NETWORKS

PREPARING FOR ELECTRIC VEHICLES ON THE IRISH DISTRIBUTION SYSTEM

Pilot Project Report Summary

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INTRODUCTION

With electricity becoming an increasingly low carbon fuel, the electrification of transport will prove one of the most economic and practical ways to meet Irish decarbonisation targets. ESB Networks has constantly strived to improve and upgrade the Irish electricity distribution network over generations and as a result has developed one of the most progressive electricity networks in the world. The use of these assets to support the electrification of transport is an efficient way of meeting decarbonisation targets at low cost.

Over the period 2011 – 2015 ESB Networks delivered a large scale trial development of electric vehicle charging infrastructure to assess the impact that the electrification of transport will have on the electricity network. This vital, cross sectoral work was delivered in partnership with ESB eCars and partners from the electricity, telecommunications, IT and electric vehicle industry, and with academic institutions, across Ireland and Europe.

The project delivered research and demonstrations, identifying what capacity is available, and developing effective ways for deciding when and where more capacity is needed. It set out to establish how much this would be expected to cost, and how it might affect Irish electricity customers.

This summary report describes some of the key findings and activities of the 2011 – 2015 electric vehicle pilot project as well as how the pilot has changed network planning and strategy today. It is hoped that the lessons learnt and the standards, systems and protocols developed in rolling this infrastructure out, can now be of value to others too. A more detailed report can be found on the CRU and the ESB Networks websites.

INVESTMENT COST AND PRICE IMPACT

Investment in the electricity network is paid for in customers' "Distribution Use of System" (DUoS) tariffs as part of their bills. The DUoS price is contained within an end users electricity bill which they get from their electricity supplier. It is essential that all network development decisions account for the likely impact they will have on the DUoS price element of a customer's bill.

Although additional investment in the electricity network can increase the total cost to be paid for by DUoS tariffs, if the network is used more to distribute more electricity to end users, then the cost per unit of electricity may go down. In Work Package 4, it is forecasted that the network investment cost to support 20% electric vehicle uptake in Ireland will be €350m. This means that an additional €350m of investment in the electricity network is required over the period to 2030 to make enough electricity network capacity available to allow these vehicles to be connected to the network.

Work Package 5 looks at how this may impact customers electricity bills (through the DUoS tariff element of the bill) when it is spread across all customers. It finds that the additional amount of electricity that is distributed through the network because of increased electric vehicle charging means that in the long term, the DUoS price would go down – the extra use balances out the extra cost. For customers who are charging electric vehicles and therefore using more electricity their overall bill will increase.

The pilot project modelled a number of different scenarios – for example with different investment costs, different amounts of electric vehicle charging each year – to see what these impacts mean to electricity costs. This project delivers the solutions to support an initial 20% penetration of electric vehicles in Ireland on existing networks, and an investment strategy to be able to support up to 100% electric transport in new housing estates in the future.

This approach ensures that the network will be able to meet EV requirements in the medium term, and to then adopt the latest technological solutions as they become available – to this end ESB Networks are already developing future solutions under its Networks Innovation Strategy.

PILOT PROJECT OVERVIEW

The developing electric transport industry in Ireland will rely on careful designs, on equipment that is rated for Irish environmental conditions, and on high performance ICT systems. This project involved putting a national charging infrastructure in place in advance of significant electric vehicle uptake in Ireland. In order to create the kind of conditions expected in the future a number of field trials were run to investigate how customers really behave, and validate how the network manages this.

As the uptake of electric vehicles was still quite low at the time of the trial, ESB Networks provided a number of electric vehicles to customers living in small clusters of locations who are connected to typical rural and urban electrical networks for a number of months.

The project was broken down into "Work Packages", each focusing on a specific challenge. Some Work Packages focus on electric vehicle charging hardware and software, others focus on electricity network impact, developing new strategies to manage this and the price impact of this on electricity customers.

Work Package 1 presents some fundamental information for any party planning to develop charge point operations – how connectors were selected, where chargers should be located, and important customer insights, for example how and where customers tend to charge. **Work Package 2** addresses some vital technical questions for those connecting charge points in future, relating to protection and earthing systems.

Work Packages 3, 4 and 5 transfer the electric vehicles charging industry insight and developments into network design and charging strategy. **Work Package 6** returns to electric transport industry insights, moving from hardware and equipment, to the software and ICT systems needed to manage charge points and customer services systems. This work package addresses the different systems and standards needed to connect, manage and operate charging.

Finally, **Work Package 7**, shares the findings and results of collaborative projects ESB Networks were involved in with partners across the EU. These projects offered the value of a far wider body of information, test sites, technologies and perspectives.

The learnings gained during the field trials in this project were then built into network modelling and planning tools. Using these models and tools, some critical design changes were identified to sustainably support electric vehicle charging into the future. New technologies and materials were also identified which have to be introduced, as part of a new, cost effective electricity network development strategy.

WHAT HAS BEEN DONE SINCE THE PILOT

Many of the Work Packages recommended new strategies and approaches, which have been incorporated into revised policies and innovation projects within ESB Networks today.

1. LOW VOLTAGE DESIGN HANDBOOK

Low voltage networks are the networks which connect homes and businesses to the electricity network. Work Package 4, Network Planning, looks at a future system development strategy which included changing how low voltage networks are designed. In 2018 new low voltage designs will be introduced which will increase the network capacity available for each household. This means that all new connections will be built ready for the electrification of heat and transport. By providing extra capacity when the network is being built the investment costs can be kept lower.

2. NEW NETWORK MATERIALS

The Electricity Network Planning Strategy developed and costed in Work Package 4 also includes a number of new network technologies which can be used where extra capacity is needed on existing electricity networks, when electric vehicles connect.

These technologies have been trialled across the world to add capacity at low cost and with minimum disruption. They can be installed in a small space with minimal impact on the built environment and allow for more advanced means of electricity network control. During 2018 – 2019, ESB Networks is working with materials suppliers to introduce these new materials into network designs.

3. INDUSTRY STANDARDS

ESB Networks is preparing to publish an "Industry Standard" in late 2018. Aimed at customers, the construction industry, and parties seeking to install commercial charge point infrastructure, this will offer a single guide to existing standards and services available.

For all connection types (standalone, domestic premises or commercial premises), the new Industry Standard will provide clear, usable information about:

1. **Electrical interface requirements.**
2. **Connection and metering configurations (current approved standards).**
3. **Connection requirements and process depending on charger sizes.**

4. CONSULTING ON FUTURE STRATEGY

In Work Packages 3 and 6 various Smart Grid and Smart Charging concepts and projects are presented. Although the pilot demonstrated that these were not mature enough at that time, the strategy developed in Work Package 4 is designed to facilitate them once they are. When the new Industry Standard is published, ESB Networks also plan to engage with customers and the electric vehicle charging industry to discuss possible new services. The views of industry and the public will inform the next steps.

