DC Share

Using latent capacity to enable rapid charging in constrained urban locations

Ricardo Energy & Environment
Western Power Distribution — Serving the Midlands, South West and Wales
Electricity North West
tps
vectos

1. Project Summary

1.1. Project Title	DC Share
1.2. Project Explanation	DC Share is a network equalisation solution designed to share system capacity across AC secondary substations with different load profiles. The available power will then be distributed to vehicle charge points via a new high capacity DC cable network to enable EV rapid charging, without traditional reinforcement.
1.3. Funding licensee:	Western Power Distribution, East Midlands
1.4. Project description:	1.4.1. The Problem DC Share will explore: 1. The utilisation of latent capacity in distribution networks, which is difficult to access using traditional means. 2. How distribution networks will provide rapid charging facilities at scale and in the locations where they are needed. These are required for those without access to charging facilities at home or work, and for en-route charging. 1.4.2. The Method DC Share will trial a DC ring that will be fed via multiple infeeds from secondary substations, allowing it to: 1. Draw power from those locations with capacity available; 2. Transfer power between substations to allow those with spare capacity to support those that are heavily loaded, deferring the need for reinforcement. The DC ring will have fifteen rapid (50-100 kW) chargers directly connected, allowing the method to make use of charging demand diversity. The DC network can be expanded to accommodate additional infeeds when required, and in future could incorporate connection of other Low Carbon Technologies. 1.4.3. The Solution DC Share will deliver effective provision of destination charging at scale and in the locations where it is required, whilst minimising network costs and maximising benefits. 1.4.4. The Benefit(s) of the project The project will provide benefits through the provision of required rapid charging facilities at lower cost than the equivalent AC reinforcement and increased utilisation of the AC network allowing the deferment of reinforcement.

	DC Share will provide the following quantifiable benefits: • £162m Net Present Value of financial benefits to 2050 • 1,800 MVA of capacity benefits • 26,000 tCO2 equivalent of carbon emission reduction		
1.5. Funding			
1.5.1 NIC Funding Request (£k)	**4,716**	1.5.2 Network Licensee Compulsory Contribution (£k)	529
1.5.3 Network Licensee Extra Contribution (£k)	0	1.5.4 External Funding – excluding from NICs (£k):	341
1.5.5. Total Project Costs (£k)	5,629		
1.6. List of Project Partners, External Funders and Project Supporters (and value of contribution)	Project Partners: Ricardo Energy & Environment (Lead), contribution £191.7k Electricity North West, contribution £50k Turbo Power Systems, contribution £143.73k Vectos, contribution £5.72k		
1.7 Timescale			
1.7.1. Project Start Date	6 January 2020	1.7.2. Project End Date	31 March 2023
1.8. Project Manager Contact Details			
1.8.1. Contact Name & Job Title	Simon Terry	1.8.2. Email & Telephone Number	Simon Terry@ricardo.com 01235 753 319
1.8.3. Contact Address	Ricardo Energy & Environment, 1 Frederick Sanger Road, Surrey Research Park, Guildford GU2 7YD		
1.9: Cross Sector Projects (only complete this section if your project is a Cross Sector Project, i.e. involves both the Gas and Electricity NICs).			
1.9.1. Funding requested the from the [Gas/Electricity] NIC (£k, please state which other competition)			
1.9.2. Please confirm whether or not this [Gas/Electricity] NIC Project could proceed in the absence of funding being awarded for the other Project.			
1.10 Technology Readiness Level (TRL)			
1.10.1. TRL at Project Start Date	6	1.10.2. TRL at Project End Date	8

Section 2: Project Description

2.1. Aims and objectives

This project will assist with rapid EV charging requirements by providing facilities where they are needed, whilst making optimal use of the available network capacity.

PROBLEM:

The connection costs for rapid EV charging facilities are a critical consideration for developers. Provision of rapid charging facilities is key to their uptake (particularly for fleets and urban delivery services) and hence high connection costs will be a barrier to the uptake of EVs. Users must be able to charge their EVs in a manner that is at least as convenient as current refuelling methods.

SOLUTION:

A Smart network solution that allows rapid charging by using the available capacity across a number of substations. The solution will determine the best connection point to draw power from and will also support heavily loaded transformers.

2.1.1 Problem

The Need for the Electrification of Transport

The Government's Clean Growth Strategy sets out the importance of accelerating the shift to Low Carbon Transport with one of its key aims being to "Develop one of the best electric vehicle (EV) charging networks in the world" alongside the policy of ending the sale of new conventional petrol and diesel engine cars and vans by 2040. The Net Zero – Technical Committee on Climate Change report published in May 2019 observes that cars, vans and heavy goods vehicles are the most significant sources of greenhouse gas emissions in the transport sector. The Committee are calling for the 2040 date to be bought forward to 2035, and to include ending the sale of hybrid and plug-in-hybrid vehicles. They also call for an end to the use of petrol and diesel vehicles (including hybrid and plug-in-hybrid vehicles) by 2050. In June 2019 parliament amended the Climate Change Act to legislate for net zero carbon emissions by 2050.

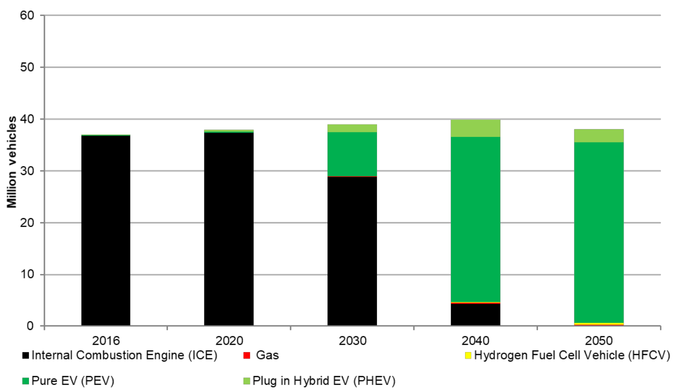

Figure 1. Predicted number of vehicles by fuel type under the National Grid "Two Degrees" Future Energy Scenario

There are currently just over 200,000 EVs in GB. National Grid's "two degrees" Future Energy Scenario is based upon 7.3 million EVs (30% of vehicles) by 2030. The majority of these are expected to be battery EVs with substantial battery capacity and rapid charge capability[1].

Overcoming Barriers to EV Uptake – the Need for Rapid Charging Hubs

[1] 2018 FES in 5 minutes Note July 2019 FES refers to 75% of vehicles being EV by 2035.

Key to user confidence for the uptake of EVs will be the availability of a range of offerings for EV charging; each having an impact on the power system and serving different charging use cases. Currently there are no large-scale availability of EV charging points in GB, however, there are several possible scenarios to be considered to provide the necessary infrastructure.

DC Share provides an approach to delivering rapid (>50 kW) charging facilities in short stay destinations such as town centres, taxi ranks, commercial vehicle and car club charging hubs.

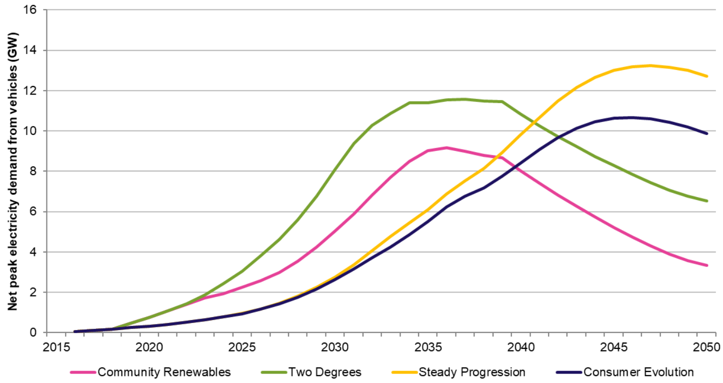

Figure 2. Net peak electricity demand from vehicles (National Grid Future Energy Scenarios)

Recent projects (for example My Electric Avenue and Electric Nation) have demonstrated that slow (7 kW and below) chargers can be largely accommodated by managed charging solutions. However, the provision of rapid (50 - 100 kW) chargers at any scale in urban environments (where users charge for short periods of time rather than hours), will be required to allow:

1. Destination charging – for those without access to domestic or workplace slow charging, or during a longer journey/prior to a return journey, and
2. High utilisation commercial individual or fleet charging – for use by taxi drivers, delivery vans etc where vehicle downtime should be minimised.

These rapid chargers will be a necessary part of the charging ecosystem that will enable longer and irregular journeys, as well as facilitating the adoption of EVs in high utilisation fleets. Furthermore, the provision of rapid chargers in cities and urban environments is particularly important to support these fleets and maximise improvements to local air quality.

In Ofgem's Future Insights Series, "Implications of the transition to Electric Vehicles[2]" it is noted that given the speed of recent improvements in battery size and vehicle range, the need for rapid charge points could change significantly in the near term. Ricardo's own analysis shows that up to 11,000 rapid chargers may be needed for cars and vans by 2030 and 300,000 depot rapid chargers could be required in the UK to electrify the HGV fleet by 2050. To combat range anxiety, blocked and non-functioning chargers it is anticipated that an oversupply of rapid chargers will be necessary.

Rapid chargers will likely be deployed in hubs (multiple chargers in one location) to minimise the cost of civil works and grid connections, and to ensure charger availability for multiple users. Rapid chargers that have been installed to date have often been deployed in small clusters (typically between two and four, meaning that chargers are likely to be busy during peak periods) and in locations where a cost-effective grid connection could be secured.

[2] Ofgem future insights - implications of the transition to electric vehicles

The location of the rapid chargers will be an important factor in the successful widespread uptake of EVs and should therefore be dictated by user requirements rather than network capacity and space constraints.

Impact of Rapid Charging Hubs on Electricity Networks

Rapid charging facilities are likely to require network reinforcement, due to the power requirements of each charger and the fact that these are likely to be deployed as charging hubs. A recent charging hub in Milton Keynes[3] houses 8 x 50 kW chargers and required installation of a new secondary substation and HV cables. In this case there was space available for the charging points and the substation.

Figure 3. The Milton Keynes coachway charging hub and the HV Network extension

Accommodating the new charging demand within networks is key to enabling the decarbonisation of transport. Rapid chargers represent a significant load to distribution networks. Table 1 illustrates the percentage of rating that 50 and 100 kW chargers represent on some example equipment.

	Transformer	Cable
50 kW Charger	10%	20%
100 kW Charger	20%	40%

Table 1. Charger demand requirements on typical network assets

An existing substation might be able to connect one or two rapid chargers but when they are required at scale network reinforcement will likely be needed. However, grid connection and reinforcement costs can be significant and are often cited as a concern for EV charging point connection customers.

The problem that the DC Share project is seeking to resolve is:

Rapid charging hubs are expected to be an important part of EV infrastructure requirements, but network upgrade costs to accommodate them are prohibitive.

2.1.2 Method being trialled

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[3] https://www.zap-map.com/milton-keynes-rapid-charging-hub-officially-opened/

DC Share will trial a Method to provide rapid charging facilities where they are required by users, utilising latent capacity in the surrounding networks to minimise the cost of connection.

The DC Share Method will use an equalisation network to provide an alternative, cost-effective solution for rapid EV charging demands, more flexibly than a traditional AC reinforcement solution. The solution seeks to explore the comparative benefits of a DC network, where power flows can be actively managed, and fault level contained, over a traditional AC network reinforcement.

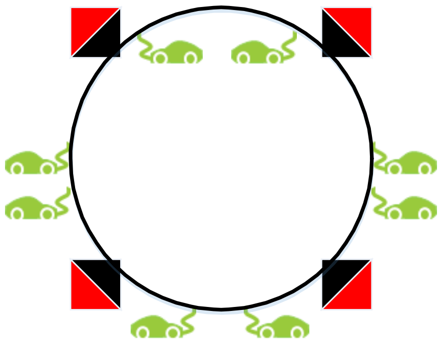

Figure 4. Overview of the DC Share solution

The Method uses an equalisation network between existing substations and makes use of the differences in demand patterns to provide the required capacity. DC Share will employ bi-directional power electronic converters to connect to existing substation low voltage (LV) boards and provide connections to vehicle charge points via a new high capacity DC cable network. The equalisation network balances demands such that transformers experiencing heavy demand receive support from those that are more lightly loaded. This offers benefits by evenly distributing loads between assets, reducing the probability of stranded assets.

The DC Share Method provides a means of sharing system capacity across AC secondary substations with different load profiles. Using a DC ring to provide the capacity for the rapid charging points leaves capacity on the existing LV AC cables for demand growth of the existing users. Meshing of AC systems is not straight forward as power flows in an uncontrolled way and fault levels are increased. Meshing on DC networks can be achieved in a controlled way without affecting fault levels. The Method allows benefits from the diversity of the dynamic charging loads and network meshing that conventional AC network designs preclude (see Appendix 10.3.1).

DC Share has been designed to offer a solution to the need for widescale rapid EV charging. These will be significant point demands, greater than can be accommodated via other smart solutions, as the ratings of the existing network equipment will preclude such large demand connections. This is further discussed in Section 3.

The DC Share network will be built from modular components so that it can be extended to address the requirements of different locations and changing needs. The DC network also has the potential for direct connection to distributed energy resources such as solar PV installations and energy storage systems.

Solution Modelling

To quantify the impact of the Method and prove its viability a network model was developed. The model used the daily load profile from four typical Western Power Distribution substations as templates and connected these via 250 kW converters to a DC ring. EV charging load of maximum demand 250 kW was modelled on each network branch between each substation.

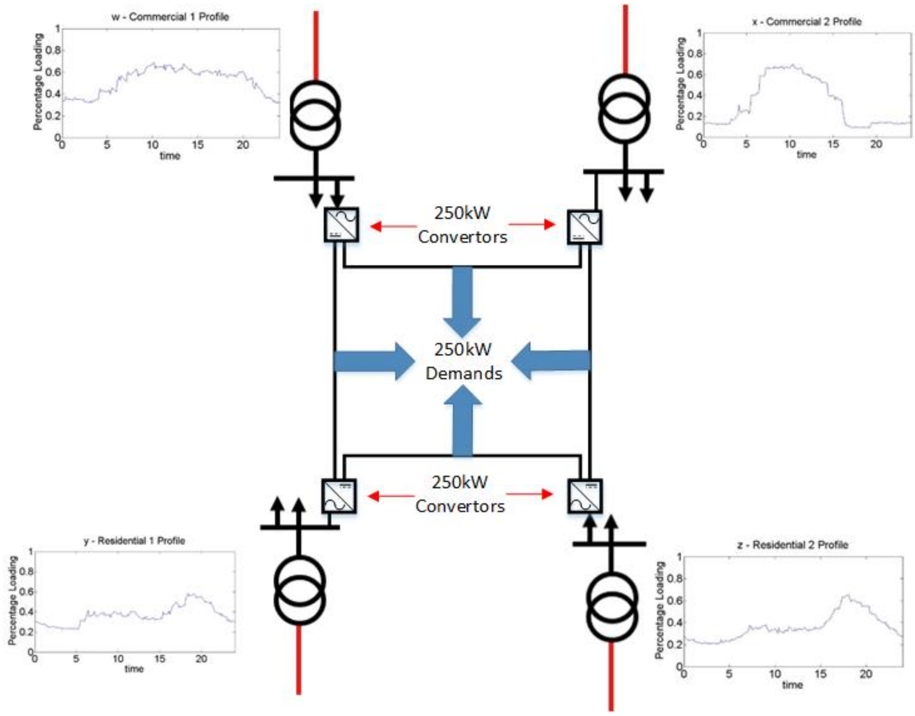

Figure 5. DC Share network model

The model then examined the effects on the substation loadings available from the Method under various EV charging scenarios.

With the DC Share network operating but no EV charging, the Method allows reduction of the substation peak demands from 70% to 50%.

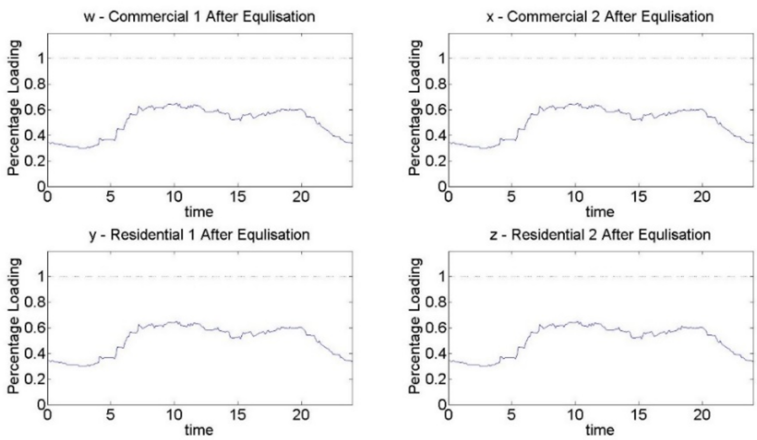

Figure 6. DC Share Model Substation profiles after equalisation, with no EV charging load

The model demonstrates that high levels of charging can be accommodated without exceeding the rating of the transformers. For example, if the probability of each charger being in use between 7am and 9.30pm is 75%, the additional charging demand can be accommodated within existing transformer ratings.

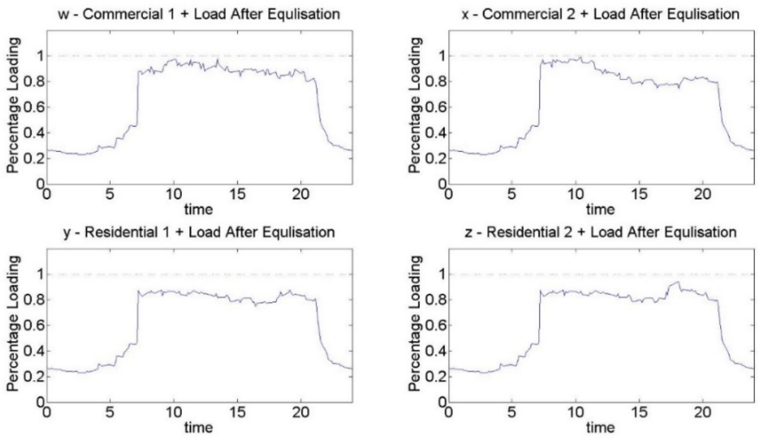

Figure 7. DC Share Model Substation profiles after equalisation, with 75% probability of an EV charger being in use between 7am and 9.30pm.

