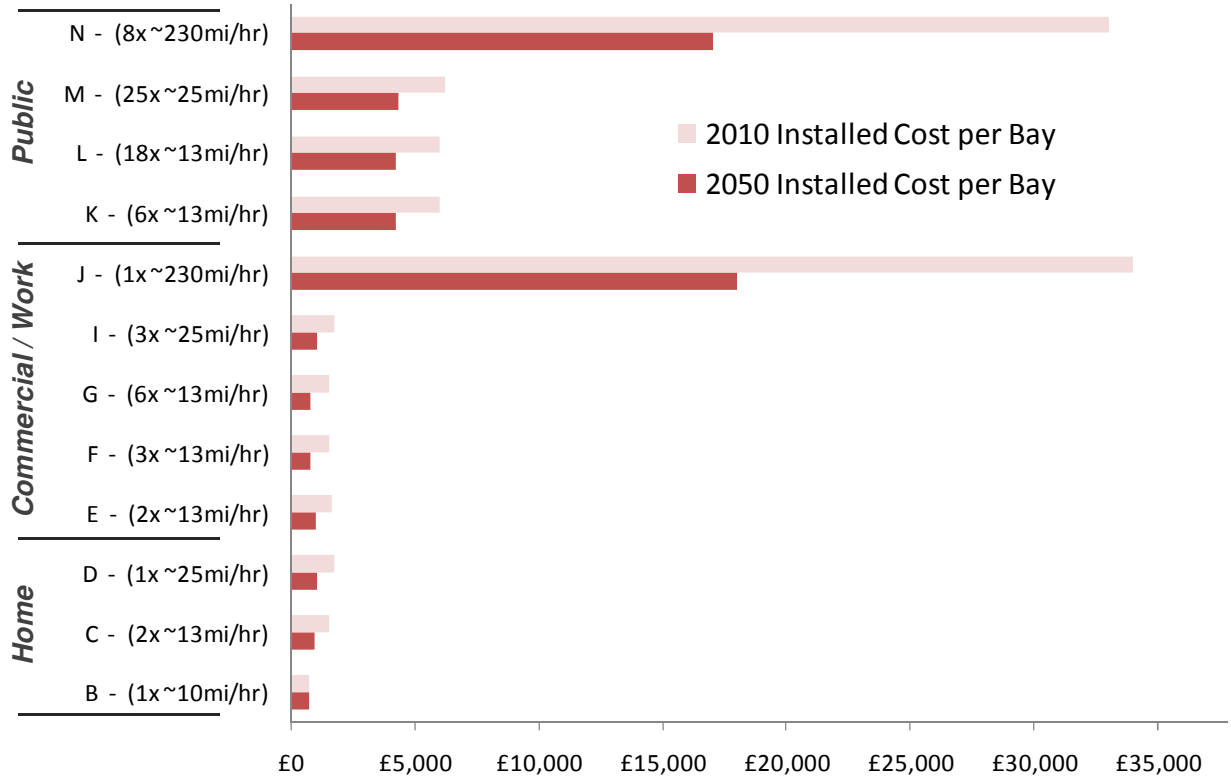
Req. ID	PR1.4	PR1.4	PR1.4	PR1.5	PR1.5	PR1.5
Power Requirements	**Commercial recharging must support 13A recharging of a number of vehicles at the same time. Recharge rates of 32A are desirable.**	**Commercial recharging must support 13A recharging of a number of vehicles at the same time. Recharge rates of 32A are desirable**	**Commercial recharging must support 13A recharging of a number of vehicles at the same time. Recharge rates of 32A are desirable**	**Commercial recharging may need to support charging at greater than 50A; higher rates are likely to be desirable**	**Commercial recharging may need to support charging at greater than 50A; higher rates are likely to be desirable**	**Commercial recharging may need to support charging at greater than 50A; higher rates are likely to be desirable**
Constraint	100A fuse	100A fuse	Three phase supply (100A fuse)	Three phase supply (63A fuse) Low baseload	Three phase supply (100A fuse) High baseload	Three phase supply (100A fuse) High baseload
Solution Title	Small Commercial Premises, 2 PiEV recharging (16A)	Small Commercial Premises, 6 PiEV recharging (16A)	Large Commercial Premises, 6 PiEV recharging (16A)	3 three phase PiEV recharging (32A/ph)	3 three phase PiEV recharging (32A/ph)	DC Rapid Recharging
Supply Upgrade - single phase		Y				
Supply Upgrade - three phase					Y	Y
Local Load Management		Y				
Energy Storage	Too expensive					Could be considered
AC conductive Charging (13A or 32A)	Y (or inductive)					
Inductive Charging	Option					
DC Rapid Charging	Too expensive					Viable Option
Wall Box	Y					N/A
Charge Post	Too expensive					N/A
Recommendation(s)	16A Mode 3 Wall Box (x2)	16A Mode 3 Wall Box (x6)	16A Mode 3 Wall Box (x6)	32A Three phase Mode 3 Wall Box (x3)		DC charger up to 69kW (dedicated supply)
Recharge rate – miles per hour	~13mi/hr x2 vhcls	~13mi/hr x6 vhcls	~13mi/hr x6 vhcls	~25mi/hr x3 vhcls		~230mi/hr x1 vhcl
Solution Cost	E	F	G	I		J