ESB Networks
Electric Vehicles Infrastructure Report 2018

5. TARIFFS AND CHARGES

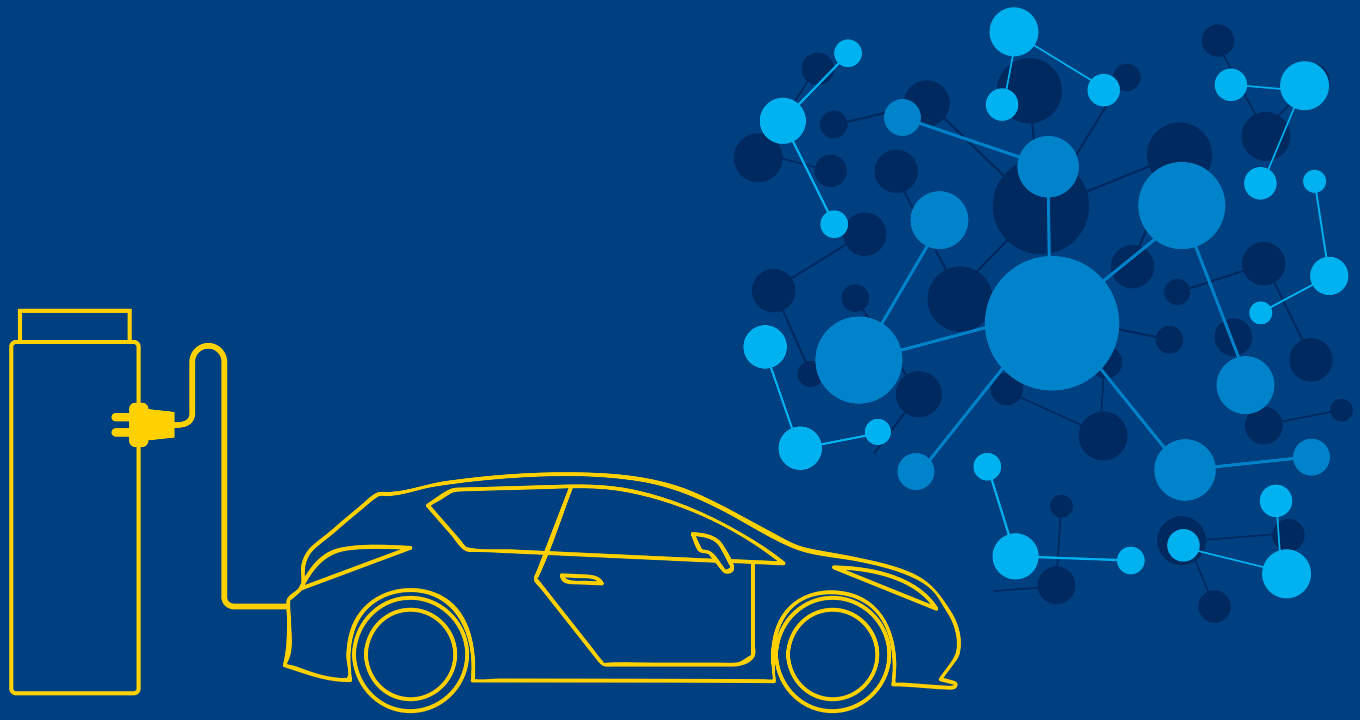
Work Package 5 shows the importance of the relationship between investment costs and the impact on customers' bills. ESB Networks is delivering a project to refine and develop its commercial policies, to ensure that the DUoS tariffs and the fees charged for connecting to the network, are a better fit for the technologies customers are choosing today. This will ensure that the needs and expectations of electric vehicle owners are included in a new set of DUoS tariffs and network connection charges.

6. MOVING FORWARD

ESB Networks' Innovation Strategy, published on ESB Networks' website, shares ESB Networks new innovation activities, which follow the 2011 – 2015 project. There is a dedicated Electrification of Heat and Transport Roadmap, as well as many projects in the other roadmaps, which address the themes and challenges introduced by the original electric vehicles pilot.

WORK PACKAGE 1

DEVELOPING THE TRIAL INFRASTRUCTURE



Objectives

Work Package 1 (WP1) focuses on how the trial charging infrastructure and demonstrations were designed, defined and selected. The key objectives of this work package were:

- To deliver a safe and fit-for-purpose trial infrastructure by identifying and installing charging equipment for home, on-street, commercial and fast charging, and reviewing options for metering.
- To deliver guidelines for safe installations that respect the surrounding physical environment including safe electrical connection methods, and safe, aesthetically pleasing installation guidelines.
- To observe and study customers' use of the infrastructure, including both customers' charging behaviour and the technical effects of different vehicles on the network.

Key Insights

FOR DISTRIBUTION SYSTEM CUSTOMERS

- This Work Package looks at how new solutions were developed, e.g. developing guidance on how to avoid electric vehicle charging affecting supply quality by carefully selecting charge point locations to account for the local network conditions.
- WP1 also looks at how careful deployment of a small numbers of electric vehicles available to ESB Networks, in an urban location field trial, revealed the key challenges needing new network design solutions (developed in later work packages).
- Supplying the trial infrastructure has not required any significant network reinforcement, and no power quality issues have been experienced.

FOR THE ELECTRIC TRANSPORT INDUSTRY

- All electric vehicles on the market at the time of writing – eight years after the pilot commenced – can still use the trial infrastructure. This demonstrates the success of the trial approach to interoperability: (1) the selection of standard connectors and charge points, and (2) to install a socket rather than a plug, where possible. This allows vehicles to carry their own bespoke charging cables (assuming a Type 2 plug on one end). Where a tethered cable is required (e.g. at fast charge points), multiple plug types are provided (CHAdeMO, Fast AC, CCS).
- Unlike many other national electric vehicle charge point infrastructure projects, the on-street AC public charge points supply three-phase power. This allows certain vehicles on the market to charge significantly faster.

2018 Update for Work Package 1

Some recent or upcoming developments since the trial ended include:

1. Tesla has installed a number of super-chargers across the country which will complement the user experience. Tesla electric vehicles can also use the trial infrastructure.
2. One limitation of the trial results is that there was no fee for public charging, so the observed charging patterns might not be fully representative. The introduction of Smart Meters in Ireland, commencing in late 2019, will enable the introduction of time-of-use tariffs.
3. ESB Networks' low voltage design standards are being updated to provide more capacity for electric vehicle charging at very low incremental cost.
4. ESB Networks is introducing new compact or active low voltage technologies in 2018/2019 to provide more capacity for electric vehicles in retrofit conditions, at minimum disruption and cost.

Results Guide

Below is a short overview of the main findings from this Work Package. More detailed information is available in pages 5-197 of the main project report.

1.1 Selecting Connectors

Identify the most appropriate connection types for use with EV chargers

In the pilot project, IEC 62196 Type 2 connectors were used for home and standard on-street AC charge points. CHAdeMO, Fixed Cable IEC 62196 Type 2 and CCS were used for fast charge points. The project outlines the types of connectors, plugs and inlets available at the time, and the relevant standards and the charging types, offering useful insight for those planning to develop charge points operations.

1.2 Specifying Charge Points

Identify the most suitable charge points for home, on-street, commercial and fast charger locations for the trial

WP1.2 describes how trial home, on street and fast charge points were selected and installed, sharing information and insight for those planning to develop charge points operations. It lays out the detailed considerations in specifying, tendering for and installing equipment, including how Codes and Standards are applied. The full report provides further information, tables and diagrams for home charge points, on-street AC charge points and for fast charge points.

1.3 Where to Connect Charge Points?

Determine the likely distribution of existing EVs during the trial period and required number of charge point installations to enable their use across the country

The planning criteria used by the infrastructure team was developed through knowledge gained from EU Projects and statistics gathered outlining the location of new registrations, etc. The initial criteria used were to locate AC and DC chargers in the large urban centres like Dublin, Cork, Limerick, Galway and Waterford. AC chargers were mainly located in on-street locations and in public car parks.
DC Fast chargers, with Chademo connectors, were then installed in service stations and at motorway service areas.

A number of DC Chargers were also installed as part of the EU funded Ten-T International Green Electric Highways. This project identified the main arterial routes in Ireland and part funded fast charger installations on these routes. The target was to have a DC Fast charger every 60km on the routes.

1.4 What are the Local Network Impacts?

Determine the effect on voltage & load of the connection of EVs to both tailed and interconnected networks in urban & rural areas

Most of the information from the field trials relates to an urban trial with up to seven vehicles on a single street. Key insights included:

- At peak (19:15 on a weekday in November) the voltage at the last house on the street dropped close to the lower allowed limit of 0.9 p.u.
- Voltage performance is usually what determines how many vehicles can be accommodated on a circuit.