Accommodating charging load of this scale using conventional network reinforcement would necessitate the installation of additional transformer capacity and the associated HV cable connections, all of which would be completed at the customer's expense.

2.1.3 The demonstration being undertaken

DC Share will build upon learning from previous projects and deliver a business ready solution to a problem that has already manifested. The problem will become more prominent as the demand for rapid charging increases and the existing locations with spare capacity are exhausted.

Four areas of development will be undertaken.

1. A new control system will be required to manage the DC Share system, incorporating communication between the vehicles, the chargers and the substation converters. The system will autonomously assess the charging load, where to draw this demand from, and the level of equalisation possible. Management of the charging load and its impact on users will be investigated during the trial, to gain insights as to the optimum ratio of charging and converter capacity that should be installed to provide optimal system utilisation against capital expenditure.
2. DC Share will expand the equalisation concept into an equalisation network, balancing a wider area and offering broader benefits. DC Share will demonstrate this at LV, where the effects of aggregation are low (i.e. the number of connected customers is relatively small, and load generally reflects a distinct domestic or commercial/industrial profile) and the potential benefits are pronounced.
3. The AC-to-DC converters to be deployed in the trial will be an evolution of the "Soft Open Point (SOP)" technology developed by Turbo Power Systems Ltd in previous innovation projects. The new units will be smaller and will connect the DC bus to a cable circuit. The smaller unit means that siting devices within substations will be possible in more locations, which will reduce the visual and audible impact.
4. As existing commercially available EV rapid chargers are all AC network fed, new EV chargers that are fed from the DC network will be developed.

Each of these development streams offers significant challenges that justify the use of innovation funding. The project will develop the solution systems and subsystems from TRL 6 and progress them such that they the system is complete and qualified (TRL 8). In order to move to Business as Usual adoption (TRL 9) the main area that we anticipate that would require further development would be the integration of the DC Share control system into DNO BaU systems.

2.1.4 The solution that will be enabled by solving the problem

DC Share will make best use of existing assets to provide rapid EV charging facilities and network equalisation.

DC Share will obtain greater utilisation of substation assets through equalisation and load management. DC Share will use the latent capacity between adjacent substations with different load profiles (i.e. some with commercial profiles and some domestic profiles) to provide capacity for EV charging from the most appropriate location.

DC Share will facilitate the fast and flexible connection of high-power charging points for EVs and support future Low Carbon Technology (LCT) demands, and the network design makes use of the diversity of charging load to provide greater capacity than BaU equivalent solutions.

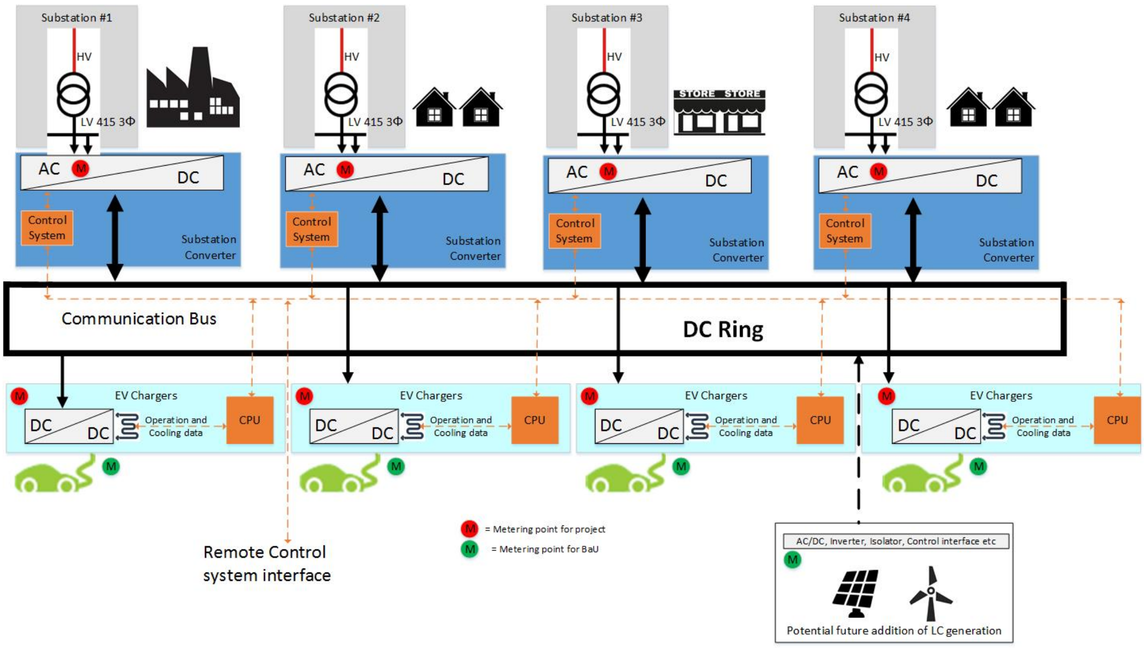

Figure 8. The DC Share solution

2.2. Technical description of project

DC Share will develop and trial a DC network to give a versatile and flexible solution for rapid EV charging using network equalisation.

The system comprises four principal components:

1. A monitoring and control system to operate the charging and equalisation system, prioritising charge speeds and equalising the local distribution network;
2. Bi-directional power electronic converters, with unique phase balance compensation, connected between the 415 V AC network and ±800 – 900 V DC distribution cable network;
3. A DC cable network with remote control sectionalising switches and connection hubs at strategic points; and
4. Rapid EV charging equipment comprising DC hubs with smart chargers to enable managed utilisation of each DC hub whilst the cars are connected.

Control System

The control system will autonomously determine the optimal point to draw demand from, provide support to heavily loaded transformers, and manage the charging load. Should the charging load approach the total available power capability of the converters and transformers then the chargers shall be instructed to reduce their load. The control system will also evaluate whether each converter is required at the time and consider entering components into a standby mode to reduce system losses.

The DC Share system will be designed to allow a degree of redundancy from both the hardware and the control system so that operation can continue, within rating limitations, when a single item is unavailable.

To establish these features, it will be necessary to have a control application in each substation that:

- Receives real time data on the available power capacity at the substation transformers;
- Exchanges data with the application in each of the other substations, and the associated EV Chargers; and
- Issues set points to the local converter and any load management instructions to the EV Chargers.

There are a number of possible monitoring and communications methodologies which would provide a robust and low-cost solution to allow real time data to be obtained, processed and actioned. This element will be delivered via a procurement exercise in the initial stage of the project.

Substation Hardware

Substation converters located at distribution substations and connected directly to the LV board will be deployed. They will provide bi-directional AC to DC conversion, with a rating of 250 kVA and a DC supply voltage of ±800 V. DC Share will demonstrate the solution with connections to four substations, but expansion of the system by including additional converters will not be precluded in the design. Bi-directional metering will be installed on the AC side of each substation converter, to allow energy settlement for the system.

The DC Network

A cable system will be installed between each converter to form a DC ring. The cable routing will run via the EV charging locations, and these will connect directly. DC Share will investigate the most appropriate cable technology for use, and the most suitable ratings and connection hardware. Suitable protection, fault isolation and network reconfiguration of the DC system will also be required, and this will be determined via examination of the requirements, existing available equipment, and the systems and switchgear used in other DC network applications, such as railways.

Rapid EV Chargers

New rapid EV chargers that are fed from the DC network of both 50 and 100 kW will be developed and their design will complement the converter design, such that they interface coherently. Consideration will be given to the ergonomics of the chargers, as members of the public will be using them, A charge point operator will be appointed to manage operation of these, ensuring that they are easy for trial participants to use and have high availability.

2.3. Description of design of trials

DC Share will install a demonstration network for a one-year trial in a location selected to maximise the technical, logistical and economic learning available.

Site Selection and engagement

We intend to work closely with a local authority, within the Western Power Distribution licence area, who is actively encouraging the uptake of EVs, so that a number of public users will be present. However, we cannot expect many people without their own charging point to buy an EV just because of the existence of the trial system proposed, so we would expect the general public user group for the trial to be those who have their own charging point but who will be attracted to use the trial points by the provision of free charging. As the success of the trial requires the EV chargers to be well utilised, we will prioritise an opportunity to charge a high utilisation fleet, such as taxis or urban delivery vehicles, as a second group of users.

Further site selection criteria will be fully developed during the initial stages of DC Share as the technical specifications are finalised, but will include:

- Charging demand, both public and high utilisation fleet;
- Mixed use property surrounding the location (commercial/industrial/residential);
- No network investment plans;
- Have local facilities in easy reach (food, drink, rest rooms);
- Safe parking location for cars and vans;
- Suitable space for the chargers either as a hub or adjacent to parking spaces; and
- Where installation would not be unduly disruptive.

Following identification of the broad geographic area, we will then review the electrical infrastructure available. Using information available to WPD, such as:

- Suitable load profiles and space at 4 substations within a reasonable distance to the charging locations;
- Customer numbers supplied from each secondary substation;
- Transformer and cable capacity;
- Maximum demand indications;
- Demand profile class and
- Network maps showing the network configuration and customer connections.

We will also perform site visits to understand local logistical issues, in terms of the geography and the electrical, transport and other appropriate infrastructure.

The converters are 250 kVA, we therefore will consider substations that have at least 250 kVA spare capacity during typical 24-hour demand profiles. Once we have identified a suitable trial area, we will undertake measurements on the substation feeders to get an accurate view of the substation utilisations.

The DNOs, Ricardo and Vectos engage regularly with local authorities during our normal business and a number that we have already engaged with have expressed an interest in being part of the trial. The support for the trial is demonstrated from the letters of support in Appendix 10.8. Once a suitable trial location has been determined we will work with the local authority to appoint a charge point provider and engage with fleet users and other EV users to ensure the trial, project timescales and the provision of rapid chargers is well publicised. An example of a typical area suitable for the DC Share solution is given in

Figure 9, where there is a mix of residential and commercial demand in close proximity with a number of locations suitable for rapid charging location.

DC Share will undertake stakeholder engagement through the Learning and Dissemination activities described in section 5.2. These will take place before, during and after the trial to capture user needs and requirements, how these may change and how EV uptake and rapid charger usage is likely to grow in the future. This will enable us to assist local authorities in gauging future demand for rapid charger provision and hence the associated network needs.

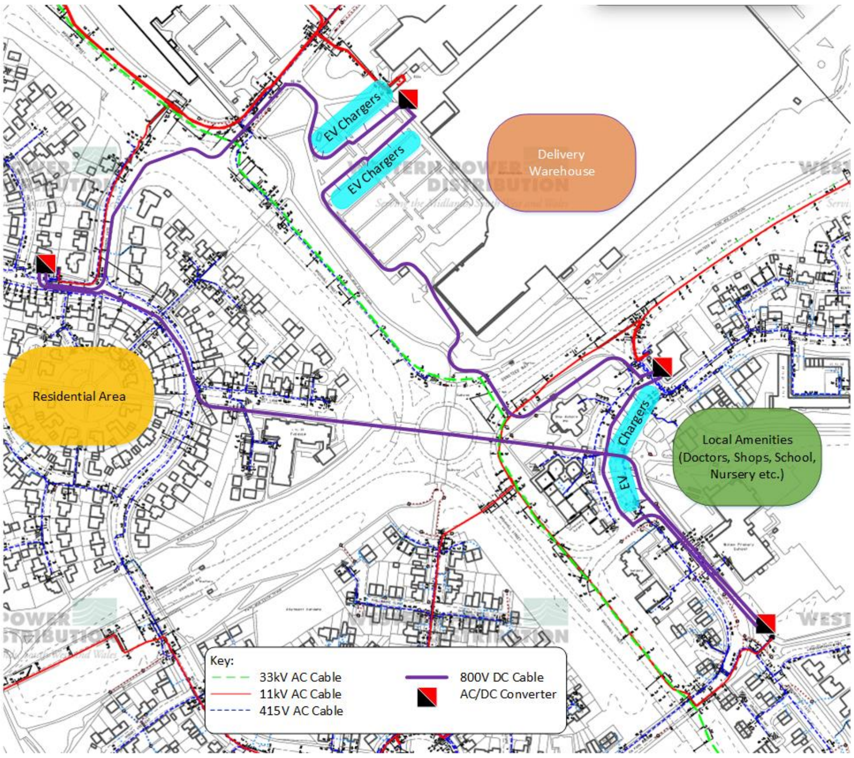

Figure 9. Illustrative Trial network layout

Trial Description

DC Share will install and operate one trial network, comprising:

- The control system and monitoring/communications equipment;
- Four 250 kVA substation converters providing 1 MVA of DC network capacity;
- A maximum of 10 x 50 kW and 5 x 100 kW DC fed rapid chargers, subject to user requirements and the site selected;
- DC cabling;
- Suitable switchgear and protection systems; and
- A suitable user interface at the charge points.

Having four substation connection points will allow the system to obtain capacity from a diverse number of sources, fully demonstrating the concept of an equalisation network.
This scale of trial was chosen on the basis that 1 MVA of charging infrastructure represents the significant level of demand anticipated for future needs. Addressing such a large new demand in a constrained urban network is likely to encompass significant technical and physical challenges. The trial will allow demonstration of the Method's ability to deliver a large-scale solution in a cost-effective manner.

The trial will be conducted over the course of one calendar year. The project will benefit from a long trial period to allow:

- A large volume of data to be collected, including from all four seasons;
- Updates and improvements to be made to the solution via the periodic review of performance data;
- Knowledge of the installation to spread ensuring high utilisation; and
- Users to gain familiarity with the system and use it in a routine way.

Learning to be Generated

DC Share will allow a detailed understanding of the solution to be evaluated. This will include collection and analysis of usage data to understand the current requirements for rapid charging and assess the effect of the provision of the chargers on users. We will set up an online platform to enable us to conduct focused surveys of the charge point users to provide qualitative data. It will be beneficial to understand, for example:

- Usage statistics such as level of charge at commencement, charge point occupancy rate, etc. which will inform diversity assumptions for future roll out;
- User profiles – what members of the public are benefitting?; how do we ensure equal access?;
- Journey types and range;
- Impact of reduced charging power; and
- User satisfaction and expectations on pricing.
- The key location considerations for charging hubs for future locations

The trial will also provide insight into the network effects of the system, such as the extent to which equalisation is possible, and the interactions between charging demand and equalisation. Investigation into the optimum ratio of chargers to substation converters will also be valuable to both the project and other stakeholders, to understand the degree of diversity in charging load possible amongst the two user groups, public and fleet. The trial will examine ways of managing the charging demand when network capacity is restricted and complete a customer survey to understand the key features, preferences for charging speed prioritisation and impact on the commercial model.

2.4. Changes since Initial Screening Process (ISP)

During the further development of the project completed since the ISP was submitted, the following changes have been identified:

1. A reduction in project costs of 6%, from £5.97m to £5.63m, based on the more detailed information available from partners and suppliers
2. A delay of the project end date from December 2022 until March 2023 to allow more time for the project findings to be analysed, interpreted and disseminated.

Section 3: Project business case

3.1. Summary of DC Share benefits

Section 2 described the significant impact that requirements for EV rapid charging is likely to have on the electricity distribution network in GB. Traditional methods of reinforcement are costly and disruptive, and traditional LV circuit arrangements and their operation are unable to react to dynamic changes in system requirements.

There are significant benefits to implementing power systems with more flexibility, enabling dynamic optimisation of use of existing assets, and providing capacity where it is needed. Once implemented, the DC Share solution will result in:

- **Significant financial, capacity, and carbon benefits associated with the EV charging network and optimisation over multiple substations** – These financial, capacity, and carbon benefits have been quantified through business case modelling, as described below:
    - **£162m** in direct financial benefits up to 2050 across GB, which will benefit the customer though network savings resulting in lower customer bills, and through enabling access to more infrastructure at a lower cost.
    - **1,800 MVA** capacity released up to 2050 across GB
    - **26,000 tCO_2e** of direct savings up to 2050 across GB
- **Substantial indirect carbon and environmental benefits through supporting the uptake of EVs and the connection of LCTs** – The availability of charging is a significant enabler of the uptake of EVs, and the release of capacity through real-time active management can enable the connection of LCTs at a lower cost. There are substantial environmental benefits, including **21 tCO2e** carbon savings through electrification of each passenger car and **67 tCO2e** through electrification of each taxi (based on average mileage and fuel/energy consumption figures). This reduction in carbon emissions will have substantial impact on air quality in the GB as the vehicle parc transfers, and DC share will facilitate this through provision of rapid charging facilities.
- **Minimise the impact of significant clusters of rapid charge points on the network** - As part of the DC Share solution, rapid charging points can be managed and optimised as part of the wider DC solution, taking advantage of flexibility in charging time and minimising the peak demand on the network.
- **Increased network flexibility** – The provision of flexible methods enables increasing uncertainty to be managed more effectively, optimising power flow in real time to react to changing network demands and providing real-time controllable support to the wider AC network.
- **Future-proofing of the network infrastructure and avoidance of stranded assets** – The solution can provide future-proofing through enabling the connection of future DC loads, generation and storage to established DC Share solutions. The topology of a DC Share solution can expand and adapt over time to meet the changing future needs of the customers. Under-utilised substations can be connected to the DC network, allowing them to provide additional capacity to the system and enabling avoidance of stranded assets.
- **Network control benefits** – Additional network control benefits using Power Electronics may be enabled through the solution, such as the ability to actively manage network voltage and power flows, which can offer customers improved quality of supply which can be maintained through changing network conditions.