Solutions for Public Environments

Req. ID	PR1.6	PR1.6	PR1.7	PR1.8
Power Requirements	**On street public recharging must support 13A recharging.**	**On street public recharging must support 13A recharging.**	**It is desirable for on street public recharging to support 13A or 32A recharging.**	**Public fast chargers (e.g. at motorway service stations) will require a three phase supply for DC charging**
Constraint	Local distribution network.	Local distribution network.	Local distribution network.	Local distribution network.
Solution Title	6 public PiEV 13A recharge bays.	18 public PiEV 13A recharge bays.	25 public PiEV 32A/ph recharge bays.	8 DC Rapid Chargers.
Supply Upgrade - single phase	New connection.			
Supply Upgrade - three phase		New connection.	New connection.	New connection Significant upstream upgrade.
Local Load Management	Y			
Energy Storage	Too expensive.	Too expensive.	Too expensive.	May be considered.
AC conductive Charging (13A or 32A)	Y (or inductive)			
Inductive Charging	Option			
DC Rapid Charging	Too expensive.			Viable Option.
Wall Box	N			N/A
Charge Post	Y			N/A
Recommendation(s)	16A Mode 3 Charge post (x6)	16A Mode 3 Charge post (x18)	32A Three phase Mode 3 Charge post (x25)	8, 69kW DC chargers (dedicated supply)
Recharge rate – miles per hour	~13mi/hr x6 vhcls	~13mi/hr x18 vhcls	~25mi/hr x25 vhcls	~230mi/hr x8 vhcls
Solution Cost	K	L	M	N

Installed Cost for Recharging Points

Costs are given in the chart below for the installed cost per recharging bay for the Solution Options presented in the tables above. These costs exclude any new connection to the electricity distribution network that may be required.



New or Upgraded Connection to the Distribution Network

The costs for new connections to the distribution network vary very substantially depending on proximity to an existing distribution network. The costs escalate rapidly from those presented below for new connections where there is no nearby distribution network. This depends very much on the particular circumstances.

Service		Description	Avg. 2010 Price
Single Phase	Domestic connection	Includes excavation and laying a new service cable, and jointing to the existing network.	£1, 100
	Public recharge post connection		£800
Three Phase	Up to 200A per phase [120 kVA (de-rated)]	Single three phase service, from passing main, including service cable, mains service joint, and termination. Service cable length up to 5 metres per service. Duct installation, excavation and backfill joint hole undertaken by third party.	£2, 047
	Up to 300A per phase [180 kVA (de-rated)]		£2, 168
	Up to 400A per phase [240 kVA (de-rated)]		£2, 890

Recommendations

- It is recommended that local load management systems are adopted (which monitor the local load and control vehicle recharging) to avoid overload due to reduced load diversity. This would minimise cost for new connections to the distribution network.
    - It is recommended that vehicle trials include equipment to determine recharge duration to connection duration to inform future algorithm development.
    - It is recommended that in all cases local load management systems must have a margin to allow for adverse cases.

- It is recommended that regulations are developed to mitigate the broader system impact (especially during the day) of vehicle recharging loads. In particular, recharging points must be enabled for time of use controlled recharging and demand side management, based on available generating and distribution network capacity.

- It is recommended that regulations be updated to require at least one of the following to be implemented at domestic properties:
    - Electrical inspection when vehicles are purchased; or
    - A separate connection to the distribution network for vehicle charging; or
    - Install a local load management system.

- It is recommended that Ofgem should:
    - Request DNOs to perform a more complete review of the possible impact upon the distribution network; and
    - Clarify the responsibilities of the DNO regarding the ownership of recharging points and the allocation of cost for any reinforcements.

- The use of standard 13A, 3-pin plugs for vehicle recharging is an enabling technology for early adoption. However, on safety grounds, it is recommended that all recharging points adopt ‘Mode 3’ recharging (providing control pilot functionality).

- It is recommended that an inductive recharge system be trialled to determine recharge efficiencies and other benefits in an integrated system context.

- It is recommended that the IEE Wiring Regulations (BS 7671) are updated to specifically include the recharging of plug-in vehicles.

- It is recommended in domestic and small commercial locations, that recharging points are supplied from a separate feed from the consumer unit.

- It is recommend that a cable sufficient for 32A recharging is installed as the minimum cable rating, thereby catering for future upgrades at little expense.

- It is recommended that a subsidy is provided for the installation of recharging points at domestic communal parking areas (e.g. for blocks of flats).