This data was used to build models of how charger location and demand affect the network, including the impact of time of use controls and operating conditions. Along with analysis from the US and the UK, this helped us identify low regret options for a new Planning Strategy (WP4).

1.5 What are the Wider Network Impacts?

Determine the effect that WP 1.2 will have with the incremental addition of EVs to the various networks

The field trials undertaken by ESB Networks and investigation of research and field trials in the UK

suggest that the most significant impact of EVs will be on the LV network. Analysis completed by UK Power Networks suggest that EV load growth is seen to have a minor impact on the overall network peak load but will impact the network at LV feeder level.

1.6 Understanding charging characteristics

Measure the electrical characteristics for different EV models and how they perform with the various charge points. Metrics to be monitored include harmonics, load, current, and others

At the time of the trial there were five electric vehicle models and four fast charge points available. The project looked at a suite of power quality measurements.

Some findings include:

1. Vehicle charging systems limit the charge rate a high percentage of the time – the nameplate charge rate only applies a small amount of the time.
2. Fast chargers have a high reactive power demand, which varies significantly between charger types.
3. Fast chargers may create significant harmonic distortion, and further interaction with charge point suppliers is needed to ensure that filtering, or other technical mitigation is put in place.

1.7 When do people charge electric vehicles?

Measure the degree of co-incident charging of multiple vehicles on urban LV network.

Based on a 12 month study of charging patterns and decisions of up to seven households provided with 20kWh battery electric vehicles, the trial looked at when people naturally choose to charge electric vehicles, in the absence of any incentives or guidance.

Some insights included that:

1. Vehicle owners were reluctant to allow batteries deplete fully.
2. Vehicle owners were unlikely to plug in when the battery is above 75% charge.
3. Most charging happened following final trip of the day, not when arriving home from work.
4. Peak period charging restrictions can shift charging away from today's peak demand, but need to be carefully designed to avoid creating new, higher peaks.

1.8 Where do people charge electric vehicles?

Determine relative use of public charging versus home charging to establish likely future impact on network

As part of the project the data from the Charge Point Management System (CPMS) was analysed. While it is important to note that no fees applied for public charging at the time of the trial, the data showed that electric vehicle owners were relying heavily on the public infrastructure. More significantly, the measured charging at public charge points alone was higher than our expected total annual electric vehicle demand.

1.9 What about other forms of electric transport?

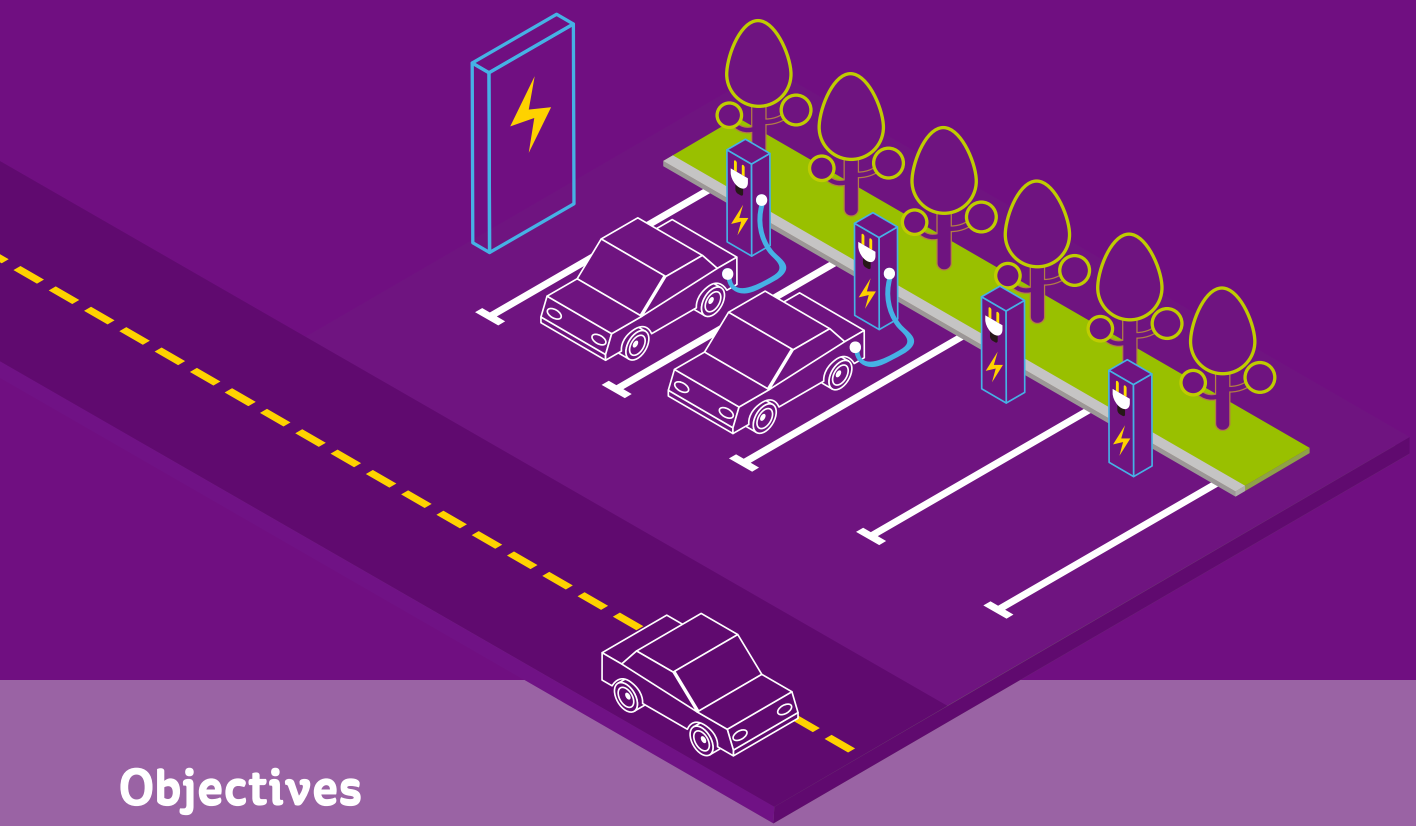
Establish demand for other technology types (e.g. electric scooters / bikes) for public charging, accounting for the charging mechanisms associated with these technologies

Over time, the network and charge point operators may need to support other types of electric transport – buses, motorcycles and scooters. The pilot also includes a study of the uptake, and charging interfaces, of other electric transport technologies.

The project looks at connectors and interface standards for motorcycles and scooters, whose uptake was very low, as well as a comprehensive study on the electric and hybrid bus technologies available.

WORK PACKAGE 2

EQUIPMENT AND DESIGNS FOR SAFETY AND PERFORMANCE



Objectives

As electric vehicle charge points become familiar street furniture in Ireland, they must be designed and installed for safety and performance, considering their physical and human environment. Work Package 2 (WP2) looks at the standards, systems and materials that were developed to deliver the pilot infrastructure.

The value delivered in this work package was:

- Identifying charge point physical and electrical needs for Irish environmental conditions.
- Developing guidance on secure installations, protection systems and vehicle interfaces.
- Developing systems for settlement and interoperability including hardware and software solutions.
- Contributing to Irish safety policies and standards for charging infrastructure in future.

Key Insights

FOR DISTRIBUTION SYSTEM CUSTOMERS

- The pilot electric vehicle charging infrastructure was installed as a form of safe and secure street furniture in towns and cities across Ireland. This Work Package discusses how it is safely connected to the electricity system.
- At the time of the pilot – and the time of writing – no fees apply for using these charge points. This Work Package looks at the billing systems and interoperability features developed to support accessible, supplier-independent and interoperable charging, when it is introduced in future.