- **Reduced Losses** - Charger losses are lower in DC Fed EV Charge points, by virtue of the simplified architecture of the devices. System losses are also lower in the DC Share case than in the "Soft Open Point" and "Solid State Transformer" cases, due to the reduction in conversions between AC and DC. Losses can also be minimised on the DC Share system, by actively managing power flows (when possible) to minimise current in the parts of the network most susceptible to losses, and by switching off converters when not required for use.

DC Share is well aligned to the Western Power Distribution, Electricity North West and overarching ENA innovation strategy, of facilitating change. DC Share will provide a coordinated approach to the deployment of EV charging points, whilst also using smart technologies to maximise capacity within the power system.

3.2 Cost Benefits model

The quantified financial, capacity, and carbon benefits included above and in the benefits tables in the appendices have been calculated using our DC Share business case cost benefit analysis model. The detailed methodology and underlying assumptions for this model is described in Appendix 10.2.

The model is based on the BaU implementation of the DC Share solution. When the solution is rolled out, the infrastructure configuration deployed will be tailored to each location, with the number of substations, number and specification of charge points, and topology of the DC network being tailored to the requirements of the site.

In order to develop the business case, it was necessary to assume a single 'representative' deployment topology, which is taken as the 'Method case'. In selecting the representative deployment, it was important to consider the likely future needs for rapid charging in urban locations. There is an established trend in vehicle and charger development in supporting steadily increasing rapid charging speeds, with likely adoption of charging capability up to 350 kW over the next decade. Therefore, the business case includes deployment of these technologies.

The business case model compares this Method case compared to a representative equivalent base case, selected from a number of counterfactual solutions, and analyses the solution over an individual, licensee (both Western Power Distribution and Electricity North West), and GB scale deployment to determine the cost, capacity and carbon benefits. The Method case, base case, and roll out assumptions are summarised below:

Method case definition – The method case topology builds on the trial topology, allowing for future higher capacity chargers (higher capacity 350 kW chargers are assumed after 2030), and is consistent with the predicted requirements for EV charge points into the future. The components include:

- A cluster of rapid chargers including a mix of 50 kW, 100 kW and 350 kW chargers totalling 2,250 kW
- 5 substation AC-DC converters located at substations within 300 metres of each other
- A DC network connecting each substation and the charge points in a ring
- Associated control and monitoring systems

This Method case solution has a capital cost of £xxxk, and an operational cost of £xxxk per year (mostly associated with system and charge point back office and maintenance). The power electronic components will have a shorter lifetime than traditional power system components and will therefore need replacing within the modelled timescales. The Method case is illustrated in Figure 20 in Appendix 10.2.

The business case model considers the following key capabilities of this Method case:

- **Supplying the rapid charge points** in four different locations
- **Releasing capacity in the connected substations (equalisation benefit)** beyond that required for the rapid charge points to further support surrounding AC connected load growth

Base Case Definition – The base case is the best assessment of the most economical solution with comparable capability in the absence of the DC Share solution. A detailed analysis was performed to compare potential base case topologies, including traditional and innovative approaches. This analysis and its results are described in Appendix 10.2.

The topology selected to represent the base case was the lowest cost out of the options identified. It included traditional reinforcement to supply to the rapid charger hub itself, and innovative solutions to help support load growth in the surrounding network. It consists of three new substations, supplying the 2250 kVA of additional load, and AC cables that supply the charge points. We have not assumed any wider HV reinforcement, however a 2 x 250m HV cable spur is included for two of the three additional substations. In cases where more significant reinforcement is required the financial benefits of the DC Share solution may be increased. This base case solution has a capital cost of £xxxk, and an operational cost of £xk per year (mostly associated with the charge points). As with the Method solution the charge points will have a shorter lifetime and will therefore need replacing within the modelled timescales. The base case is illustrated in Figure 21 in Appendix 10.2.

It is assumed that the innovative solutions being developed through other innovation projects and programmes, such as more informed rating, demand side response, and voltage control, would be able to be deployed to support much of the LV network load growth, significantly reducing the need for traditional reinforcement. The base case associated with the equalisation benefits of the DC Share solution assumed that three of the five substations can be supported through innovative technologies, with an associated cost of £xk per substation, and the remaining two require a relatively low-cost traditional reinforcement at a cost of £xxk. In the Method case, these costs are not completely mitigated, but are deferred for an average of 6 years.

Roll out assumptions –The expected number of rapid chargers required over GB up until 2050 has been assessed by the Ricardo Sustainable Transport team using the Government's 'Road to Zero' sales targets as a guide to forecast the total plug-in vehicle fleet. The results of this assessment are given in Figure 22 in Appendix 10.2.

It has been assumed that 40% to 50% of rapid chargers will be located in urban areas, and 60% of rapid chargers in urban areas will be associated with a DC Share solution, with the remainder being completed via traditional reinforcement or another innovative approach, as described in Appendix 10.2.1. These factors together with a reasonable initial roll out profile was used to determine the model roll out of DC Share solutions. The roll out profile assumptions are shown in Figure 23 in Appendix 10.2.

In order to determine the roll out profiles for Western Power Distribution and Electricity North West scale deployment, the urban populations served by each licensee was compared. This guided the process of predicting the split of deployed solutions between each licensee. This is illustrated in Figure 24 in Appendix 10.2.

Cost Benefits Model Results

The first step of the business case modelling included considering an individual deployment of the Method. This found that the cost benefits of a BaU deployment of the DC Share Method £134k. The business case model considers the BaU deployment installation in the year 2023 (the deployment of the first BAU case) and operation up to 2050. All costs are in 2019 value, using a discount factor of 3.5% for the first 30 years and 3% thereafter, and with NPV calculation from when the installation programme begins (2023).

Figure 10 and Table 2 below show the forecasted financial benefits of the DC Share Method up to 2050 over all of GB.

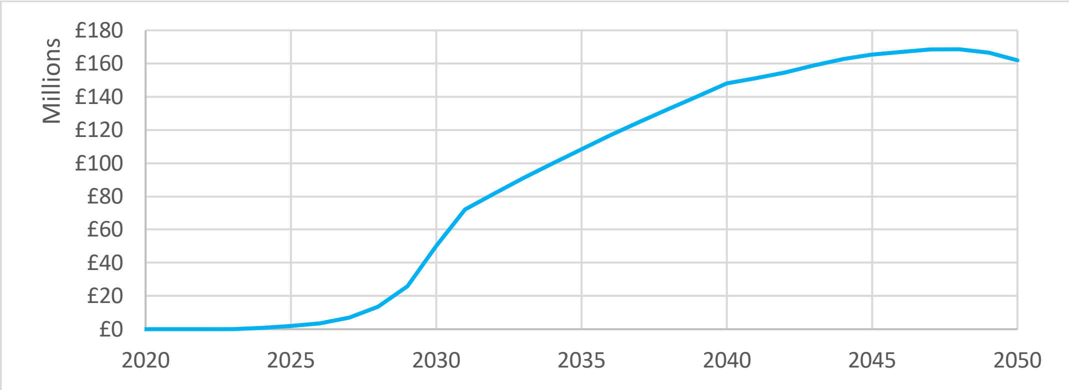

Figure 10. GB Scale deployment benefits (£m)

	Base Costs (£m)	Method Costs (£m)	NPV (£m)
2030	251	201	50
2040	758	610	148
2050	943	781	162

Table 2. NPV of DC Share solution (£m)

The shape of the benefits profile features a small dip towards the end of the model period up to 2050. This is due to the need to replace the power electronic equipment at the end of the asset lifetime; this requirement is higher in the method case, as there is more power electronics being deployed compared to the base case. The assumptions around this replacement are conservative, as it could be assumed that in the future power electronics may be built to be more robust, and the replacement costs may reduce.

The total customer funding required to implement the DC Share solution into BaU includes the project cost funding request of £4,716m, and any additional funding required to fully integrate the IT systems and processes, which is estimated at £500k.

DC Share will produce benefits that breakeven with customer funding in 2027, as shown in Figure 11.

3.3 Capacity Benefits

The capacity released by the DC Share Method is derived through two main sources:

- Optimisation of charge point and DC system operation taking advantage of flexibility in charging time and minimising the peak demand on the network. This enables the release of 1,100 kVA per solution deployed.

- Additional capacity released through equalisation, beyond that required for the rapid charge points, to further support surrounding AC connected load growth. This enables the release of 110 kVA per solution deployed for the first 6 years of its lifetime (as this reinforcement is deferred rather than mitigated).

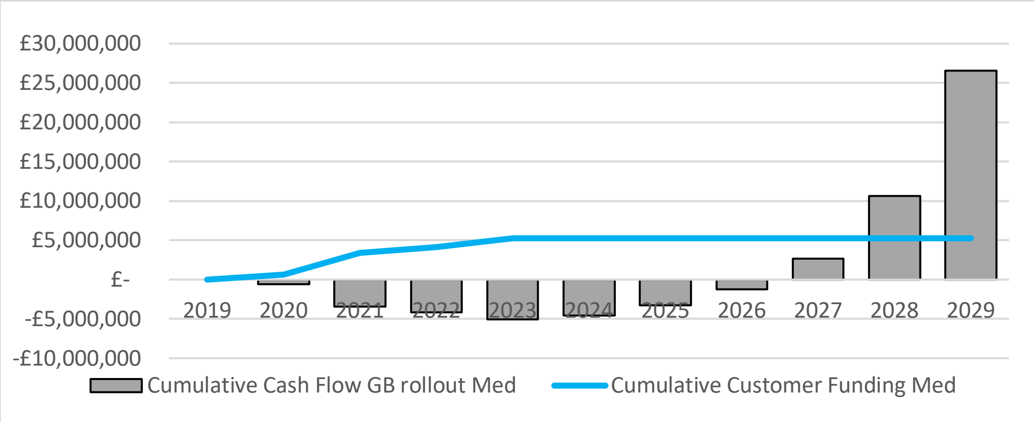

Figure 11. Breakeven analysis of the DC Share solution compared to customer funding.

The capacity release figures were determined through modelling of the solution. Table 3 below shows the forecasted capacity benefits of the DC Share Method up to 2050 over all of GB.

Year	Capacity released (MVA)
2030	466
2040	1,501
2050	1,789

Table 3. Capacity Release by the DC Share BaU deployment over GB (MVA)

The capacity released by each deployment is assumed to be the same, 1.2 MVA, hence the differences in the scenarios is as a result of the roll out assumptions.

3.4 Environmental Benefits

The environmental impact of the DC Share solution is considered in two ways:

- **Direct Carbon Benefit Model** – The direct carbon benefit model compares the carbon cost of the DC Share Method with the base case. This includes the direct carbon costs of the production and installation of equipment.
- **Indirect Environmental Benefits** considering the wider impact of the solution.

Direct Benefits

The direct carbon benefits of DC Share are driven by the creation of capacity for a lower carbon cost than the base case.

To quantify the carbon benefits in our model, we have researched the carbon emissions associated with the manufacture of the materials required in both Method and base solutions. The results of our calculations are that the as installed carbon impact of the substation convertors is 0.41 tCO2eq, and for each secondary transformer it is 6.1 tCO2eq. On this basis the direct carbon benefits for each deployment is 16 tCO2eq (based on the base case of three substations, and the method case of five converters). At GB scale using the assumed roll out the direct carbon benefits are shown in Table 4.

Year	Direct carbon benefits (tCO2e)
2030	6,208
2040	21,100
2050	25,957

Table 4. Capacity Release by the DC Share BaU deployment over GB (MVA)

Indirect Benefits

A key objective of DC Share is to enable the adoption of LCTs and low carbon behaviours, which combined has the potential to greatly reduce carbon emissions for the GB.

The future energy scenarios (FES) identified by National Grid give a view on the carbon benefits of the adoption of such technologies, based on the four energy scenarios. Figure 12 shows the total carbon emissions for the GB in the Two Degrees scenario.

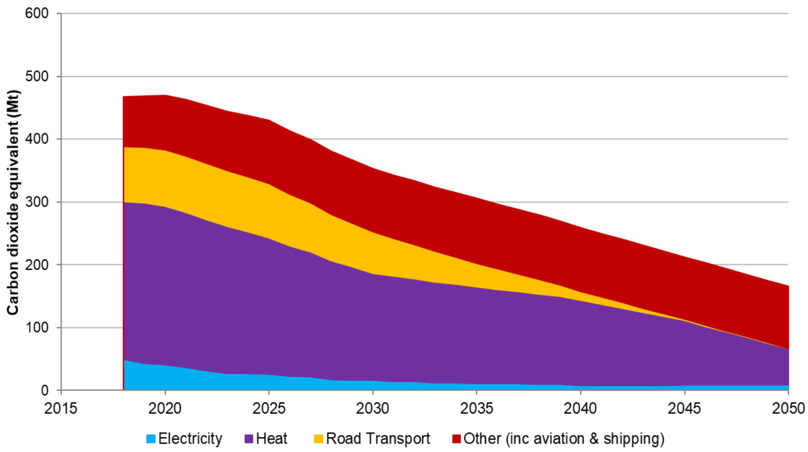

Figure 12. Carbon emissions in the Two Degrees scenario (NG FES 2018)

DC Share supports and enables these carbon savings, by enabling the adoption of LCTs and behaviours. Without these or similar tools, the uptake of such technologies may be restricted, for example by restricting affordable connections.

Table 5 compares the lifetime carbon emissions from combustion engine and electric vehicles. This illustrates the carbon benefits of the electrification of domestic passenger cars and taxis:

	Domestic Passenger Car	Taxi
Combustion engine vehicle	27574	83,781
Electric vehicle	6687	16,897
Benefit	20,888	66,884

Table 5. Lifetime CO2 emissions from vehicles (g CO2)

The provision of convenient rapid charging facilities is a key enabler to encouraging the uptake of EVs and unlocking the carbon benefits shown in Figure 12 and improving air quality in urban and suburban locations that the Method is designed for.

Section 4: Benefits, timeliness, and partners

(a) Accelerates the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing Customers

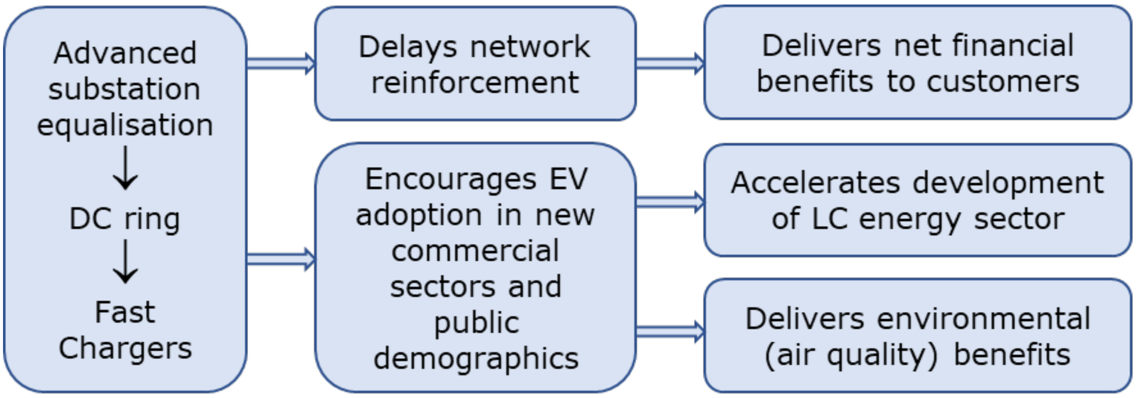

Figure 13 Overview of benefits

Many cities are actively responding to the need to de-carbonise ahead of the 2050 targets, in which zero carbon transport will be a key objective. For example, in June 2019 Greater Manchester launched the UK's first city-region Clean Growth Mission to achieve carbon neutral living by 2038[4] and Lancaster has declared a "climate emergency" after city councillors voted unanimously to work towards creating a zero-carbon district by 2030[5].

The adoption of EVs is an important part of this decarbonisation journey and is especially valuable in areas of poor local air quality. There is notable support for the adoption of EVs from many local councils. For example, Milton Keynes Council are actively encouraging EVs, Coventry launched a "Go Electric" taxi scheme in 2018 and Birmingham City Council are introducing a clean air zone from 2020 which whilst not excluding modern Internal Combustion Engines (ICE) will encourage EVs.

The facilitation of EV rapid charging in urban areas is an important part of the GB EV adoption pathway. We anticipate this charging solution being necessary for taxis, commercial vehicles and car clubs wherein low vehicle down time is key to the mobility business solutions, and for private vehicle owners who are visiting the local area, and who do not have charging facilities at home or else who need a mid-journey top up. The Net Zero Technical Report by the Committee on Climate Change proposed targets to stop sale of non-zero emission cars by 2035, which will be hard to meet without a substantial number of rapid chargers for private and commercial users.

A significant barrier to the roll out of rapid chargers, particularly in urban areas, is the lack of existing network capacity at the scales required, and the potential cost and timescales in providing that capacity when required. In order to support the economic roll out of rapid chargers in urban areas, there is a need for smarter solutions which can use existing spare capacity in the network to reduce rapid charger deployment costs and timescales.

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[4] Greater Manchester's plans for carbon neutral living
[5] Lancaster declares climate emergency

The DC Share approach solves this issue by reducing the amount of traditional AC reinforcement required to install rapid chargers by releasing unused capacity for EV rapid charging. This reduces costs to customers by making more effective use of existing assets and deferring capital expenditure on substation capacity enhancement.