FOR THE ELECTRIC TRANSPORT INDUSTRY

- This Work Package shares the value of experience built up as a national pilot infrastructure was delivered, including insight into equipment standards, site location, and the monitoring and inspection needs and arrangements for different types of charge points.

2018 Update for Work Package 2

Performance of our Design and Inspection Activities

- Since the pilot concluded, the continued secure and safe performance of the public charging infrastructure has validated the practices and information shared in this Work Package. Since installation, the charging network has not been subject to excessive vandalism or accidental damage.

Growing Need for Careful Design and Selection

- ESB Networks continues to engage with automotive manufacturers, standardisation bodies, and other utilities to identify and develop best industry practices. This is critical, as vehicle manufacturers focus increasingly on electric vehicle manufacturing.

Metering and Billing

- At the time of writing, there is still no charge or billing for the use of the pilot charge points. However, the back-office systems installed during the pilot will deliver open and interoperable access when this is introduced.

Results Guide

Below is a short overview of the main findings from this work package. More detailed information is available in pages 198-227 of the main project report.

2.1 Selecting Secure Equipment and Sites

Measured impact of environmental factors

This project deliverable looks at the performance of the charge point infrastructure in terms of the physical and human environments that charges point operate in. This includes details of the equipment, protection and their environmental condition ratings as well as layout design information. In relation to environmental conditions, the charge point equipment used in this project performed well in the Irish climate and no notable reduction in the integrity of the units due to their environment was observed.

2.2 Ongoing Monitoring and Inspection Needs

Monitoring of physical integrity of cabinets

WP2.2 describes the remote and on-site monitoring needed to ensure the ongoing safety and performance of public charge points. This includes standard inspection and monitoring activities, and how internal and contractor activities are managed. WP2.2 also describes some of the differences between normal AC charger and DC fast charger equipment and locations, and how they drive different monitoring needs and contractual arrangements (for example with hosting service stations).

2.3 Safety

Assessment of safety of physical location protection systems and vehicle interface

Users' safety when they are using or are near to charge points is managed by protection systems and vehicle interfaces, these are described below for the three main connector types in Ireland.

- Type, 2 Mode 3 (IEC 62196-1) – safety is ensured by a protective earth circuit interlock, contact pilot and proximity pilot circuits.
- CHAdeMO – fail-safe design, CAN bus communications, isolating transformer and pre-connection isolation tests ensure fast charger safety.
- Combined Charging System (CCS) – safety features of this connector are an adaptation of the Type 2, Mode 3 connector (for fast charging).

2.4 Interoperable, supplier-independent billing systems

The design of a cost effective supplier independent system for EV charging, metering and billing

The charging infrastructure delivered by ESB Networks was designed with the flexibility to grow and adapt, considering the need for openness, transparency and customer choice. WP2.4 describes how this was achieved through modular (or "building block") design of hardware, telecoms, network management, billing and customer relationship management systems.

2.5 Technology Review

Technology Acceptance Report

WP2.5 is published separately from the original main report. This report presents the state of electric vehicle technology acceptance across Europe at the time the pilot concluded in 2015. This includes legislative changes and project funding delivered by the EU, with a view to reducing European CO_2 emissions, and the work of standardisation bodies.

Already by that time, the vast majority of automotive manufactures had electric vehicle offerings, in contrast with earlier introductions of electric vehicles market entries, for example by General Motors with the EV1 release from 1996 to 1999.

2.6 Electrical Protection:

EV Charging Electrical Protection Report

WP2.6 is also published separately from the original main report. This includes protective equipotential bonding, screening, overcurrent protection and earth fault protection, and the additional safety features of Mode 3, Mode 4 and CHAdeMO protocols. The pilot charging network met and exceeded the existing IEC standards and international practices, with the additional protection and isolation of interface pillars, and tilt switches to automatically disconnect charge points if they were knocked over.

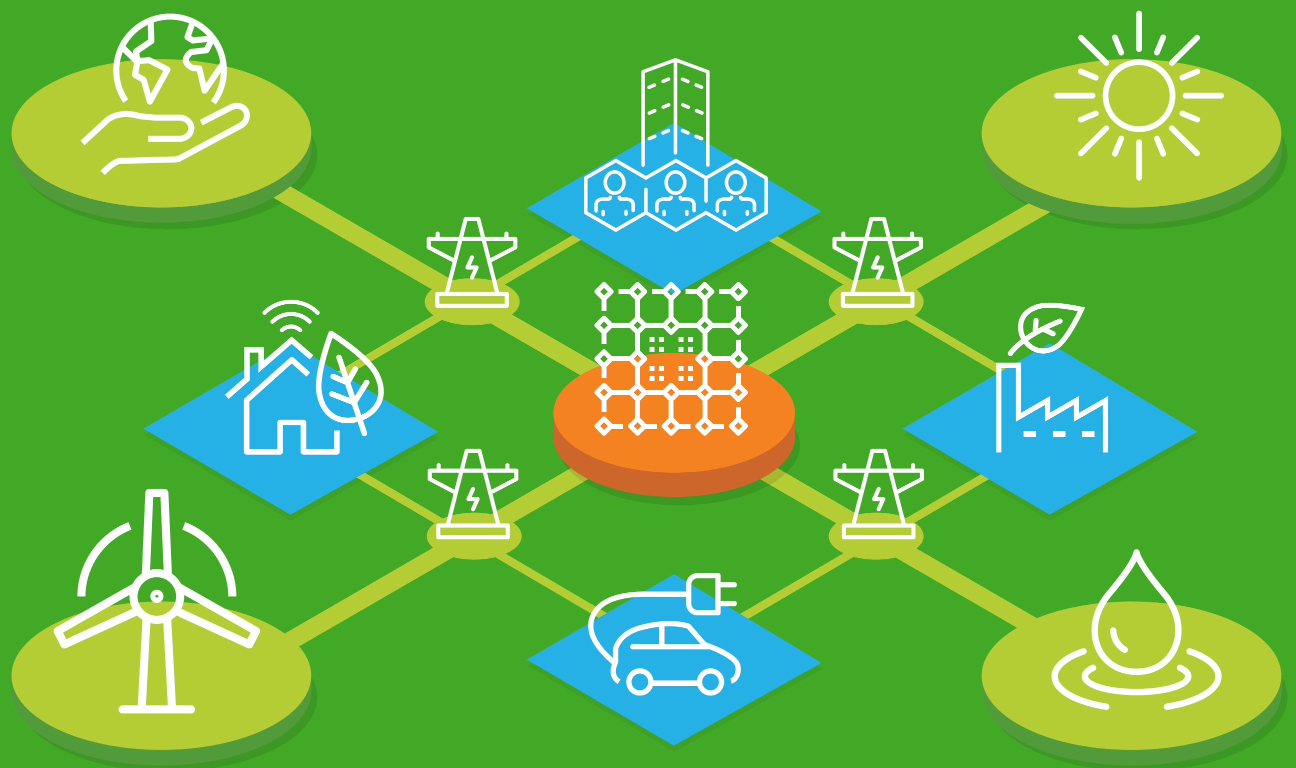
2.7 Policies and Standards

Develop Policies and Standards for Ireland

WP2.7 is also published separately from the original main report. To deliver the pilot infrastructure new interfaces needed to be developed to the electricity system, civil and electrical designs and markings. The report looks at the new interface pillars, earthing requirements, parking space marking, charge point foundations, electrical certification and metering requirements. It also focuses on designs for apartment block and work-place charging.

WORK PACKAGE 3

SMART CHARGING AND SMART GRID



Objectives

At the time of the trial, smart charging and smart grid developments were immature, but developing. However these concepts and solutions will likely form part of how electric vehicle charging on the Irish electricity system is supported and managed in future.

The objectives of Work Package 3 (WP3) were:

- **Smart Charging:** to develop a clear understanding of the scope of many different smart charging solutions, and how they interact with network development, and
- **Smart Grid:** to develop and test smart grid solutions, to help create more capacity for electric vehicles.

Key Insights

FOR DISTRIBUTION SYSTEM CUSTOMERS

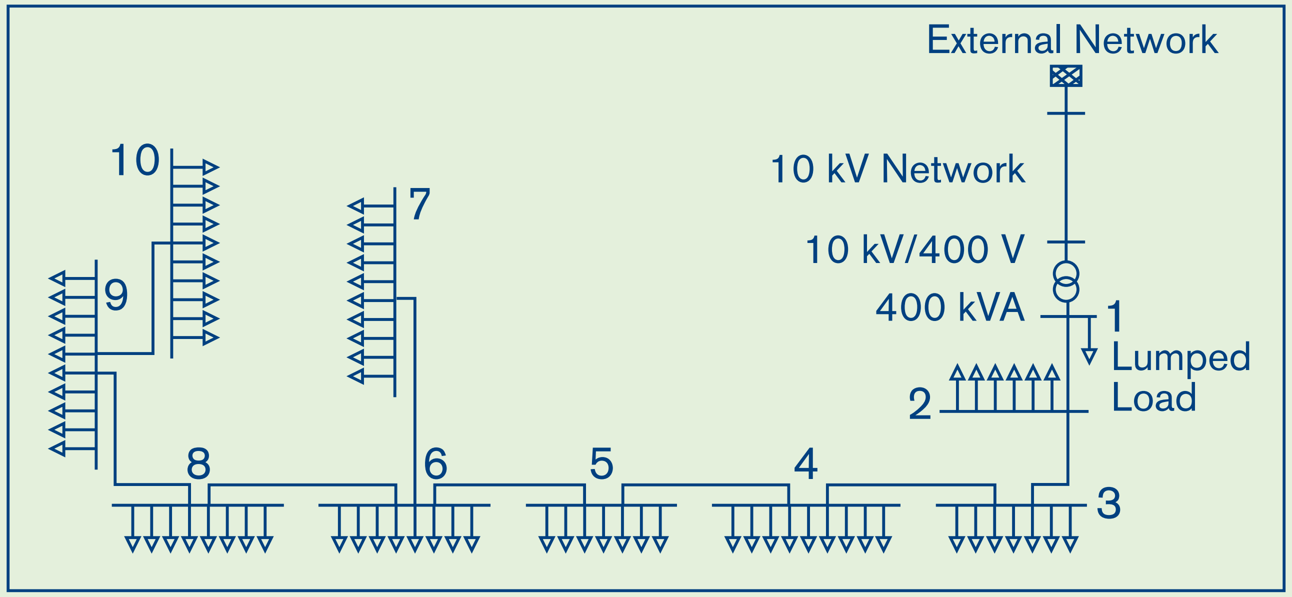
- Smart charging and smart grid solutions are different from normal network management – in a smart grid solution, customer behaviour, technologies and services, have a very different role in network development. WP3 gives customers some examples of what this means. It offers examples of smart charging and smart grid services they may be offered in future, and an opportunity to consider how they feel about them.

FOR THE ELECTRIC TRANSPORT INDUSTRY

- WP3 demonstrates some of the smart charging options which will likely go hand-in-hand with the growth and development of the Irish electric transport industry over the coming years. This will allow for a wider discussion on ESB Networks role in supporting the development of smart charging services in the electric transport industry.

2018 Update for Work Package 3

ESB Networks is preparing to publish an Industry Standard in late 2018, laying out the services for electric vehicle connections available today. This paper will also present a number of ideas and questions for public consultation, addressing some of the less mature solutions and services which could be offered in future, to support the development of new smart services for electric vehicle charging.



Results Guide

Below is a short overview of the main findings from this work package. More detailed information is available in pages 228-269 of the main project report.

3.1 Smart Charging for Cost Reduction and Network Management

Project 1 – EnLIVE EV Charging

- **Charging Community Organisation – coordinated charging to stay within local network limits.**
- **Charging Local Optimisation – individual charging to use lower cost electricity.**

Though the system operated as it should, coordinated smart charging could not always keep the local network within its operating limits. It was possible to reduce charging cost by charging when electricity price is low and this also meant that more renewable energy was used (as price is often low when wind is generating).

Smart Charging for Electricity Cost Savings

Project 2 – Enernet Optimisation

This Work Package also looks at the EU Enernet trial, testing a smart charging control system on a single electric vehicle. The controller was successful in shifting charging to off-peak times when price was low and renewable generation high. The report looks at what savings might be achieved in a larger deployment by applying the results to data from US Federal Highway administration data.

Smart Charging for Grid Balancing Services

Project 3 – Finesce

The 3rd project in this Work Package was the Irish trial of the EU Finesce project, testing elaborate control systems to coordinate real time network data and electric vehicle charging in very short timescales – down to one second. Though still ongoing when the pilot report was written, the full set of FINESCE Reports on the completed trials, including the Irish trial, are now available at the Finesce website (www.finesce.eu).

In a live trial and large scale simulations, Grid Emergency and Grid Supply-Demand charging responses were tested, achieving sub-one second communication latency. This significant result shows that grid balancing services only provided by large power stations and grid scale storage today can be provided by electric vehicle charging control.

3.2 Smart Grid, releasing more capacity to support electric vehicles

Report on the potential benefit of Smart Network Operations to Increase hosting capacity of EV's

This Work Package looks at studies and trials of how low voltage networks could be operated differently, moving from 'radial' to 'parallel' or 'closed loop' operation, to release greater capacity in existing networks for electric vehicle charging.

Desktop studies showed how this allows 60% more electric vehicles to connect and charge on a test network, and reduces electricity losses. There was also a technological solution for this developed by Alstom, which delivered increased capacity for electric vehicles and loss reduction, validating the desktop studies. However the technology costs were not yet economic relative to the solutions which are included in the new Planning Strategy, developed in Work Package 4. This trial, delivered in ESB Networks' training school in Portlaoise, used a "load bank" to create real life test conditions without disrupting customers.

WORK PACKAGE 4

NETWORK PLANNING

Objectives

Work Package 4 (WP4) presents the development of a low-cost and flexible strategy to deliver network capacity for 20% EV penetration, using incremental investments on existing networks as and when they are required. This Work Package delivered the basis of network planning today and provides insight as to the economic and technical approaches underpinning this.

In WP4 a 'Real Options' investment approach is applied, to develop a network planning strategy which balances risk and cost, in providing for the future needs of electric vehicles in a flexible and adaptable manner. This common-sense approach avoids lasting, costly commitments until future information is available, while pursuing initial no-regret investments, which are structured to minimise risk and costs.

WP4 also provides the economic and technical analyses and approach underpinning the development of a common-sense planning strategy which:

- Uses existing network capacity.
- Develops flexible, low cost, quickly deliverable network solutions to deploy where problems are expected to develop.
- Accepts the immaturity of many smart solutions in development today, allowing more sophisticated technology to develop in time.

There is a specific focus on the areas where work and costs will be required - retrofit situations, where electric vehicles connect in existing, established networks, areas and communities.

The emphasis is on medium and low voltage networks, as analysis has shown that other factors, such as economic growth, and changes in industry, are far more influential in high voltage investment.

Many electric vehicles will also connect in new estates and developments. The findings of this analysis, and follow-on projects being delivered today, to update and change ESB Networks' new planning standards so that more capacity is provided from the outset, mean that the cost of accommodating these electric vehicles will be far lower.

Key Insights

FOR DISTRIBUTION SYSTEM CUSTOMERS

- In a time of uncertainty, when EV uptake and charging patterns cannot be fully known and 'smart' technologies are as yet immature, distribution system customers need to understand how their interests and concerns are reflected in strategic planning decisions. WP4 breaks down some of the uncertainties and makes them more certain. It also offers and explains key insights including:
- New technologies that provide scope to increase capacity on existing and new urban estates at low cost.
- In rural areas there is spare capacity on many existing transformers, to accommodate initial electrification.
- The estimated costs of accommodating 20% penetration of EV's would be €350m.
- Sophisticated control mechanisms to manage EV charging on a network are better justified when penetration is much higher.