The benefits of this project are associated with meeting the GB decarbonisation targets by encouraging the uptake of EVs, the cost savings in network reinforcement costs that would otherwise be passed on to the customer, and benefits associated with improved air quality. These benefits include:

- **Provision of rapid EV charging hubs** in urban areas which are electrically and physically constrained by optimising the use of existing network capacity. The DC Share solution has greater reach than an LV AC solution, allowing it to support rapid chargers and optimise power flows over a larger area. Locating rapid chargers in popular areas should encourage the use of EVs in town centres, assist with the electrification of taxis and commercial vehicles and give all EV users confidence in their ability to charge.
- **Equalisation benefits to the AC network** which can support AC load growth, including the uptake of LCTs like EVs and heat pumps, with reduced requirement for traditional network reinforcement. This is enabled by drawing power from those substations with the most headroom, and injecting power to those requiring support. The amount of accessible capacity will be dependent on the specifics of the trial but could be in the order of 110 kVA.
- **The capability to connect LCTs** directly to the DC equalisation network, enabling the connection and management of EV charging infrastructure, as well as battery storage and low carbon generation such as solar panels. Incorporating this technology into the managed equalisation network allows it to be monitored and **optimised to minimise the impact on, or even provide benefits to, the wider AC network** to which it is connected.
- **Preparing the network infrastructure for the future** to allow for the changing needs of the customers and society, as it is modular and adaptable, enabling the network solution to be developed over time as rapid charger deployment and size increases. For example, additional DC cable routes could be added in order to support the connection of EV charge points and LCT optimisation over a larger area. There is an expectation that in the future very high > 350 kW capacity chargers may be required, especially for commercial vehicles, and in urban areas where there are a number of existing substations in close proximity the solution proposed here can be adapted to accommodate this extra power requirement.

  Additionally more substations can be incorporated, allowing maximum benefit from the existing infrastructure, and avoiding stranded assets.
- **Carbon saving and improved air quality** in central urban areas due to encouragement of consumers switching from ICE cars to EV. Local authorities and electricity customers will benefit from the improvements in air quality that results from the reduction in ICE vehicle and the uptake of EV.

(b) Provides value for money to electricity distribution/transmission Customers

This project was originated by Ricardo responding to an ENA NIC third party call. Western Power Distribution will be the Funding Licensee and Electricity North West will collaborate on this project. Ricardo will take the lead in delivering the project and have the relevant experience. We have put together an experienced team of project partners to ensure the success of the project. All our partners have previous experience of working on innovation projects in GB and/or Europe and understand the balance of effort required to manage and ensure a successful project whilst involving stakeholders and informing third parties about the findings. Project partners Ricardo and Vectos are demonstrating their commitment to providing value for money by providing a 10% discount on their normal professional rates. Project partner Turbo Power Systems is demonstrating their commitment to providing value for money by providing a 20% discount on their normal professional rates.

To ensure the cost of the project is well founded and delivered competitively the resource requirements have been calculated using a bottom up approach based on the project plan. Detailed subtasks and the associated effort have been derived from inputs for the project partner experts.

We will use a competitive procurement process to select suppliers for the control and communication system, the cable and the associated protection and isolation equipment during the project. To minimise installation cost we intend to use contractors who are familiar with Western Power Distribution's base requirements, and work with them to accommodate the necessary new policies and procedures for the DC equipment installation.

The project costs for each Task as a percentage of the total are summarised in Figure 14 with the person costs for each stage by partner (FTEs) in days in Table 6.

Other significant costs are the cost and installation of the converter, cable, control system and other ancillary equipment as well as the charger equipment. The cable material and installation cost will be dependent on the distance between the substations identified for the trial. As discussed further in (e) below, we have also made an allowance for the cost of electricity for the rapid chargers during the trial. These costs are summarised in Table 7.

Figure 15 illustrates the split of person cost by partner and task before partner and DNO contributions are taken off.

Whilst we have made every effort to forecast accurately the expected activities and equipment we have allowed a contingency of 10% throughout for unforeseen events.

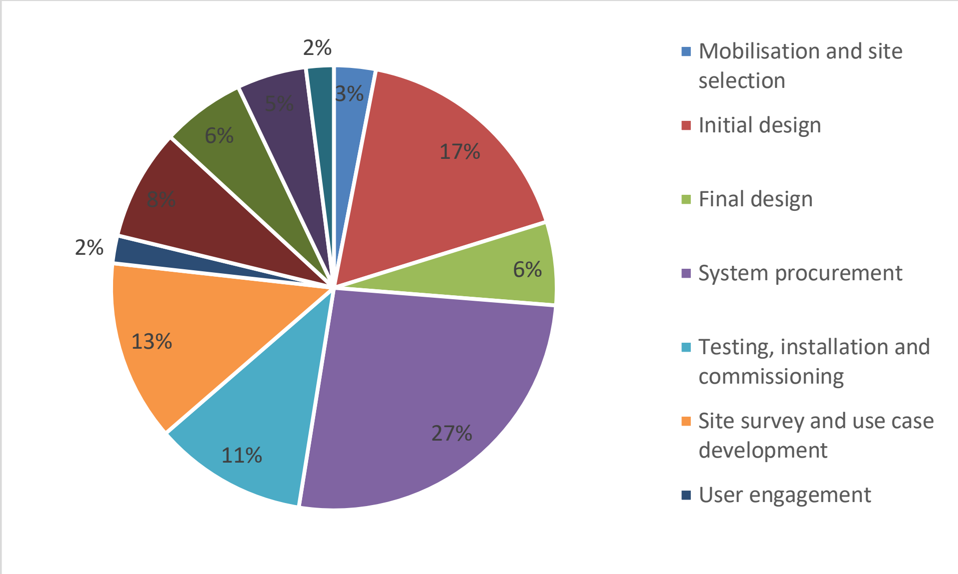

Figure 14. Summary of project costs breakdown by task

	person cost £k	number of days	cost / day £
Mobilisation and site selection			
Initial design			
Final design			
System procurement			
Testing, installation and commissioning			
Site survey and use case development			
User engagement			
Trial phases 1 and 2			
Trial phases 3 and 4			
BaU analysis			
Annual reports and closedown report			
Total			

Table 6 Summary of project tasks by cost and person

	Equipment cost £k	Allowance for Electricity cost £k
System procurement		
System installation and commissioning		
Trial operation phases 1 and 2		
Trial operation phases 3 and 4		

Table 7 Summary of other significant costs

Figure 15 Chart of split of person cost by partner and task (before contribution)

(d) Is innovative (i.e. not business as usual) and has an unproven business case where the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness

The increasing power demands in constrained urban areas mean the conventional AC reinforcement solution is not necessarily the most cost effective. For power demand greater than 1000 kVA (a secondary transformer) the business case has determined that the use of a DC network equalisation system is cost beneficial. This solution has not been demonstrated and as the converter device is new and as yet untested NIC funding is required to prove the technical and commercial viability.

While there are many network innovation techniques and technologies being trialled which support load growth due to EVs and other LCTs, the supply of rapid EV charger hubs requires the provision of a significant amount of network capacity in a single area of the network. This issue has not been addressed by innovation projects to date.

The most significant innovation is the concept of the DC ring equalisation network with multiple LCT connection points. In the project these will be EV charging points but could include PV and/or storage technologies in the future.

Equalisation across AC networks has been explored in UK Power Networks NIC project "Active Response for Distribution Network Constraints", and was previously demonstrated in Flexible Urban Networks LV, where the existing network capacity is maximised using power electronics to control flows, and in Western Power Distribution's Equilibrium project, which considered controlled sharing of power at 33 kV. The DC Share solution extends these concepts to a DC network such that optimisation is available over a wider area, and the connection of DC loads and other DER is facilitated and managed. The system components are anticipated to be autonomously controlled and self-configuring to optimise for network demands, assist with constraint management and minimise losses.

The Solid-State Transformer (SST) and AC equalisation network proposed by Scottish Power Energy Networks in the LV Engine NIC project builds on the FUN-LV project learning to demonstrate the benefits of AC equalisation using SSTs and intends to have a radial DC customer connected to the SST. DC Share expands on this idea by demonstrating the benefits of a DC ring equalisation network.

(e) Involvement of other partners and external funding

Ricardo is the project lead and will have responsibility for co-ordinating the project. Western Power Distribution will be responsible for cable procurement and equipment installation. Turbo Power Systems will be responsible for the converter and charger equipment specification and design and Ricardo will contract suppliers for the other necessary equipment such as the overall control system, communication system and ancillary equipment using competitive tendering processes during the project.

Ricardo will also be responsible trial site selection; trial design and management; technical analysis; development of BaU recommendations; dissemination of learning and results and production of progress and project reports. They will be supported throughout by Western Power Distribution and Electricity North West.

Vectos will provide oversight of the charger aesthetic design and work with the local authority to obtain necessary permissions, such as planning for the siting of the chargers.

Western Power Distribution and Electricity North West will contribute 10% as the licensees, Turbo Power Systems have agreed to a 20% contribution on engineering labour and Ricardo and Vectos project partners have agreed to a 10% contribution on manhour cost.

The total project cost is estimated to be £5.63 million. Allowing for the DNO contribution of 10 % the cost for NIC funding is £4.76 million, the breakdown of which is shown in Table 8.

The project trial will offer fifteen rapid charge points for use by public charging customers and/or commercial customers. We intend to work closely with a local authority to inform the site selection process, so that a good volume of public users is present. To enable demonstration of the equalisation solution it will be important to encourage cars to charge and may be necessary to offer free charging within the project trial. Hence, we have allowed for the cost of the provision of electricity to charge cars at fifteen charge points. The actual offering will depend on the choice of trial area, the charge point provider, any existing incumbent in respect of EV charging offering and the existing local EV charging point model.

Whilst this is an innovative solution, it is likely that other OEMs will follow rapidly if the solution is successful, developing their own equivalent solution. Hence the project partners will have a limited opportunity to gain a commercial advantage, through first mover position.

Tasks	NIC funding requirement £k
Mobilisation and site selection	179
Initial design	855
Final design	232
System procurement	1,485
Testing, installation and commissioning	602
Site survey and use case development	162
User engagement	110
Trial phases 1 and 2	439
Trial phases 3 and 4	320
BaU analysis	261
Annual reports and closedown report	114
Total	4,759

Table 8. Summary of NIC funding requirement by task

(f) Relevance and timing

Uptake of Ultra Low Emission Vehicles

The UK Government's Road to Zero strategy has set a clear commitment to transitioning almost all road transport to zero emissions by 2050, stopping sales of ICE cars and vans by 2040. Since then, the Government has accepted the recommendations of the Committee on Climate Change (CCC) to set even more ambitious targets for Net Zero emissions in the UK by 2050, requiring a full decarbonisation of cars, vans and HGVs by 2050 and stopping the sale of ICE vehicles as early as 2030. Meeting these ambitious targets will require an incredibly fast increase in the uptake of EVs in GB.

The most rapid increases in uptake are likely to be seen across urban fleets and users, such as taxi fleets, car clubs, delivery fleets and other company and commercial vehicles. This is driven, in part by the deployment of Clean Air Zones and Zero Emission Zones, as well licensing and policy changes by cities and local authorities. Nottingham and other cities have already introduced a requirement to transition to zero emission taxis while Oxford is introducing Britain's first zero emission zone.

To support this rapid uptake, a substantial development of the charging infrastructure system will be required.

Required charging infrastructure

At present, plug-in vehicle uptake makes up around 2% of all new vehicles, with a total number of EVs around 200,000. Even so provision of charging infrastructure, especially rapid charging, is seen as a significant challenge due to the costs associated with securing grid connections and upgrades, as well as limitations on deploying infrastructure in urban areas where charging demand is likely to be highest and spare grid capacity is hardest to find. Our estimates suggest that there could be a need for over 80,000 rapid charging points in Britain, many of which will need to be located in urban areas.

With increasing demand from fleets in urban areas and users with no off-street parking or access to charging at work, access to rapid chargers in urban areas is key to enabling the uptake of EVs. Rapid charge points will have a particular appeal when combined with the option for short-term parking in city centres.

Fleets like Uber are aiming to electrify all of their 40,000 vehicles in London by 2025, with 20,000 on the road by 2021[6]. Many other taxi, car club and urban delivery fleets are following a similar trend. These vehicles will require a considerable amount of rapid charging infrastructure to facilitate high utilisation daily operations.

Development of rapid charging hubs in urban areas is a key enabler to electrification of transport. The recently released London EV infrastructure delivery plan[7] has already committed to the development of such charging hubs across London. Milton Keynes[8] already has its first charging hub and another has been recently completed in Newcastle[9]. More cities will follow this approach in coming years. These hubs will need to be located in convenient areas that can be easily accessed by commercial fleets and public users and will have high power requirements in areas where power availability is likely to be limited and grid upgrade costs could be prohibitively high. Therefore, a solution like DC Share is necessary to enable a cost effective deployment and grid connection of such hubs.

Why now?

The uptake of EVs and deployment of charging infrastructure are closely linked. Increasingly, evidence shows that users want to see a developed charging network before committing to EVs[10]. Development of infrastructure takes time and must lead ahead of EV deployment. If the intention is for EVs to make up close to 100% of all vehicles sold by 2030, then development of infrastructure must increase immediately and challenges around limited grid capacity and cost of reinforcement must be addressed as soon as possible to avoid becoming a barrier.

It is therefore critical that the DC Share solution is developed and tested now. If successfully demonstrated, the solution can be used as BaU to enable deployment of rapid charging hubs in urban areas so that EV uptake is not inhibited.

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[6] https://www.uber.com/en-GB/newsroom/uber-helps-london-go-electric/
[7] http://lruc.content.tfl.gov.uk/london-electric-vehicle-infrastructure-taskforce-delivery-plan.pdf
[8] https://www.zap-map.com/milton-keynes-rapid-charging-hub-officially-opened/
[9] https://www.ncl.ac.uk/press/articles/archive/2018/04/4mrapidchargingstations/
[10] https://trl.co.uk/reports/cvei-d52-consumer-uptake-trial-report

Section 5: Knowledge dissemination

The project partners will conform to the default NIC IPR arrangements.

5.1 General

DC Share will provide learning to enable the widespread deployment of rapid EV charging in urban locations.

All parties involved in the planning and delivery of DC Share are committed to maximising learning from the project and to the accurate and thorough dissemination of learning to any interested party. Interested parties will primarily include other Network Licences, technology developers (specifically relating to power electronics and control systems), vehicle manufacturers, local authorities, property developers and end users of the charging points including the general public and commercial operators.

In the BaU case, the general public user group will include a wider demographic than the current demographic of EV owners, who would typically have their own parking space with charging point.

The commercial operator's user group will comprise urban services that need minimum down time between trips such as taxi operators and local couriers. In the future it is conceivable to extend the commercial operator sector to include those that would desire very high charge rates (350 kW), this being based on ability to upscale the DC ring vs demand profile of potential users. By appealing to these demographic and commercial sectors, we would hope to encourage wider adoption of EVs, particularly in urban areas where air quality is of interest and with distribution network constraints. We also expect that the project will be of interest to parties with low carbon generation, storage and heat pump technologies who could potentially benefit from DC connection.

By partnering with Electricity North West we ensure that from the start we develop a solution that can apply to more than one DNO. During the course of the project we will actively engage with other DNOs, particularly regarding site selection. We believe that suitable sites will be found in many urban areas in the GB, making this learning especially valuable to the GB roll out of a low carbon energy sector.

5.2 Incremental Learning Expected

The key use case that this project addresses – supporting the connection of rapid EV charging infrastructure and other LCT in built-up and constrained areas – is one that is relevant all over the GB in towns and cities of all sizes. The project will create knowledge about the technical requirements and commercial viability of DC equalisation networks supplying rapid EV charging in urban areas. This learning will be applicable to many locations with short-term parking, particularly areas with clean air and EV uptake ambitions.

In urban areas where land for new substations is difficult to obtain, the ability to maximise the use of capacity in the existing secondary transformers and potentially help specific 11kV networks by providing equalisation will be of value across the GB. This learning will also be transferable to new property developments in urban areas which require fast charging provision.

The project builds upon learning from previous NIC projects including Flexible Urban Networks LV, Smart Street, My Electric Avenue, Active Response, Celsius and others as shown in Figure 16.

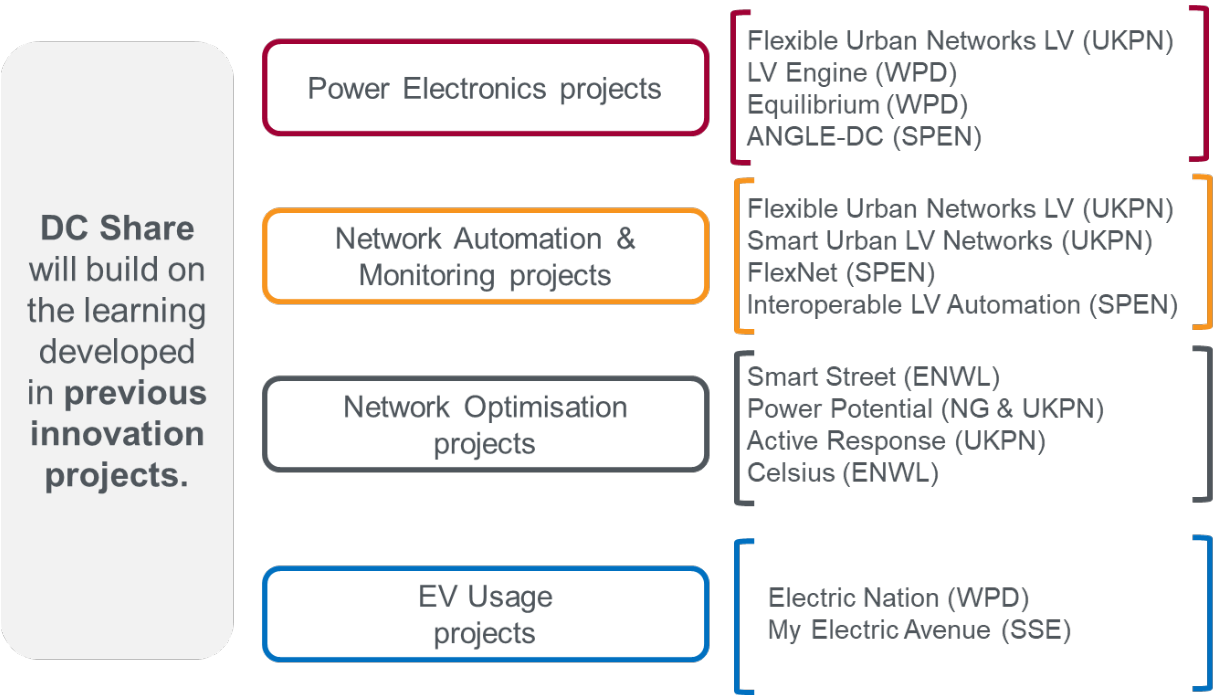


Figure 16. Relevant projects

We will undertake extensive stakeholder engagement before and during the trial to capture user needs and requirements, how these may have changed during the trial and how EV uptake and EV rapid charger usage is likely to scale up in the future. This will enable us to assist local authorities in gauging future demand for scaling up rapid charger provision and the associated network needs.