FOR THE ELECTRIC TRANSPORT INDUSTRY

- Though WP4 is largely focused on network development, it also offers insight and comfort to those pursing the development of the Irish electric transport industry. The underlying message of WP4 is that a 20% uptake can be accommodated with limited additional cost or disruption.
- Of particular interest to those planning charge point operations or demand aggregation services, WP4.4 offers some discussion of charging and tariff arrangements, and WP4.6 describes the new commercial role of an EV Aggregator, in multi-unit developments (particularly apartment buildings and offices).

2018 Update for Work Package 4

As of Q2 2018, the new Design Standards for Housing Schemes prepared by ESB Networks based on the analysis of WP4, will increase design loading per household from 2.3kW to 5.5KW, using 630kVA unit substations (with extra LV circuit) instead of 400kVA units.

These changes have minimal incremental costs (the transformer is only a small part of the overall cost) and increases in transformer costs are at the margin and better positions the substations to support with EV loads. Further increases are feasible by the retrofit of High Capacity Tap Changing Transformer and 'Sidewalk Transformers'.

For apartment buildings and offices, guidance is being developed and provided to ESB Networks engineering officers in 2018, for implementing the "EV Aggregator" concept, to minimize connection costs in these buildings and developments, comply with the Alternative Fuels Directive and provide best value to customers.

Finally, as part of its Innovation program, ESB Networks is arranging the design, manufacture and installation of the materials needs identified in WP4.

Results Guide

Below is a "map" to guide interested readers to more detailed information in the main project report.

4.1 Where do our numbers come from?

Residential Demand Profiles and EV Charging

Two points underpinning this strategy are (1) what underlying domestic demand looks like today and into the future and (2) the likely EV uptake. This Work Package addresses these questions, with worked examples, illustrations, and detailed insights of the terms, techniques and tools used in network planning. WP4.1 also explains how the SEAI 'Energy in Transport – 2014 report' projected purchase rates informed the selected 20% penetration rate as a realistic horizon for new planning strategies.

Finally WP4.1 looks at the rationale for making provision on new housing estates for EV charging at low cost, to avoid extra costs arising in future.

4.2 What are the costs and benefits of 'smart' and 'passive' solutions?

Network reinforcement requirements for various levels of EV penetration and the impact of dumb charging on urban Low Voltage circuits based on existing EV trials

This section of the Work Package considers the relative roles of smart charging and targeted use of new passive technologies, to deliver a cost effective and future-proofed strategy. This builds on the results from field trials described in WP 1.4 – 1.8 and WP 3.1 – 3.3, showing that even well loaded networks could generally support 10% - 20% penetration. WP4.2 looks in detail at the role of different connection polices for electric vehicles, or strong Time of Use charging (developing on the points first introduced in WP 1.7), examples of the set of passive solutions available and the scope for demand side management (DSM) to manage EV loads.

This Work Package concludes that the best strategy is to:

(1) use existing capacity which is already available.

(2) deploy low cost solutions (detailed in WP 4.6) to reinforce when and where needed.

(3) adopt and use DSM solutions and services as they are developed and offered as a by-product of the new and maturing opportunities arising across the energy management sector for DSM, using smart meters and other ICT technologies.

4.3 What will capacity for electric vehicle charging cost?

Estimate approximate reinforcement costs for widespread roll-out and how they might be minimised

A key finding of the pilot was the expected total network cost of providing for 20% EV penetration, which is estimated at €350m. This is broken down as €150m for urban areas, €127m for rural areas, and an additional €68m if individual separate metering for domestic EV chargers is called for. The full report shows a breakdown of how these figures were calculated, and the alternatives and strategies selected to minimise these costs.

4.4 What changes should we make today? Charging and Tariffs for Charge Point Operations

Establish design rules for the maximum number of on-street EV charge points on an LV group in order to minimise reinforcement costs for DUOS customers

WP4.4 looks at the economics of charge points, with revenue and cost analysis for the range of domestic and commercial charging options, including EV charging at private residential homes, apartment blocks, on street public charging either by a private company or as ESB Networks infrastructure and also EV charging in publicly accessible, privately owned, commercial areas such as shopping centres or hotels.

This considers how to treat the cost of extending the services provided for other similar mass connection types, such as Bus Shelter Advertising and Telecom Kiosks, to charge point operators, wherein the customer provides a flexible list of locations and ESB Networks provides a price for the lowest connection cost.

WP4.4 also examines the effectiveness and development needs of Irish network tariff arrangements, which balance the needs of "normal" and "EV charge point" customers into the future.

4.5 What changes should we make today? Network Materials

Examine the conductor and cable sizes for future networks taking account of EV demands

WP4.5 explains the analysis that informed a decision not to change conductor sizes, but rather to design for a higher number of circuits in future, including the declining returns of increasing conductor size.

This Work Package also presents some retrofit solutions, for example additional 'sidewalk' substations, which can be installed as and when required. It discusses the practicability, cost and feasibility of other approaches, for example providing three phase supplies on new underground networks.

4.6 What changes should we make today? Designs for housing schemes

Revised Housing/Apartment Scheme Design Details

This section builds on the findings of WP4.2 and WP4.3, testing new network technologies and operational practices, and developing solutions to fully utilise any existing capacity available and provide low-cost incremental network reinforcement measures for when they are required.

The solutions are detailed and illustrated for new housing estates, new apartment and office blocks, including the new role of "EV Aggregator", existing housing estates and existing apartment blocks.

4.7 Changes we should make today? Designs for rural developments

Review of rural non-scheme connection standard

WP4.7 provides key insights into Irish settlement patterns and how they relate to rural network design in Ireland. The conditions which will drive reinforcement, how this lines up with where reinforcement would be required in the future and the most cost-effective choices.

WORK PACKAGE 5

IMPACT ON DISTRIBUTION TARIFF PRICE

Objectives

The overarching purpose of the electric vehicles pilot was to identify how the distribution system is managed and developed to support electric vehicle uptake in Ireland, and to develop the effective, low-cost solutions needed. Work Package 5 (WP5) shows what the impact would be on the final cost of electricity, and specifically, the network tariff prices that customers pay.

All electricity customers pay for investment on the electricity distribution system through "distribution use of system tariffs" (DUoS tariffs). Electric vehicles affect the DUoS price per kWh sold in two ways. Though they will increase network investment costs – as described in Work Package 4 – they will also increase use of the distribution system, or the number of kWh units sold.

As electric vehicles use a lot of electricity (kWh units) relative to the relatively low network cost they drive, electric vehicle uptake may well have a neutral impact in DUoS price, or cause a slight price reduction. WP5 aimed to analyse and test this with detailed cash flow analysis.

Key Insights

FOR DISTRIBUTION SYSTEM CUSTOMERS

- This work package considers the needs and impacts on today's distribution system customers, answering questions about how supporting electric vehicles will likely affect the DUoS price they pay. The two conclusions of this work package are that electric vehicle penetration of up to 20% can be supported without major distribution system reinforcement, and the cost of the reinforcement necessary should be more than paid for by electric vehicles use of the system (meaning no price impact for other users) based on today's tariff model.

FOR THE ELECTRIC TRANSPORT INDUSTRY

- Though this Work Package focuses on the price impact for distribution system customers, the analysis needed to answer this question provided useful and interesting information about electric vehicle charging behaviour, collected over the course of the electric vehicle trials. This information might share insight and analysis that is useful to any party across the electricity or transport industry seeking to develop services or other offerings supporting the uptake of electric vehicles in Ireland.