The learning that DC Share is expected to generate is wide-ranging with several potential beneficiaries, all leading to ultimate **environmental** and **economic** benefits in line with the goals of the NIC and the environmental targets of UK government.

Learning categories

We can break down the learning into three categories:

- Equalisation at the substations and the DC ring
- DC Charging points
- Adoption and user satisfaction

Equalisation will be applied to four substations connected to a **DC ring**

- **Learning** is expected to be generated in the topics of;
  - Effectiveness of equalisation between the substations which will aid planning to defer reinforcement;
  - Effects of the extra demand on the LV capacity available to customers.
  - Reliability and losses in the interface converters.;
  - Effects on HV and LV network voltage.;

    - Losses in the DC ring and impact of the choice of cable;
    - Installation techniques;
    - Operation and management of a DC network;
    - Equipment specification;
    - Control system effectiveness and functionality;
    - Exploration of possible BaU interface with DNO network level control systems.
- Potential learning that modelling could lead to may include;
    - Effects of the local addition of LC generation and/or storage devices/V2G.
    - Expansion of the ring to more than four substations;
    - Equalisation at HV network level.

DC Charging will be provided at approximately fifteen charging points with a variety of charging capacities.

- **Learning** is expected to be generated in the topics of;
    - Location of charging points vs their usage;
    - Reliability of and losses within the chargers;
    - Equipment specification and installation;
    - DC switching and metering.

At the time of writing BSI have a draft standard for DC metering. It is expected that a real-world demand for the use of this standard would result from DC Share, hence hastening the finalisation of the standard and the ability to develop a meter. Until that point in time AC settlement will be performed at the substation.

Adoption of the charging points by general public and commercial EV users. The project will undertake collection and analysis of usage data to understand the current requirements for rapid charging and assess the effect of the provision of the chargers on users.

- **Learning** is expected to be generated in the topics of;
    - Usage of the various capacity charging points in different locations: Locations convenient to the users, not necessarily convenient to the distribution network;
    - Effectiveness of the equalisation and charging systems working together.
    - Most appropriate communication system for system control;
    - The potential for managed rapid charging i.e. how best to manage reductions in charging power available, when capacity is limited;
    - Journey types, distance and frequency of users;
    - How to ensure access is available to all types of user;
    - Demographics of commercial and general public users will help drive marketing for further adoption;
    - What private and commercial users of the chargers would be prepared to pay. Potential business models other than the obvious pence per kW/h model. For example, a taxi company may have the electricity cost beneficially bundled into their licence cost, encouraging EV use instead of ICE;
    - Satisfaction of users. Will they "*recommend to a friend*"?

Learning beneficiaries

- **Beneficiaries** of the DC Share learning will include:
    - **DNOs** will learn if distribution on DC is viable in terms of engineering and economics. They will gain an appreciation of efficiency, effectiveness,

reliability and losses in the equalisation conversion process. They will gain extra knowledge to aid in the medium-term planning of reinforcement.

- **Power electronics and associated control system developers** will have increased knowledge of the use and demand for interface conversion and control. Potentially this could include incorporating equalised substations into the grid control system.
- **EV Charge suppliers** will learn more about demand for DC charging by different user groups, influencing their planning of charging locations.
- **General public EV users *and potential EV users*** that are currently nervous regarding charging when considering EVs will be able to more seriously consider the purchase of EVs. These potential users are likely to live in suburban locations (those in city centres are less likely to own or want a car) but will not have their own dedicated parking space onto which they could install a low capacity AC charger.
- **Commercial EV users and *potential EV users*** that either don't have a central depot for charging their vehicles or need to charge their vehicles between depot returns and thus are currently discouraged from EV uptake. Such operators could re-consider their strategy regarding choice of EV vs ICE based on the wider presence of fast charging points.
- **Local Authorities** will learn about demand for fast charger stations in urban environments, thus aiding planning to meet environmental targets.
- **Property Developers** will benefit when furnishing residential sites and business parks with EV charging, removing the immediate need for new substations, reducing infrastructure costs and freeing up land for other uses.
- **EV Manufacturers** will gain more knowledge about the demand for DC (vs AC) charging of future vehicles. They will have extra evidence to be able to market their vehicles to different commercial and private user demographics and will have data regarding specific town locations.

5.3 Learning Dissemination

Dissemination of project learning can include several methods and approaches:

- Wide availability of project information and documentation via Learning Portals, possibly including interactive activities such as forums, Twitter tags etc;
- Events and conferences including project-specific events and Low Carbon Networks and Innovation Conference;
- Publicising project activities and benefits; and
- One-to-one and ad-hoc dissemination.

Availability of Project Information and Documentation

This will be achieved through the establishment and maintenance of a project website. The website will provide a range of information, including:

- Project information including aims, completed and planned activities, timescales, and governance.
- Technology and solution information aimed at varying audiences, for example tailored to the general public, to DNOs, power electronics and EV manufacturers.
- A description of key benefits and findings.
- Access to project documentation, including regular progress reports.

Events and Conferences

Industry and academic events and tradeshows are a good opportunity to disseminate learning. Project presentations are an effective way to engage attendees in the project and its findings, and such events can be used as an opportunity for face to face discussions with potential stakeholder groups. There is also opportunity for the presentations at these events to be video recorded and/or streamed, and for the footage to be disseminated and promoted on websites and social media feeds.

Project-Specific Events

Project specific dissemination events such as seminars, webinars, discussion groups, interactive workshops and possibly even small mobile exhibition(s) will be organised throughout the project. We would expect such events to be tailored and aimed at the specific stakeholder groups discussed previously.

We have developed a dissemination plan that includes conferences, web and social media and targeted dissemination techniques (for example to DNOs and commercial vehicle operators). The Dissemination Plan is given in Appendix 10.5.

One-to-one and Ad-hoc Dissemination

As project learning is built up and the learning is disseminated, it will become clearer how each potential key stakeholder will be able to use the information. The detailed discussion and support from the project team may help such stakeholders in developing this picture.

To facilitate this level of dissemination, the project will offer one-to-one sessions where the project learning can be discussed, focussing on the relevance to the given stakeholder. It is envisaged that this will be most useful for the DNOs and technology developers, and the offer of these sessions will be actively promoted to them.

One-to-one and Ad-hoc Dissemination to the general public may be possible though online forums that will be linked through the various dissemination platforms.

Publicising Project Activities and Benefits

There should be a particular effort to publicise key project messages, such as project aims and benefits, to a wider audience beyond those who will attend industry and academic events. This audience includes:

- Customers, who will be informed of the innovation activities carried out within the industry, as they are the parties who are funding the work and who should benefit from the outcomes.
- Stakeholders in other industries or fields, who may be interested in the learning which is relevant across sector boundaries or may be able to contribute to the learning with developments from other industries and their applications in power.
- Other stakeholders who may not otherwise be aware of the project and who would be interested in learning more, and hopefully in contributing to online discussion groups. These could, for example, include suppliers/customers of LC generation/storage technologies and would hopefully bring in international participants – a great benefit of placing heavy emphasis on dissemination via social media.

5.4. IPR

We intend that a declaration of background IP is made in the consortium agreement to clearly define what each partner brings to the projects as already established IP in line with the default IPR arrangements. The project partners will conform to the default NIC IPR arrangements for foreground IPR.

Section 6: Project Readiness

6.1 Introduction

Ricardo Energy & Environment ("Ricardo") have developed a robust plan to ensure that the DC Share project starts, continues, and delivers benefits successfully; delivering best possible value to electricity customers and for the general benefit of a low carbon GB energy sector.

Ricardo have planned, proposed and will deliver this innovation project according to our Project Management Process, a process which fully meets the requirements of ISO9001 and ISO14001, many of the principles of PRINCE2 and meets standard UK Government project management QA methodology requirements.

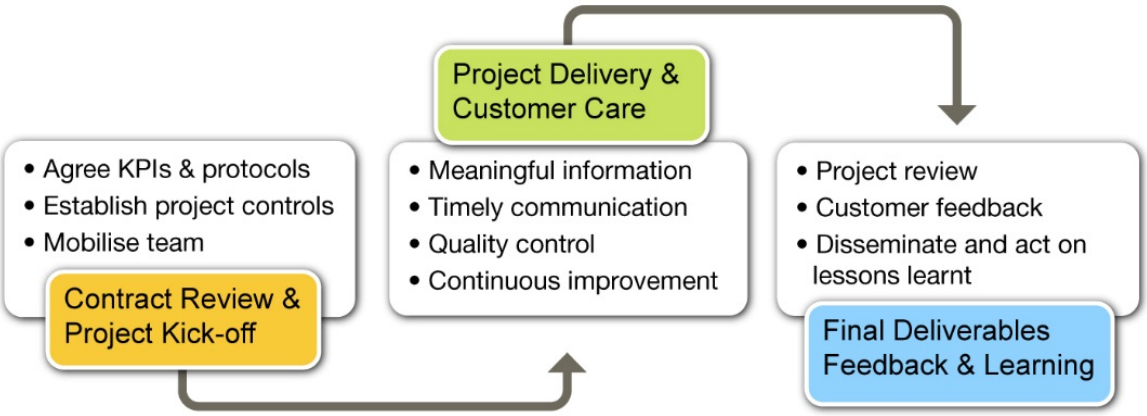


Figure 17 Project management process

Given that NIC projects are funded directly by electricity customers, it is especially important that their money is controlled and spent properly with a comprehensive audit trail. To ensure an efficiently delivered project, we will have produced the documents, plans, project governance and relationships to ensure that the project is ready to go from day-one. In particular we appreciate that project contingency will only be allowable in exceptional circumstances and certainly will not be drawn to compensate for poor project management.

6.2 DC Share can start in a timely manner

We are confident that DC Share can begin in January 2020. Our confidence is demonstrated through significant experience with previous NIC projects and specifically for DC Share:

- The project will be managed and led by Ricardo who have assembled a suitable team of experts and confirmed their availability and back-ups should they become unavailable. A clear project management and governance structure has been identified, and is detailed below.
- Our key technology partner, Turbo Power Systems, is engaged and has provided detailed specification, pricing and planning for the power electronics developments required for the converters (which are key to the equalisation network) and fast chargers.
- Detailed discussions and agreements are in progress regarding the boundary of responsibility between partners. An example would be the process of installation of

chargers: Western Power Distribution will appoint a contractor to physically install the chargers (mounting on plinths etc) and to connect the DC Ring. TPS will then supervise the commissioning of the chargers. Similarly, in the substations, Western Power Distribution will physically install the converters and connect the DC ring and LV tails, whereupon TPS will supervise their commissioning.

- We have begun discussions with several local authorities including Milton Keynes, Coventry and Somerset West and Taunton regarding positioning of the rapid chargers. In each of these areas we have identified suitable adjacent secondary substations that could provide spare capacity from equalisation. We expect several more to be engaged while before the commencement of the project.

- We plan to run a robust procurement exercise for the control and communication system, in preparation for which we have been in discussion with a potential control system supplier to establish the viability and approximate price of a typical solution. We have also performed initial research regarding communications system with candidates including fibre laid with the DC ring (possibly with diverse path), mobile (4G network) or powerline. Based on these investigations we are confident that there are several potential solutions to be evaluated as part of the project.

- Commercial agreements between Western Power Distribution, Electricity North West, Ricardo, Turbo Power Systems and Vectos have been drafted, as have draft agreements with potential other partners such as local authorities, commercial operators, other equipment suppliers etc.

Project Management and Governance Structure is Clearly Defined

The project plan used to develop this submission will be reviewed at the start of the project, based on the proven Ricardo Project Management Process. The plan took on board learning from previous innovation projects such as Active-Response, Flexible Urban Networks LV, My Electric Avenue, Electric Nation and others.

The project plan acts as a guide to the project as it moves from bid into the design and through delivery stages. It specifies the overall aims of the project and the key success criteria, the organisational structure of the project, the governance structure which will enable clear decision making, the key reporting and control processes that support that governance structure.

The project team comprises stakeholders from multiple companies (i.e. Western Power Distribution, Electricity North West, Ricardo, Turbo Power Systems and Vectos) from the start and others that will be appointed as the project develops, potentially including stakeholders from other technology suppliers, local authorities, a charge point provider and commercial transport companies. This approach will provide transparency, facilitate cohesion and collaboration amongst the stakeholders, and avoid duplication of work and thus efficient project delivery.

We have defined the project management and governance structure to enable the project to commence in a timely manner. The project will be delivered via five workstreams:

- Workstream 1: Hardware Development and Deployment
- Workstream 2: Trials and Analysis
- Workstream 3: System Benefits and Limitations
- Workstream 4: Learning & Dissemination
- Workstream 5: Project Reporting, BaU Recommendations and Close out

Each Workstream contains a number of tasks and defined deliverables as detailed in Table 9.

Workstream	Task	Deliverable
WS1 Hardware Development and Deployment	Task 1: Project Mobilisation	Deliverable 1: Project mobilisation report
	Task 2: Preliminary Design phase	
	Task 3: Final Design Phase	Deliverable 2: Final System Design Report
	Task 4: Procurement / manufacture	Deliverable 3: Factory Acceptance
	Task 5: Installation support and commissioning	Deliverable 4: Installation Complete
WS2 Trials and Analysis	Task 6: Trial design	
	Task 7: Trial – interim	Deliverable 5: Trial Interim Report
WS3 System Benefits	Task 8: Trial report	Deliverable 6: Trial Results Report and EV Charging Customer Experience
WS4 Learning and Dissemination	Input from all tasks	Mandatory Deliverable: Comply with knowledge transfer requirements of the Governance Document
WS5 Project Reporting	Task 9: BAU	Deliverable 7: Close Down Report. Final Conclusions and BaU recommendation Mandatory Deliverable: Comply with knowledge transfer requirements of the Governance Document

Table 9. Workstream tasks and deliverables

The key project roles and responsibilities are defined as follows:

- **The Project Steering Group** comprises key stakeholders and decision makers within the Partners, including the Project Sponsor. This group is ultimately responsible for the project and will make decisions that have an overall impact on the benefits and outputs that the project will deliver.
- **The Project Manager** will be responsible for the day-to-day management of the project. This includes but is not limited to reviewing the project progress against plan, presenting the project progress report to the Project Steering Group, updating the project plan, monitoring project risks and project budget.
- **The Design Authority** reviews and approves all key project deliverables. However, ultimate responsibility for the delivery of the solutions rests with the project delivery team. On the DC Share project this role will be fulfilled by a partnership of key staff from Western Power Distribution, Electricity North West, Ricardo, TPS and Vectos.
- **Project Management Office** provides support to the Project Manager as required.
- **Project Support and Workstream Leads** assists the Project Manager to discharge their duties, particularly those associated with the delivery of key project deliverables.

Organisation Overview

Western Power Distribution, Ricardo and the other project partners have the experience and capability to successfully deliver large complex technical projects to time, cost, and quality targets, including several innovation projects.

To advance the power electronics technologies to be deployed for DC Share, we have commitment from TPS who have been involved in the DC Share solution since its concept, being based on technology used elsewhere, including NIC projects.

To ensure that the roll out of EV chargers is managed successfully we also have commitment from transport planners, Vectos. They provide expertise in gaining planning permission for the installation of EV charging points through successful collaboration with planning and highway authorities.

The Project Partners recognise the potential of the solutions and the impact they could make on distribution networks and EV usage and have significant experience in the subject areas in which they will contribute.

We are all keen to deliver innovative, reliable, efficient and commercially viable solutions for the benefit of GB DNOs and ultimately GB customers. These committed and qualified project partners have been actively engaged in the development of our full submission to ensure that the project can commence in a timely manner.

We have identified and appointed the appropriate people to fulfil the key project team roles to enable the project to start promptly in January 2020. The selected team have appropriate seniority, world-leading technical skills and knowledge and have experience of delivering innovation projects. We will select the remainder of the team upon project award.

A team is organogram is given in Figure 18, with details of the project team in Appendix 10.7.

Robust Project Plan

The project plan has been drawn up based on the extensive experience of our power systems experts and on lessons learned from earlier and current Low Carbon Network innovation projects such as Flexible Urban Networks-LV, Celsius and Active Response. The plan has been validated by our senior management team and our project partners' management for their inputs on the project scope and delivery phases. This combined input, feedback and guidance ensures that the resulting project plan is thoroughly robust.

The detailed project plan is in Appendix 10.6. This robust project plan will enable the project to commence in January 2020 and will be revised as necessary at the start of the project and throughout the delivery.

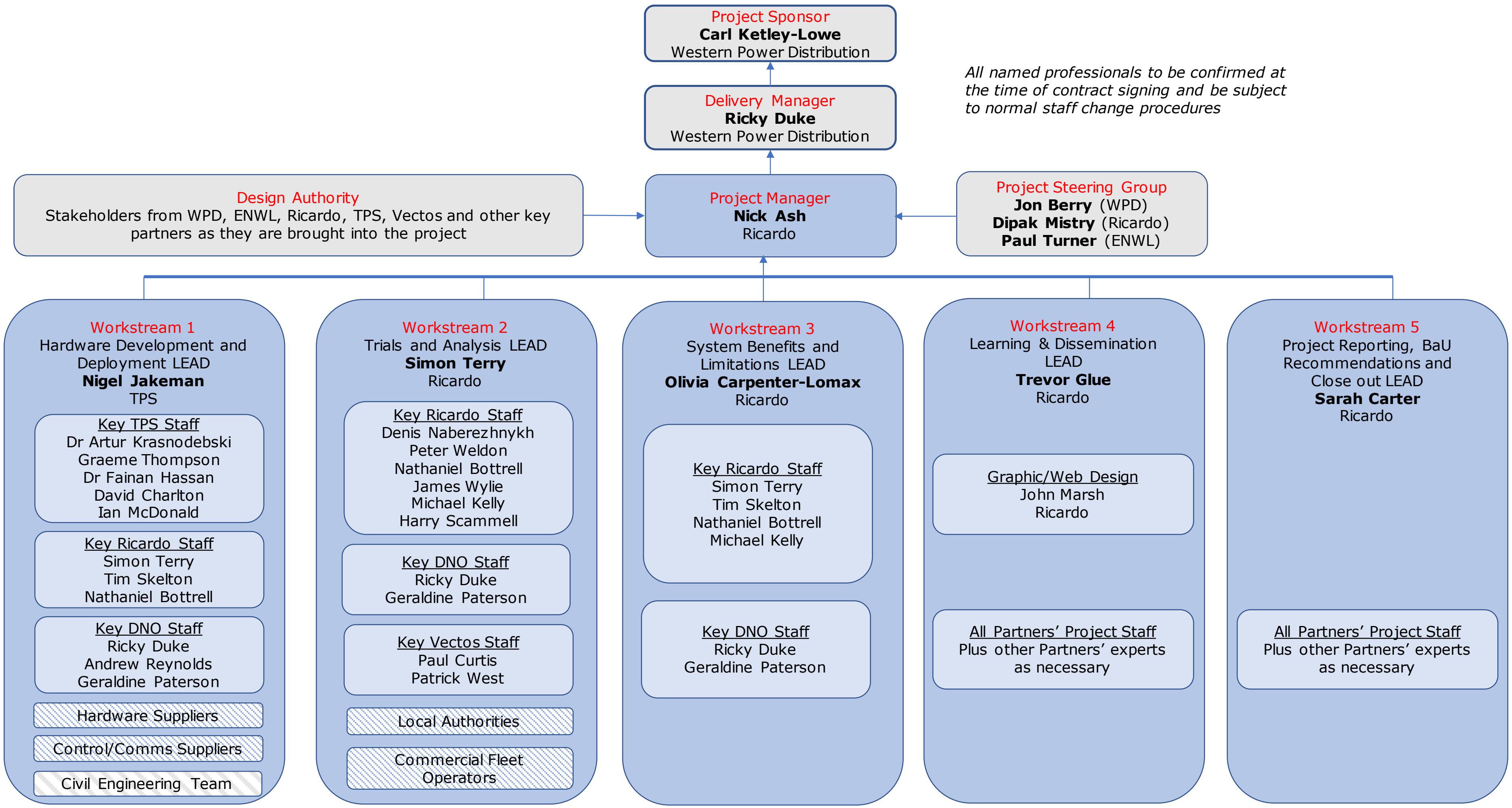


Figure 18 Project Organogram

Identification of Key Project Risks

Project risks and mitigations have been identified so that we have a high level of confidence that no insurmountable problems will be encountered, see Appendix 10.6.

The trials have been designed to build upon one another in a logical manner and allow risks between the individual project elements to be decoupled.

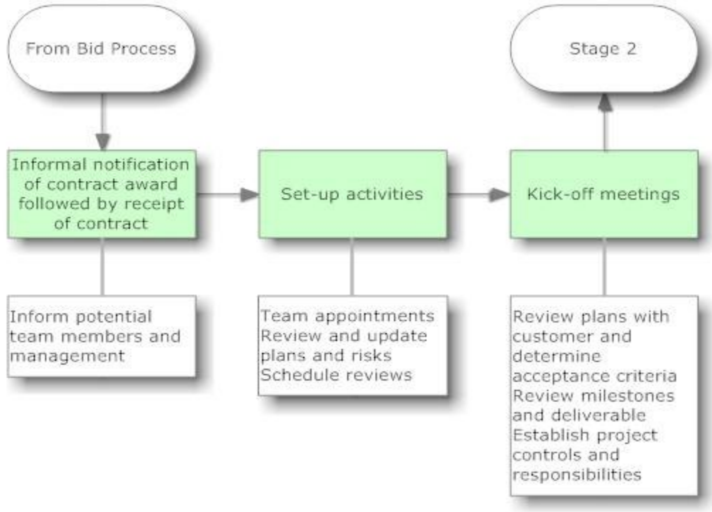
Following the detailed design and site selection processes we will reassess the project plan and budgets to ensure that they are still feasible and adjust these where necessary.

6.3 Measures in place to minimise the risk of project overruns

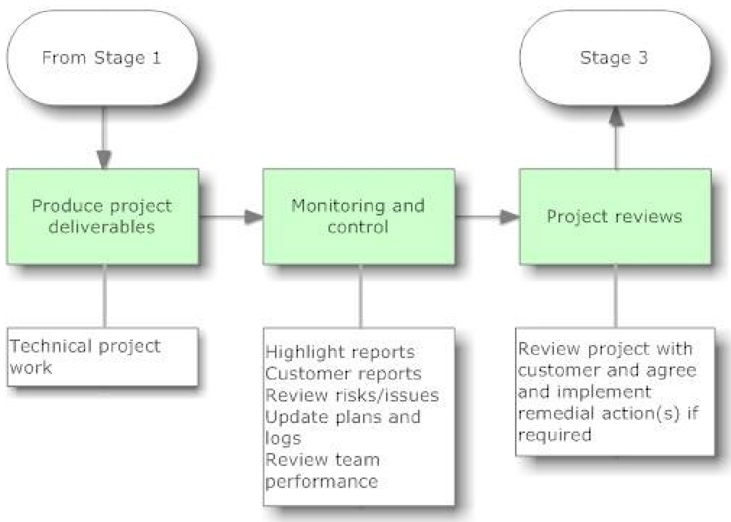
Ricardo has a strong track record for not only minimising project overruns but delivering projects within budget.

Our project delivery is driven by the Ricardo Project Management Process, a procedure that has been developed over decades of delivering successful projects and which comprises of three stages:

- Stage 1: Contract Review and Project Kick-Off
- Stage 2: Project Delivery & Customer Care
- Stage 3: Final Deliverables, Feedback & Learning



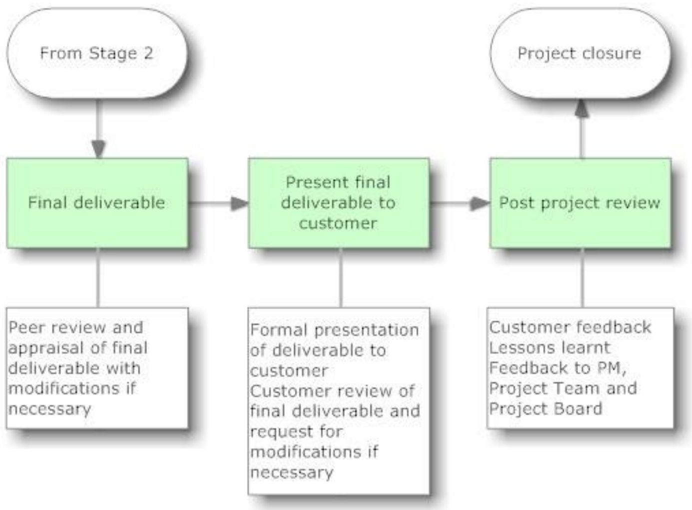
Stage 1: Contract Review and Project Kick-Off is concerned with three groups of activities centred around the receipt of an informal notification of a contract award or formal contract, set-up activities including team appointments and reviewing outputs from the bid process such as plans and the analysis of risks, and finally the project kick-off meeting where the Project Manager and team define a number of project criteria with the customer and establish internal controls and responsibilities.



Stage 2: Project Delivery & Customer Care focuses on the development of project deliverables and the associated monitoring and control activities that ensure stakeholder expectations are met and that the project runs smoothly and effectively throughout its duration. For DC Share the customer takes the form of several stakeholders i.e. Ofgem, Western Power Distribution, the local authority, charge point provider and EV drivers.

Stage 2 also concentrates on assurance that the project will be managed to time and on budget.

During Stage 2, our Project Manager will maintain appropriate contact with the stakeholders and Ricardo management, such that any risks that are identified are responded to with the appropriate action in order to maintain the project on a course towards successful completion.



Stage 3: Final Deliverables, Feedback & Learning is the final stage in the Project Management Process and deals with the tasks associated with signing off the final deliverable(s) within Ricardo, delivery to the stakeholders and responding to issues identified in the customer review. Once the project deliverables have been completed successfully, feedback is obtained from the relevant stakeholders on the overall management of the project, recording any lessons learnt during the project for future reference, as well as identifying any future opportunities. The project is then reviewed with the Programme Team and Programme Board (as appropriate) before formally closing the project and the associated financial accounts.

Specifically, to minimise the risk of project overruns for DC Share, we have produced a risk register to detail the identified risks and mitigation strategies in Appendix 10.6.

6.4 Confirmation of our information verification process

We have performed extensive research to ensure that all of the information included within this full submission is accurate. Information included within the proposal has been gathered from within Ricardo, the project partners, suppliers and other subject matter experts. All of this information has been reviewed to confirm and refine understanding, whilst evaluating the validity and integrity of the information.

The project information has been produced on the following basis:

1. A top down and bottom up costing exercise, using knowledge and experience gained on other innovation projects, and incorporating reasonable levels of contingency.
2. Reasonable estimates of hardware costs including converters and chargers from TPS.
3. Extensive modelling for the business case based on data obtained from credible and citable sources.
4. Some sensitivity analysis has been performed in the business case to demonstrate a likely range on the benefits that will be obtained.

The project team will continually asses and review the data used to determine project costs and estimated benefits throughout the project, and particularly after the inception phase is complete, sharing the findings in the relevant project reports.

6.5 How we will ensure learning in the event of low uptake of EVs

DC Share has been developed to enable DNOs to optimise the use of their existing assets and enable and encourage GB's transition to a low carbon future via EVs.

DC Share is not dependent on a specific level of EV uptake in the trial area in order to deliver learning, but the benefits are maximised when a reasonable level of EV charging is accommodated.

The EV users of the trial are intended to fall into two groups:

1) Commercial fleet operators such as taxi companies and local delivery services
2) General public users

In the present social climate, we feel it unlikely that such a scheme will be uninteresting to potential users. However, in order to mitigate the risk of low usage of the chargers we plan several measures including:

- We will carefully select suitable sites to attract the widest set of users with the help of the local authority and our partner Vectos. As well as being within viable reach of the equalised substations and the DC ring, the sites will be attractive for short term stops for both the targeted user groups.
- In order to encourage the use of the trial network the use of the fast chargers may not require payment from the users during the trial period.
- We have already begun discussions with several interested commercial operators, such that the potential for a high utilisation fleet charging at the installation can be considered during site selection.

If it transpires that the usage is still lower than anticipated then:

- With the four substations linked and equalised, we will be able to make detailed modelling of available power profiles.
- We can demonstrate the equalisation ring without DC load (cars). We have identified site selection criteria and are intending to choose our trial site carefully to ensure there will be a fleet (vans or taxis), or work-based charging demand.

- We can simulate some of the test scenarios we wish to examine, for example:
    - where the charging demand is greater than that available from the substations, such that we reduce the charging demand; We can then determine at what point this has a negative impact on users experience and perception.
    - Alternatively, we may wish to turn off a converter for a period of time and see how the system responds, in order to understand what ratio of converters to charging points is currently required, the impact of an outage on the system, etc.
- Although not a desirable trial outcome, lack of interest of targeted users will be valuable learning in itself. For example,
    - "Why are each of the user groups not interested?"
    - "What businesses or demographics or locations might generate more enthusiasm?"
    - "Would chargers of different power be more attractive?"

6.6 Project Suspension Circumstances

As part of Ricardo project management governance, there are number of processes in place to identify, assess and manage any issues that may affect the project. These processes help to maintain the smooth running of the project, whilst also aiding identification of the most appropriate course of action at any point.

The Ricardo Project Governance and Control process has a gate approval process which reviews the project at critical stages throughout its life-cycle. The project must meet the mandatory entry/exit criteria for any particular gate (which takes into account business case, risks, issues, benefits realisation and financial position), of which the Project Manager will need to provide evidence. If the project does not meet the mandatory entry/exit criteria, or if the Project Manager has identified a risk or issue that has exceeded the agreed tolerance the Project Steering Group has the authority to suspend the project where it is the most appropriate course of action, pending permission from Ofgem that the project can be halted.

Section 7: Regulatory issues

Since submission of the ISP consideration has been given to the metering arrangements for DC Share. We do not believe that this project will need a derogation from WPD's licence conditions, however we have started conversations with Elexon to look into complex metering arrangements to enable Western Power Distribution to own the DC network beyond the meter. These conversations will continue up to the project start, and if needed any derogations from licence conditions defined.

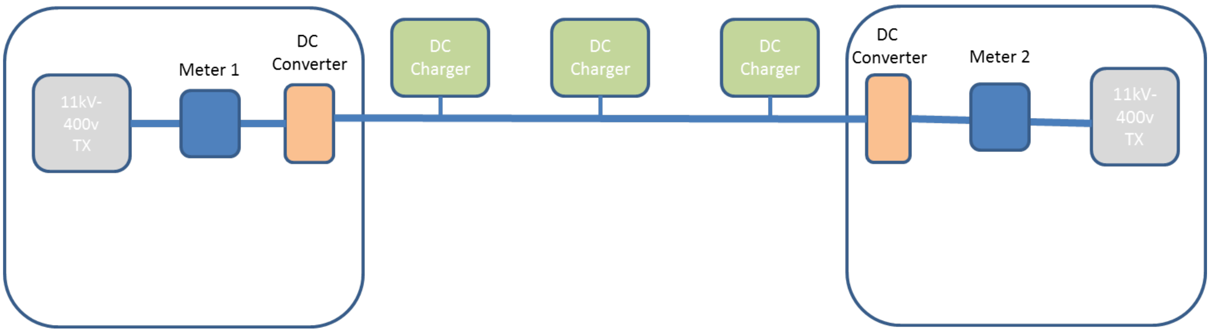


Figure 19. The proposed metering solution.

Figure 19 is an example of how the DC network that we intend to build for DC Share could be metered. The DC links are designed to balance loadings between LV substations, and the released capacity to be utilised for rapid EV charging via DC-DC car chargers connected on these links.

Ideally we would meter the individual DC chargers, but there is currently no approved available technology to do this, and the specification for DC metering is in draft. In the above diagram meter 1 and meter 2 are LV current transformer (CT) Code of Practice 5 Half Hourly 100 kW – 1 MW meters. These are positioned within the substation between the transformer and DC converters and programmed to meter both active import and active export units.

We note that the DNO should not normally own assets beyond the metering point or own assets that export to their own network. Licence Condition 43A and OFGEM's Prohibition on Generation Guidance is intended to prevent conflicts of interest arising from the operation of generation or storage to provide flexibility services, and states that this policy does not stand in the way of future innovation in the distribution sector.

In the above diagram, reverse power flows through the metering points would only occur as the load balances between the network and different LV substations. The intention is not to export power; it is to primarily balance LV network loadings. Section K of the Balancing and Settlement Code defines exports as generation, which we do not believe applies in this case as there is no generator connected. In our view, reverse power flows are best viewed as 'negative imports'. We would propose that the meters in the above example be settled in the following manner:

Active Import units Meter 1 = Active Import units Meter 1 - Active Export units Meter 2

Active Import units Meter 2 = Active Import units Meter 2 - Active Export units Meter 1

This differencing would take place in the computer systems of the Half Hourly Data Collector. There would be no export MPANs. We believe that this arrangement would take account of any losses on the DC network and the import Line Loss Factor Code would function correctly.

This metering arrangement would not be used for settlement on the individual car chargers, instead users would have to pay a one off charge per use, or use may be free during the trial to incentivise use. The project will cover the cost of the energy used during the trial, minus any income from payments for charger use.

For this solution to roll out into business as usual, DC metering must be available to provide settlement for the chargers, the project has time allocated to encourage the development of the specification that is currently in draft.

Section 8: Customer Impact

DC Share will be delivered with minimal negative impact on customers.

The project has been developed to provide financial and environmental benefits to customers through the release of network capacity from substation equalisation. The purpose of substation equalisation is to extract maximum capacity from the existing network assets and to delay reinforcement of the distribution network – a process that is likely to cause significant disruption, especially in urban areas.

The converters will be housed inside substations and so will not have adverse visual or audio impact. It is possible that some substations could be within customer premises, and therefore access to these will be arranged in accordance with normal DNO operational procedures.

No supply interruptions are expected due to the manner in which the converters will be connected to each substation.

The DC system will have adequate protection in order to isolate faulty items of equipment. This will be designed such that minimal network equipment is removed from service for faults or maintenance. Each charger will be individually isolatable under fault or maintenance situations.

The control system will be designed with redundancy so that in the event of equipment or communication system failure, the majority of the DC network will continue running. In the event that the entire DC network is unavailable, customer supplies from the connected substations will remain unaffected, with only the charging demand affected.

There will be civil works in public areas to install required cables and EV chargers. The project will work to minimise the impact to the public by all civil works and all work will be carried out by Western Power Distribution contractors who are suitably qualified, experienced and insured and will use standard approaches to cable laying.

Vectos will consider the aesthetics of the DC chargers and their location to minimise visual impact to the public.

Due to the incomplete standard for DC settlement metering, and to encourage trial users it is likely that no fee will be requested from the public for the electric charge provided during the trial period. In the BaU case, we would expect a DC metering standard to be ratified and for meters to be connected to each charge point to allow settlement quality measurement of electric charge provided to each user. Payment models could be simple payment per kWh or it could involve a licencing or subscription model.

Section 9: Project Deliverables

The DC Share deliverables have been designed to demonstrate clear progress towards the project objectives and disseminate valuable learning.