2018 Update for Work Package 5

Electric Vehicle uptake

- As of end 2018, electric vehicle penetration is still sufficiently low that little or no reinforcement is necessary to support it. In itself, the absence of significant upfront investment reflects the planning strategy developed in WP4. It does, however, provide limited additional information to further substantiate the findings of WP5.

DUoS Tariff design

- In 2018, ESB Networks has commenced a review of all distribution tariffs, with a view to ensuring that they fairly reflect the needs of all new kinds of use of the distribution system, including those of electric vehicle connections. The analysis completed in WP5 is being built into this project from the outset, so that enduring value can be derived of this work.

Results Guide

Below is a short overview of the main findings from this work package. More detailed information is available in pages 424-456 of the main project report.

5.1 Parameterised Models to support DUOS Impact Analysis

Work Package 5.1 provides 5 different scenarios to how supporting electric vehicles on the distribution system may affect DUoS price. In all cases, electric vehicle uptake eventually results in DUoS price reduction, as the additional use of system overtakes the cost of work to support this.

In the worst-case scenario, an initial price increase of a little over 0.5% is projected, before prices eventually decrease. In another scenario – where electric vehicles do not need a separate meter – a price reduction from the outset is predicted, as a result of electric vehicles on the distribution system.

The full report also provides background information on DUoS tariffs and the cash flow model used to calculate these results.

5.2 How much electricity will electric vehicles use?

Real time data capture of typical charging behaviour through commercial & domestic scenarios

How customers charge electric vehicles will affect network investment planning and costs, and how much they charge will affect the impact on tariffs as seen in WP5.1. The real time data from four of the trials was collected from On Screen Display on Electric Vehicle Chargers, Smartphone Applications and from ESB's Charge Point Management System.

In terms of how customers charge, the trials showed that night charging with time of use tariffs would create a longer (but not much higher) night time peak. Also, customers tended to plug in at 6.30pm, and also at 10.30pm, with coincident charging from 8pm onwards peaking at 11pm.

In terms of how much customers charge, typically customers topped up by 8 – 9 kWh per charge (about half the battery capacity). They rarely topped up by the full battery capacity of 16kWh. Customers seemed reluctant to let their batteries run out, but also rarely plugged in if the battery had 75% its charge left.

5.3 Discussing and validating the price impact

Final Report on Project Impact of EV Rollout on DUOS Charges

Work Package 5.3 discusses developments and issues which affect the two main conclusions – electric vehicle penetrations of up to 20% can be supported without major distribution system reinforcement (with up to 15% more on a pro-rata cost basis), and the cost of the reinforcement necessary should be paid for by the increase in electric vehicles use of the system (which will mean no price impact for other users).

This Work Package also looks at how demand response could increase or decrease the cost of supporting electric vehicles, and a solution for managing this without system reinforcement. Finally the Work Package explains how the costed technical proposals delivered in Work Package 4 apply equally to other emerging low carbon solutions such as heat pumps, and that interaction between electrification of heat and transports also needs to be considered at the end of the sentence.

ESB Networks
Electric Vehicles Infrastructure Report 2018

WORK PACKAGE 6

SYSTEMS AND STANDARDS FOR A COMPETITIVE MARKET

Objectives

The objective of Work Package 6 (WP6) was to develop and test the IT and telecommunications systems needed for charge point management, including how this could be used to deliver smart grid services.

The value of this work package was:

- To deliver electric vehicle charge point management ICT systems to facilitate a competitive market.
- To deliver a standards-based protocol for charge point management and control.
- To facilitate roaming and interoperability, with a particular focus on the island of Ireland.
- To demonstrate the charge point management system's smart grid functionality.

Key Insights

FOR DISTRIBUTION SYSTEM CUSTOMERS

- Many of the ICT systems and standards developed for the trial will become vital services for electric vehicle drivers in future. However, electric vehicle charging management could support more efficient electricity market and system operation with the development of new "smart" customer-centric services.
- Smart grid services rely on multiple interconnected components working together reliably, for example:
  - The Charge Point Management System (CPMS) must be able to accept incoming requests or instructions.
  - The CPMS must be able to issue instructions to charge points to vary their power demand
  - Charge points must be able to vary their power demand.
  - Charge points must be able to reduce power to a "safe" fall back level if the CPMS is unavailable.
  - The electric vehicles must allow the charge point to vary the power delivered.

FOR THE ELECTRIC TRANSPORT INDUSTRY

- In this work package, ESB Networks contributed to a significant development to the electric vehicle charging industry globally: the "OCPP" protocol. This standard protocol for centrally managing charge points is now freely available.
- WP6 also shares the experience of building a system using real-time data, and the challenges encountered. Mobile telecommunications links were not always reliable and first-generation charge points attempting to connect to the central system encountered difficulties.
- Finally, WP6 shares a comprehensive overview of how roaming and settlement can be delivered for electric vehicle charging.

2018 Update for Work Package 6

As electric vehicle charging moves towards a commercial model, there has been a market-led shift away from charge point management being an integrated part of the retail electricity market. This means that ESB has been able to combine its charge point management IT systems into a single platform. This second-generation charge point management system (CPMS) offers more robust and mature management and control features, more smart charging support, and dedicated electric vehicle billing, tariff and payment processing abilities.

- The OCPP protocol has continued to be developed. As a founding board member of the Open Charge Alliance, and a key technical contributor, ESB had a central role authoring and releasing two new versions; 1.6 in 2016, and 2.0 in 2018.
- M2M communications technology and mobile network coverage has matured, contributing to improved reliability of charge point communications. The ability to roam across networks has been added, and alternative M2M-based products are now being used in specific locations to improve reliability.
- Roaming and interoperability services continue to be closely monitored. The CPMS is connected to three major European hubs and these connections can be activated by concluding roaming agreements with other charging network operators.

Results Guide

Below is a short overview of the main findings from this work package. More detailed information is available in pages 457-480 the main project report.

6.1 Connecting Charge Points to the Charge Point Management System:

Charge Point Integration and OCPP Compliance

Connecting new charge points to the charge point management system is the first vital step in delivering managed charging activities. WP6.1 lays out the set of activities to connect charge points to the CPMS, and common issues encountered in doing this. Identifying the root cause of connection issues can be challenging, particularly in the absence of official OCPP compliance certification and test toolkits. An overview of how the OCPP protocol was developed for communications and control between the CPMS and chargers across the country is included.

6.2 How the Charge Point Management System Works: Implementation and Go-Live of All Island CPMS

The Charge Point Management System (CPMS) was the innovative software platform designed and developed to remotely manage, control and operate the trial infrastructure across Ireland. WP6.2 describes this cloud-based software-as-a-service product, and its internet-powered applications available on a web-based interface. It also looks at the different interfaces and layers which provided specialised functionality, for example call-centre personnel or field staff.

6.3 Back Office Customer Service System: The IBM Intelligent EV Enablement Platform

For any commercial charge point operations to develop, they will need an IT platform for customer provisioning, support, account management, billing, payment processing, energy market settlement and international roaming. WP6.3 presents the Electric Vehicle Enablement Platform (IEVEP) - the back-office IT system developed jointly by ESB and IBM for the pilot, and how each of these customer service features is provided.

6.4 Using Charge Point Management to Deliver Grid Services:

Demonstrate Smart Grid Capabilities Including Frequency Response

This part of the Work Package describes some smart charging services, demonstrated using the CPMS, chargers and electric vehicles in a number of field trials. We focus in particular on the smart grid services trialled as part of the FINESCE project, by remotely varying charging demand.

6.5 Using the Charge Point Management System to deliver Electricity System Services: Develop solution and business/contractual framework for virtual spinning reserve capability

"System Services" of "DS3 Services" are specialised electricity system security products which are delivered almost exclusively by large generators today. WP6.5 is published separately from the original main report. In this newly published material, it is explained how ESB Networks hoped to demonstrate that coordinated charge point management could deliver these services in future. However at that time, the technology that was needed was not yet mature, and the System Services market itself was still in its design phase when the pilot concluded.

Since the trial has ended the technology needed has developed significantly. Two new versions of OCPP have been released, supporting load management and smart charging, version 1.6 in 2015 and version 2.0 in 2018. Many charge point vendors have also begun to include smart charging abilities in their equipment.

As ESB can now use its Charge Point Management System to intelligently control charging, the trials to develop a commercial product offering are now being completed.

6.6 Open Communication Standards for Electric Vehicle IT systems:

Development, Adoption, and Promotion of the Open Charge Point Protocol

WP6.6 gives an overview of the Open Charge Point Protocol (OCPP), an open standard application level protocol for communications between electric vehicle chargers and the central management systems.

6.7 Seamless Roaming for Electric Vehicle Charging: Roaming and Settlement

Roaming – using other operators' services when abroad – can be delivered by the electric vehicle charging industry. In an additional section, published alongside this summary report, how full interoperability between Irish and international charging infrastructures has been delivered, and some of the demonstrations in which we showcase roaming across Europe are explored.

WORK PACKAGE 7

EU PROJECTS AND COLLABORATION

Objectives

Work Package 7 (WP7) provides an overview of EV infrastructure initiatives underway across Europe. It assesses the different standards and specifications chosen, and explores the methods used to install EV charging systems in different countries and regions.

Understanding the approaches, technologies, and lessons learned across Europe is an effective way of broadening the information and perspectives available to ESB Networks and the Irish electric vehicle charging industry.

The value of this work package was:

- To collect wider technological knowledge on the technologies not available in reasonable scale in Ireland, and alternatively, efficient and safe solutions to support charging infrastructure.
- To help future-proof infrastructure installed for the trial, maximizing the value of the trial investment.
- To ensure that Irish conditions are reflected in charging standards being developed internationally, by participating in standards development for safe, open, efficient and interoperable charging.
- To gain experience integrating with marketplaces with a view to developing the systems to enable electro mobility services, for example such as international roaming in a pan-European context

Key Insights

FOR DISTRIBUTION SYSTEM CUSTOMERS

- The projects in WP7 focused in particular on smart technologies to release greater capacity in the existing network, for example:
  - » A "soft open point" to control and balance load locally across normally open points (Green eMotion project).
  - » Demand management to maximise renewable energy, and manage charging costs and battery life (Enernet project).
  - » Coordinated smart charging, to make best use of limited network capacity (Amsterdam Arena providing it is more economic).
- European projects were also a way to address the wider challenges of interoperability and roaming access to charge points across Europe. These projects addressed IT architecture, standards and interfaces, marketplaces for charging services.

FOR THE ELECTRIC TRANSPORT INDUSTRY

- This work package provides a repository of information from working with partners across the e-mobility sector, including BMW, Daimler, Nissan and Renault. This includes tables of technical information on different models' charging characteristics, IT standards lists and market place design schemes.
- This work created opportunities for automotive consultants and OEMs to demonstrate their products in Ireland, including Mitsubishi, Nissan and Renault's early models, and products from Siemens, Alstom, ABB and other power companies.

2018 Update for Work Package 7

Smart Solutions

- As of Q2 2018, there is insufficient EV demand to drive smart charging or advanced network technologies (soft open points, voltage or load balancing). ESB Networks continues to develop the relevant policies and standards for rollout of the best solutions, as required. In Q4 2018, ESB Networks plans to publish a consultation which seeks industry views on smart solutions and information services for future system development

Inductive Charging

- As of Q2 2018, the majority of automotive OEMs do not provide an inductive charging option for electric vehicles. Inductive charging is used in only a very small number of locations in Ireland, and large domestic uptake remains unlikely.

Public Transport Policies

- As of Q2 2018, policies to reduce the carbon footprint of public transport fleets have driven investment primarily in retiring legacy diesel vehicles and replacement with hybrid or bio-gas alternatives. As the price of electric buses drops, some routes in Ireland will likely be serviced by plug-in hybrid electric buses or full electric buses.

Results Guide

Below is a short overview of the main findings from this work package. More detailed information is available in pages 481-625 of the main project report.

7.1 Public and Shared E-Transport Market (2012): Interim Report on EV Charging in Green eMotion

This Work Package details the status of the EV market in Western European regions including Denmark, Ireland, Spain and Sweden at the end of 2012, with a focus on fleet and public or sharing commercial models.

It sets out the different EV models available on the market in 2012, their charging methods and uses in fleet, as applications. The detailed range, energy demand, and carbon performance information research is shared, with a view to information opportunities in the Irish e-mobility market (electric assisted bicycles, taxis or buses).

7.2 Public and Shared E-Transport Market (2014): Final Report on EV Charging in Green eMotion

This report details the status of the market for commercial or fleet EVs in Europe at the end of 2014. It illustrates the significant advances in technology, availability of infrastructure and price points subsequent to completing 7.1. This report details policies EU member states adopted to encourage the electric transport market. It details factors, including rising fuel prices, which have made EVs increasingly attractive to fleets, providing detailed commercial performance information.

Insights and findings shared include the detail of EVs deployment in courier, postal, pool, taxi and utility fleets, detailing usage patterns, maintenance costs, lease and purchase options, emissions, fuel economy and other drivers of commercial performance.

7.3 Marketplaces for Charging Services: Green eMotion Marketplace Report

The Green eMotion Marketplace report describes the development of a centralised B2B charging services marketplace. This was the platform for offering and contracting electro mobility services between multiple parties and across multiple territories. This marketplace was used to demonstrate two services – international roaming and the provision of real-time charge point location and availability information. International roaming was enabled in France, Spain, Germany, Italy, Belgium and Sweden, using RFID access cards issued by ESB eCars.

Charging station availability information was provided on a web portal, for all charging infrastructure across all project regions.

7.4 Information Technology: IT and Standardisation

This Work Package also looks at the ICT standards landscape to connect charge point hardware with third party software systems for electric vehicle management, billing, payment processing, and driver-centric applications and services. It details the standard data objects, communications protocols, and interface specs for data transfer, to ensure quality, interoperability, and to avoid vendor lock-in.

At the time of the pilot, the necessary IT standardisation was still in the early stages of development. Though both open and proprietary protocols were in use, the Open Charge Point Protocol (OCPP), deployed in over 50 countries, was emerging as the de facto standard for charging station to back-office use. The efforts of the eMI3 (eMobility, ICT, Interoperability, Innovation) group to drive standardisation are described in the full report.

7.5 Advanced Charging and Network Technologies: Technology Report Green eMotion

EU projects created opportunities to test and learn about a wider range of advanced charging and network technologies, including demonstrations of Inductive Charging, a Soft Open Point and DC Fast Charging. Some insights into consumers' preferences and perceptions, included that:

1. induction charging is seen as a cleaner, tidier alternative to conductive charging.

2. the positioning of the vehicle over the induction pad is universally acknowledged as difficult.

3. commencing and terminating charging is seen as very straightforward.

This section also describes the installation and testing of a Soft Open Point device, which aims to deliver an efficient network development solution by allowing controlled power flow between adjacent feeders and the use of targeted fast charger installations to help eliminate queuing.

7.6 Smart Charging and Charge point Management System: Smart Charging Report

This report summarises four smart charging projects that ESB Networks participated in. These include managing charging to absorb high levels of renewable energy, minimise cost and maximise battery life (Enernet trial) and the use of smart protocols and for information exchange between user and charge point for charging where there is limited supply capacity (Amsterdam Arena project).

The smart functionality of ESB Networks' charge point management system was also reviewed, including its OCPP compliant commands and proposed advanced functionalities including SCADA integration, frequency response and spinning reserve.