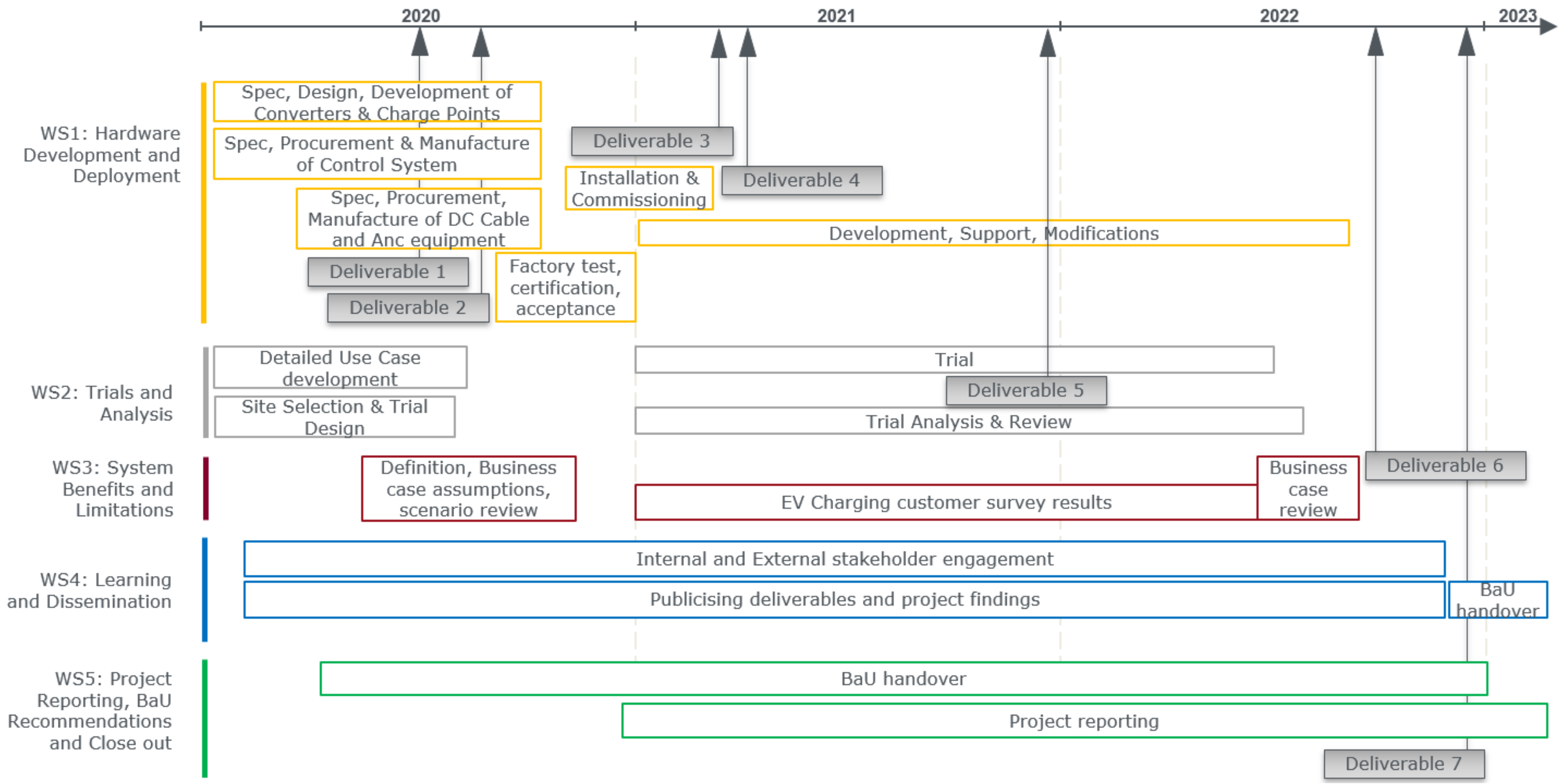
All learning reports will be published on appropriate websites.

Prior to issue, each deliverable will be peer reviewed by the project partner. In addition, and in accordance with version 3 of the Network Innovation Competition Governance Documents, we may obtain "Independent Verification" that the project deliverables have been achieved. based on this approach, we propose the following deliverables and related evidence.

Reference	Project Deliverable	Deadline	Evidence	NIC funding request (%, must add to 100%)
1	Site Selection Complete	May 2020	Report detailing: • Process used to select the site including equalisation benefits estimations, planning considerations, charger usage estimations • Evidence of support from relevant Stakeholders • Final trial site decision • Next steps action plan	5%
2	Final System Design Report	September 2020	Report detailing: • Full description and specification of the trial installation • Final system design and product specification, • System Functional Definition Document, • Detailed status of developments of hardware and software	15%

Reference	Project Deliverable	Deadline	Evidence	NIC funding request (%, must add to 100%)
3	Factory Acceptance	March 2021	Factory acceptance of Chargers, Converters, Control system, Integrated system. Proof of certification of compliance with relevant standards. Report detailing: • Description of the testing, installation and commissioning processes, • Equipment acceptance and compliance certification, • Detailed plan for onsite installation, • Analysis of the results and improvements for future iterations.	30%
4	Installation Completion	July 2021	Installations completed and presented for inspection: • Equalisation at substations, • DC ring cabling, • DC charge points, • Other system components such as switching, metering, control and comms system.	25%
5	Trial Interim Report	January 2022	Interim report detailing: • Lessons learned during installation and initial testing, • Details of activities and success in engaging with potential users, • Customer survey interim results, • Details of events and conferences.	10%

Reference	Project Deliverable	Deadline	Evidence	NIC funding request (%, must add to 100%)
6	Trial Results Report and EV Charging Customer Experience	November 2022	Report detailing: • Analysis of the data obtained from the trial installation, • Its effectiveness to deliver rapid charging and network equalisation benefits, • Public presentation of the results from customer engagement to determine positive and negative elements of the trial installation (e.g. location and logistical factors, prioritisation logic/curtailment of charging power logic). •	10%
7	Close Down Report. Final Conclusions and BaU recommendation	March 2023	Report detailing: • Summary of project findings and recommendations for BaU application, • Recommendations for follow-up projects.	5%
[Note this is a common Project Deliverable to be included by all Network Licensees as drafted below]				
N/A	Comply with knowledge transfer requirements of the Governance Document.	End of project	• Annual project progress reports, • Close down report, • Evidence of attendance and participation in the Annual Conference.	N/A


2020
2021
2022
2023
WS1: Hardware Development and Deployment
Spec, Design, Development of Converters & Charge Points
Spec, Procurement & Manufacture of Control System
Spec, Procurement, Manufacture of DC Cable and Anc equipment
Deliverable 1
Deliverable 2
Factory test, certification, acceptance
Deliverable 3
Installation & Commissioning
Deliverable 4
Development, Support, Modifications
WS2: Trials and Analysis
Detailed Use Case development
Site Selection & Trial Design
Trial
Deliverable 5
Trial Analysis & Review
WS3: System Benefits and Limitations
Definition, Business case assumptions, scenario review
EV Charging customer survey results
Business case review
Deliverable 6
WS4: Learning and Dissemination
Internal and External stakeholder engagement
Publicising deliverables and project findings
BaU handover
WS5: Project Reporting, BaU Recommendations and Close out
BaU handover
Project reporting
Deliverable 7

10. Appendices

We present the following appendices:

- 10.1 Benefits Tables
- 10.2 Project Business Case modelling (NPV and breakdown)
- 10.3 Technical Appendix
- 10.4 Comparison to other projects
- 10.5 Dissemination time table
- 10.6 Programme, Risk Register/Contingency Plan
- 10.7 Project Team
- 10.8 Letters of Support
- 10.9 Glossary of Terms

10.1 Benefits Tables

The benefits tables are shown below, including cost, capacity and carbon benefits. The figures shown are for the medium case scenario, and the details of the benefits case modelling and associated sensitivity analysis are provided in Appendix 10.2.

Cost Benefit (All figures shown in £m)

Scale	Base Case Cost	Method Cost	2030	2040	2050	Total number of sites to 2050
Individual deployment (BaU)			0.16	0.17	0.13	1
WPD Scale	240.74	199.30	12.68	37.55	41.44	411
ENWL Scale	75.82	62.90	4.33	11.78	12.91	128
GB Roll Out Scale	943.25	781.12	50.10	147.99	162.12	1,606

Table 10 Cost Benefit summary

Capacity Benefit (All figures shown in MVA)

Scale	2030	2040	2050	Total number of sites to 2050
Individual deployment (BaU)	1.1	1.1	1.1	1
WPD Scale	172	389	457	411
ENWL Scale	57	121	142	128
GB Roll Out Scale	466	1,501	1,789	1,606

Table 11 Capacity Benefit summary

Carbon Benefit (All figures shown in tCO2e)

Scale	2030	2040	2050	Total number of sites to 2050
Individual deployment (BaU)	16.2	16.2	16.2	1
WPD Scale	2,296	5,497	6,645	411
ENWL Scale	760	1,714	2,069	128
GB Roll Out Scale	6,208	21,100	25,957	1,606

Table 12 Carbon Benefit summary

10.2 Project Business Case modelling (NPV and breakdown)

A high level summary of the financial and non-financial benefits of DC Share is described in Section 3. This appendix describes in more detail the business case modelling performed in order to produce the cost, capacity and carbon benefit figures as stated in Appendix 10.1 Tables 10, 11 and 12, and the associated sensitivity analysis and assumption validation.

10.2.1 Model assumptions

In summary, the model compares the Method solution with a representative equivalent base case, and analyses the solution over an individual, licensee (both Western Power Distribution and Electricity North West), and GB scale deployment to determine the cost, capacity and carbon benefits.

Method Case Definition

The model is based on the BaU implementation of the DC Share solution. The model was developed considering the two main use cases described in Section 2; destination charging and high utilisation urban fleets. Both of these use cases assume that there is a cluster of rapid chargers located close together in an accessible location. When the solution is rolled out, the infrastructure configuration deployed will be tailored to each location, with the number of substations, number and specification of charge points, and topology of the DC network being tailored to the requirements of the site. It is also expected that once installed, a DC Share solution may be further developed; a significant benefit of the solution is that it can evolve to meet changing requirements for charging, or even incorporate other DC loads, storage and generation.

In order to develop the business case, it was necessary to assume a single 'representative' deployment topology. This is an average case representative of the range of future deployments. In selecting the representative deployment, it was important to consider the likely future needs for rapid charging in urban locations. There is an established trend in vehicle and charger development in supporting steadily increasing rapid charging speeds. 50 kW and 100 kW charging is becoming increasingly common, which will be the range of charging speeds represented in the project trials. However, the adoption of faster charging capability up to 350 kW over the next decade is highly likely, and so it was decided that the business case should include these technologies.

The method case used for the business case modelling includes:

- **A cluster of rapid chargers including a mix of 50 kW, 100 kW and 350 kW chargers totalling 2,250 kW.** This configuration builds on the trial solution, allowing for future higher capacity chargers (higher capacity 350 kW chargers are assumed after 2030), and is consistent with the predicted requirements for EV charge points into the future.
- **5 substation AC-DC converters located at substations within 300 metres of each other.** While the trial will include 4 substations, the method case requires 5 converters to meet the higher charger demand as compared to the trial. The substations will have differing load profiles, providing the opportunity to optimise allocation of charging load and sharing of AC load across the DC network. Our initial investigations have shown that 300m is a typical distance between substations in the types of urban areas being considered for deployment, with a mixture of industrial, commercial and residential loads, suggesting that a roll out of this configuration would be feasible.

- **A DC network connecting each substation and the charge points in a ring**. This network will supply power to the charge points and will be used to share load between the connected substations.
- **DC Fed chargers**: We have assumed a cost of 50 kW DC fed chargers of £xxx (exclusive of installation and signage) based on a cost estimate from TPS.
- **Associated control and monitoring systems.**

This configuration is shown in Figure 20.

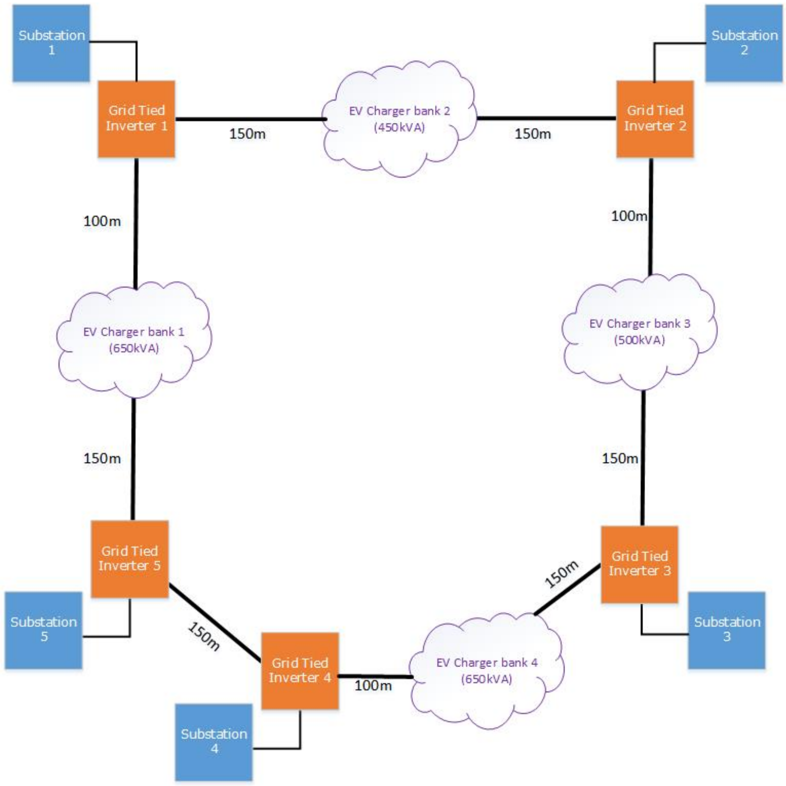


Figure 20. Method Case layout

The assumed cost of a single implementation of the DC Share solution is £xxxk, with an annual operational expenditure of £xxk per year. These costs are based on best estimates for BaU volume costs of the system components listed above. It is assumed that the power electronic equipment (including the converters and the charge points) has a lifetime of 20 years, at which point it will be replaced. The replacement costs assumed are 60% of the original deployment cost due to assumed improvements in power electronic technology and economies of scale.

Sensitivity analysis was performed on the configuration, to ensure that the business case was viable even where the final deployments differed from this representative configuration. This was done by varying the DC network topology, number of converter units, and chargers used to ensure that small changes in method case were still financially viable. This configuration will be further investigated and validated throughout the trial of the project.

In addition to supplying the rapid charge hub, the DC Share solution also provides equalisation benefits; load growth within the surrounding AC network can be supported by sharing and equalising load between the connected substations, taking advantage of complimentary load profiles which peak at different times. This benefit can be quantified by estimating:

- **The cost of reinforcing the existing substations** – While traditionally, this reinforcement would have been achieved through transformer replacement or the addition of new substations, it must be recognised that there are innovative solutions that will enable the support of load growth through less costly methods, such as demand side response or improved asset cooling. It was assumed that three of the five substations can be supported through these innovative technologies, and the remaining two require traditional reinforcement. Traditional reinforcement was assumed to cost just under £xxk, and innovative solutions will be significantly less than the traditional reinforcement, at cost of just over £xk per substation (25% of the substation reinforcement cost).
- **When it would have been required without the support of the DC Share solution** – It was assumed that the five substations that would be connected to the DC Share solution will experience an average of 3% load growth per annum, over an existing peak load ranging between 50% and 70% for the five substations. This would mean that the substations will reach capacity between 13 and 25 years.
- **The amount of time that reinforcement can be deferred with DC Share** – In the Method case, these costs are not completely mitigated; it is assumed that AC load will continue to grow to beyond that which can be supported by DC Share. This is a conservative estimate, as some reinforcements may be mitigated completely. It was assumed that reinforcement is deferred for an average of 6 years.

Base Case Definition

The base case is the best assessment of the most economical solution with comparable capability in the absence of the DC Share solution. This is so that the base case is representative of the alternative solution to meet the need into the future. It is important to consider both traditional and innovative methods when producing the base case. The following subsections describe the innovative and traditional methods explored to determine the most appropriate base case.

Traditional Reinforcement

As the load of the substation grows beyond the rated capacity of the substation, the assets are replaced with higher rated components. The cost and configuration of this solution would depend on the capacity required, and the rating of the original asset. For example, if the existing overloaded transformer was a 500 kVA transformer, then it could be replaced with an 800 kVA transformer releasing 300 kVA. If, however, the additional capacity required was significant, or the existing transformer was already rated at 1000 kVA, it is more likely that the reinforcement approach would include installation of a new additional transformer, either extending an existing substation, or adding a new substation.

A traditional reinforcement approach has been designed that would be appropriate to supply a rapid charging hub. This solution is illustrated in Figure 21 below. This consists of three new substations, supplying the 2250 kVA of additional load, and AC cables that supply the charge points. We have assumed a cost of 50 kW AC fed chargers of £xxxxx (exclusive of installation and signage) based on cost data from previous installations.

We have not assumed any wider HV reinforcement, however a 2 x 250m HV cable spur is included for two of the three additional substations. In cases where more significant reinforcement is required the financial benefits of the DC Share solution may be increased.

There are no equalisation benefits released in this solution, as the existing network is not altered.

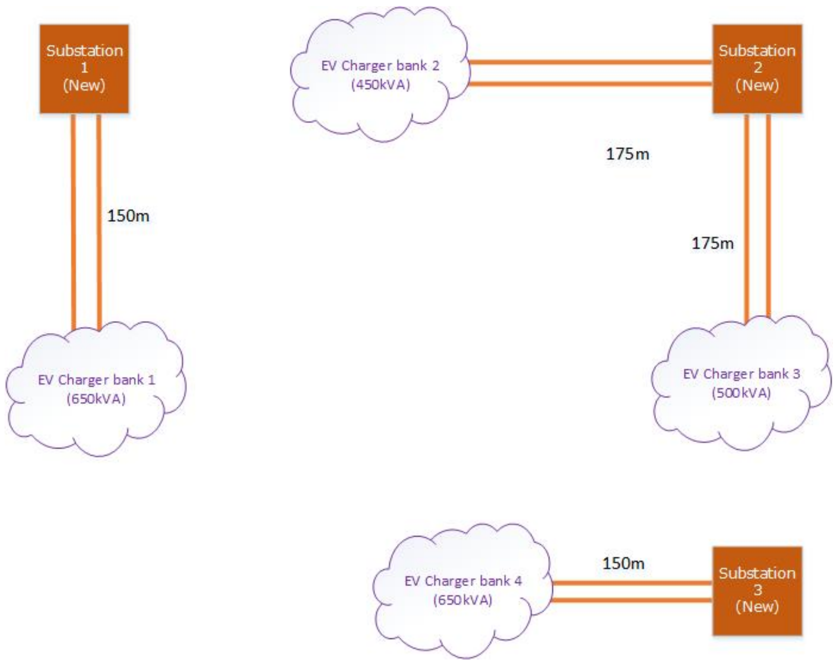


Figure 21. Base case layout

Soft Open Point as demonstrated in FUN-LV

The innovation project Flexible Urban Network-LV (FUN-LV) trialled the use of back to back power electronic converters at AC called Soft Open Points (SOPs). These allow network meshing through a controlled connection, therefore supporting equalisation and capacity release between two adjacent substations. The FUN-LV project was led by UK Power Networks, starting in January 2014 and concluded in December 2016. The FUN-LV solution involved 36 trial sites demonstrating both controlled and uncontrolled equalisation techniques with the aim of releasing capacity at constrained sites. The project successfully demonstrated three methods and showed that these were particularly beneficial where the cost of conventional reinforcement option is above average, where the flexible dynamic capabilities are required, or where reduced deployment timescales were required.

The FUN-LV solution is well suited to support LV load growth, including the uptake of LCTs such as domestic EV charging and heat pumps, in applications where traditional network reinforcement is complicated by high land costs or complex access or routing issues. It was not aiming to develop a solution for the supply of a rapid charger hub. However, for the purposes of providing a useful counterfactual for DC Share, a solution was developed using the FUN-LV technology to provide a viable and comparable solution to that provided in this project. This solution is illustrated in the diagram below.

This solution uses the FUN-LV SOPs to provide a controllable AC equalisation network, which is directly comparable to the DC equalisation network proposed in DC Share in that it connects together five substations in a controllable way, enabling capacity release from any of these substations as required to supply the chargers, and to release equalisation benefits. It uses three SOPs that manage between two feeders (2T SOPs), and one that manages between three feeders (3T SOP).

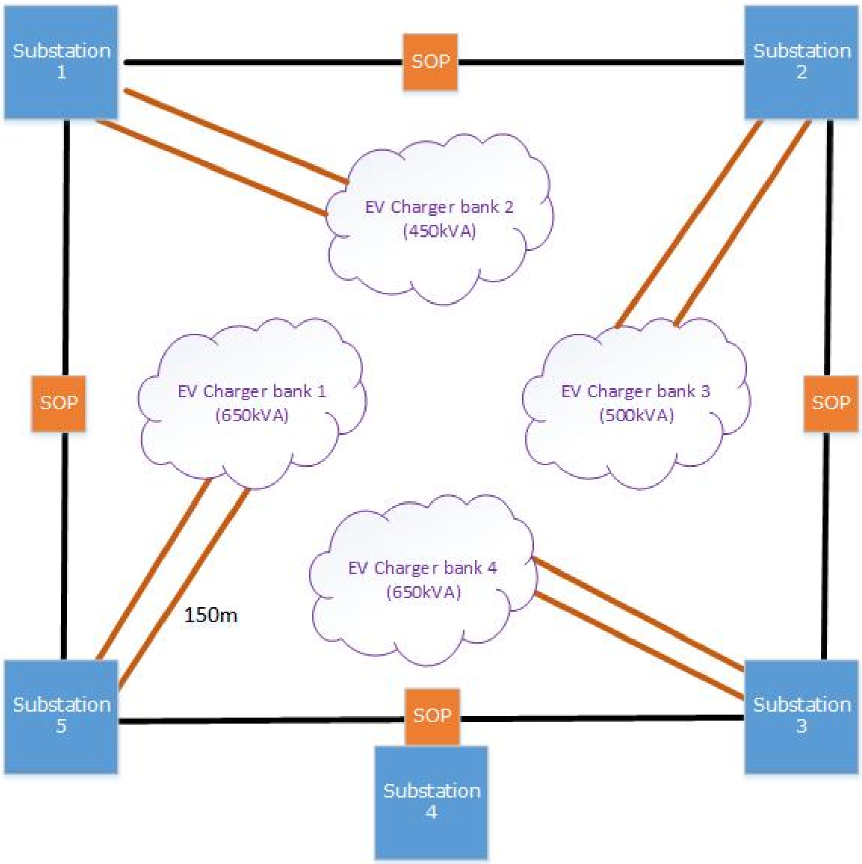


Figure 21. Counterfactual case using technologies from FUN-LV

There are several key differences between the FUN-LV solution and the DC Share solution, in that the FUN-LV solution:

- **Uses an AC network** – The FUN-LV solution includes only AC network, which could be seen as an advantage as this is in line with the operating practices of the distribution networks today. However, there are advantages to DC including potential reduction in losses and increased network reach.
- **Has an increased number of conversions –** The AC equalisation network is controlled through three two-port and one three-port SOPs. At each SOP, power is converted from AC to DC and back to AC, and it is this conversion that gives control of how much power is passed through them. However, in the DC Share solution, as the equalisation network itself is a DC network, there are significantly fewer conversions between AC and DC in order to control equalisation power.
- **Uses AC fed chargers** – The FUN-LV solution consists only of AC network, so the rapid chargers must be fed by AC. As described in the Method Case Definition above, charge points fed by DC are lower cost than those fed by AC and have lower conversion losses.

This solution topology has been developed to best support a rapid charging hub of the scale envisaged to be common in destination charging scenarios. Further investigation of a possible FUN-LV rapid charging solution suggests that it would be better suited to a smaller rapid charge load, including up to five rapid chargers, which could be served by supporting load sharing and equalisation between two or three substations with a single SOP. While this is a valid use case, it is not the one being investigated for this project.

Solid State Transformer as demonstrated in LV Engine

The LV Engine project is trialling the use of Solid State Transformers (SSTs) connected to traditional transformers to support load equalisation. SSTs are transformers which can control the power flow through them. When used in a mesh with another transformer, this enables direct influence over where loads are being fed from, enabling load sharing and equalisation. The SST can also control voltage levels and provide a DC supply.

The application explored in the LV Engine project business case, submitted as part of the FSP, is that of an overloaded transformer with feeders which are intermittently outside of voltage limits, which is a likely scenario resulting from LV load and generation growth due to the uptake of LCTs such as solar generation, electric vehicle charging and heat pumps. The traditional solution would include reinforcing the transformer and the LV feeder cables, which is costly and disruptive, and the LV Engine project is trialling a potentially lower cost and more beneficial alternative.

Like the FUN-LV solution, the LV Engine project is not aiming to develop a solution for the supply of a rapid charger hub, and the solutions described in the FSP may not be suited to this application. However, for the purposes of providing a useful counterfactual for DC Share, a solution was developed using the SST technology, including the equalisation capability. This solution is illustrated in the diagram below.

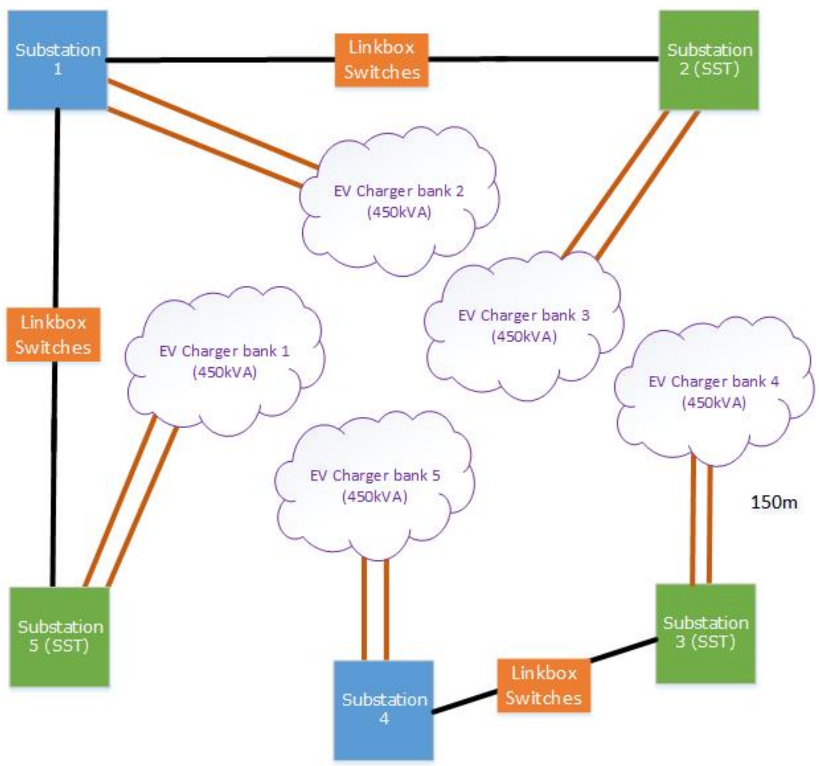


Figure 21. Counterfactual case using technologies from LV Engine

The solution uses SSTs to support supply to the rapid charge points through two separate networks; one including a traditional transformer and an SST, and one with two SSTs and a traditional transformer. In each case, the SST replaces a traditional transformer in an existing substation. The charger banks are fed from a combination of the SSTs and the traditional transformers, with equalisation and load sharing managed by the SSTs.

This configuration minimises the number of SSTs and cable length required to supply the rapid charger bank, but as it is made up of two separate networks, there is less opportunity for equalisation across the substations than compared with the DC Share solution. Note that the rapid charge points are AC fed; while the SSTs in the LV Engine project can supply DC loads, supplying the chargers with DC would not enable use of traditional equalisation and would therefore increase the number of SSTs required to meet the charger demands.

There are several key differences between the LV Engine solution and the DC Share solution, in that the LV Engine solution:

- **Uses an AC network** – Like the FUN-LV solution, the LV Engine solution includes only AC network, which could be seen as an advantage as this is in line with the operating practices of the distribution networks today. However, there are advantages to DC including potential reduction in losses and increased network reach.
- **Uses more complex conversion and equalisation equipment –** The SSTs are made up of several conversion processes, using both power electronics and traditional transformer technologies. This is likely to produce higher losses and a more complex control requirement.
- **Replaces the traditional transformer in three substations –** the SSTs replace traditional transformers and will feed a mixture of the rapid charge points and other existing loads, as well as equalising with adjacent charge points. The control requirements to ensure that all of these elements are adequately supported are highly complex, and it is not clear that all scenarios will be possible.
- **Uses AC fed chargers** – The FUN-LV solution consists only of AC network, so the rapid chargers must be fed by AC. As described in the Method Case Definition above, charge points fed by DC are lower cost than those fed by AC, and have lower conversion losses.

This solution topology has been developed to best support a rapid charging hub of the scale envisaged to be common in destination charging scenarios. It is suggested that the SST technology is well suited to release capacity in LV networks to support generalised load growth, but the technology being trialled in the LV Engine project is not suited to supporting significant point loads such as rapid charger hubs.

Other innovative technologies

There are a wide range of innovative network technologies and solutions that are being developed through innovation projects across the industry. Many of these release network capacity through an alternative to traditional reinforcement. For example:

1. **Remote network meshing and reconfiguration** – the Smart Street and FUN-LV projects trialled the use of remotely controllable switches in substations and linkboxes in order to mesh and reconfigure the network, in order to enable capacity release.
2. **More informed substation asset rating** – Producing more informed rating of the substation assets through monitoring, which is higher than the nominal rating. The Celsius project is investigating this concept, and early assumption from this project was that up to 13% capacity could be released through this method, although this number is much lower for most substations.
3. **Management of heat in substations assets** – Introducing cooling technologies and heat management, such as fans and improved ventilation. This concept is also being investigated by the Celsius project, and an early assumption was that up to 30% capacity could be released within a substation using this approach.
4. **Demand Side Response** – Demand side response (DSR) is where energy users dynamically change their energy use or generation behaviour in response to

incentives or signals from the power system. This can be used to release additional capacity through peak shifting.

5. **Optimisation of voltage and power flows** – Smart Street is a system designed to optimise voltage and power flows on the LV AC network resulting in a reduction in demand. The project concluded that that there could be a 5.5-8.5% energy reduction as a result of a 6-8% voltage reduction.

These innovative technologies are capable of releasing capacity across the AC network, and this will be deployed to support AC load growth, including that associated with slow charging of EVs. However, these solutions are not capable of releasing the significant amounts of capacity in a single location that is required to support a cluster of rapid chargers. As the supply for the fifteen rapid charge points requires significant capacity, the options above are not suited to providing a viable counterfactual for the DC Share solution.

Solution Roll Out Profile

Figure 22 shows the expected number of rapid chargers required over GB up until 2050. This has been assessed by the Ricardo Sustainable Transport team using the Government's 'Road to Zero' sales targets to forecast the total plug-in vehicle fleet. The 'high' scenario is directly based on UK policy, with 70% of new cars and 40% of new van sales to be ultra-low emission by 2030 and 100% by 2040, and that cars, vans, and small rigid HGVs in use in GB will be plug-in electric by 2050. As these are ambitious targets, we have added in a 'medium' (50% car and 30% van sales are ultra-low emission by 2030) and 'low' (30% car and 20% van sales are ultra-low emission by 2030) scenario.

The graph below shows the expected number of rapid chargers required over GB up until 2050. This has been assessed by the Ricardo Sustainable Transport team using the Government's 'Road to Zero' sales targets to forecast the total plug-in vehicle fleet. The 'high' scenario is directly based on GB policy, with 70% of new cars and 40% of new van sales to be ultra-low emission by 2030 and 100% by 2040, and that cars, vans, and small rigid HGVs in use in GB will be plug-in electric by 2050. As these are ambitious targets, we have added in a 'medium' and 'low' scenario to represent 50%/30% cars/vans and 30%/20% cars/van sales by 2030.

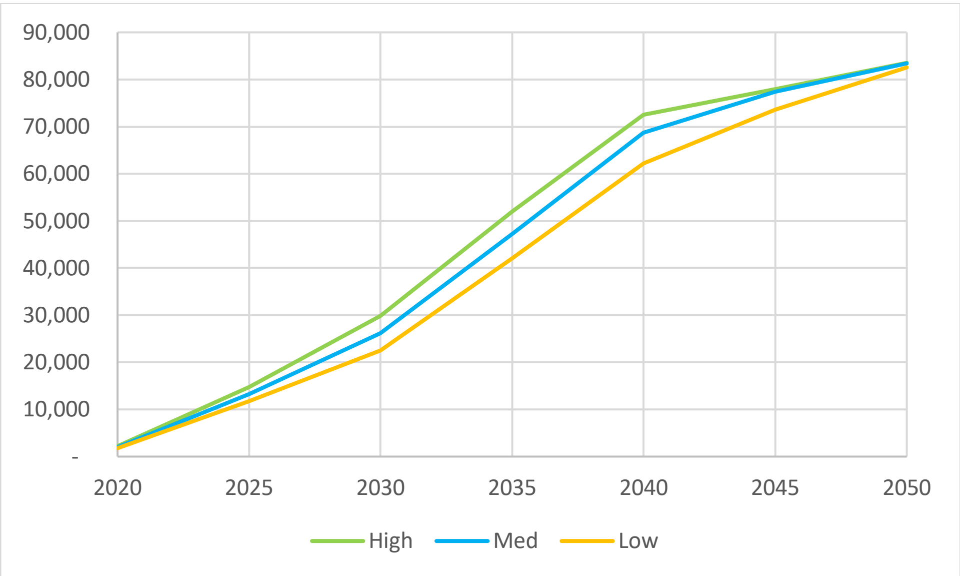


Figure 22. GB Rapid Charger requirement

It cannot be assumed that all of the future rapid chargers in GB will be associated with DC Share solutions. The business case roll out model estimates:

- **40% to 50% of rapid chargers will be located in urban areas** – The rapid charging use cases covered by DC Share (namely destination charging or high utilisation urban fleets) require clusters of rapid chargers in urban areas. The proportion of rapid chargers that are located in urban areas is assumed to be 40% for public chargers and 50% for commercial chargers. This is considered to be a conservative estimate, as it assumes that the majority of rapid chargers are located in other non-urban locations (most likely at service stations), however it is thought that charge points are likely to be located at destinations such as shops and leisure facilities, which are more common in urban areas.
- **Situations suitable for DC Share** – The DC Share solution is adaptable to the requirements of the network, and so is likely to be technically feasible in most urban situations. However, the solution is not suitable for charge points that are not clustered, where a traditional or FUN-LV-based solution is likely to be more appropriate. Note that it is thought that most rapid chargers will be associated with at least some clustering, to provide maximum convenience to the user when planning charging times and locations. Other aspects such as proximity to suitable substations and feasibility of cable routes may prevent the application of some Share solutions even for clustered sites, though the design of the DC Share solution allows significant flexibility in the location and load profiles of connected substations which would increase the likelihood that it can be deployed to support in most situations. It was assumed that 60% of the predicted urban rapid chargers could be installed onto a DC Share solution.

These two factors were applied to produce the total number of rapid charge points that could be connected to a DC Share solution. This is then divided by the number of charge points in each DC Share solution to give the total number of DC Share solution deployments. A reasonable roll out profile is assumed in the early adoption phase of the deployment, starting at one solution in the year following the end of the project, and then increasing speed of roll out until the deployment of DC Share solutions has caught up with the potential demand for solutions.

Figure 23 shows the cumulative roll out profile associated with these assumptions for the high, medium and low scenarios described above.

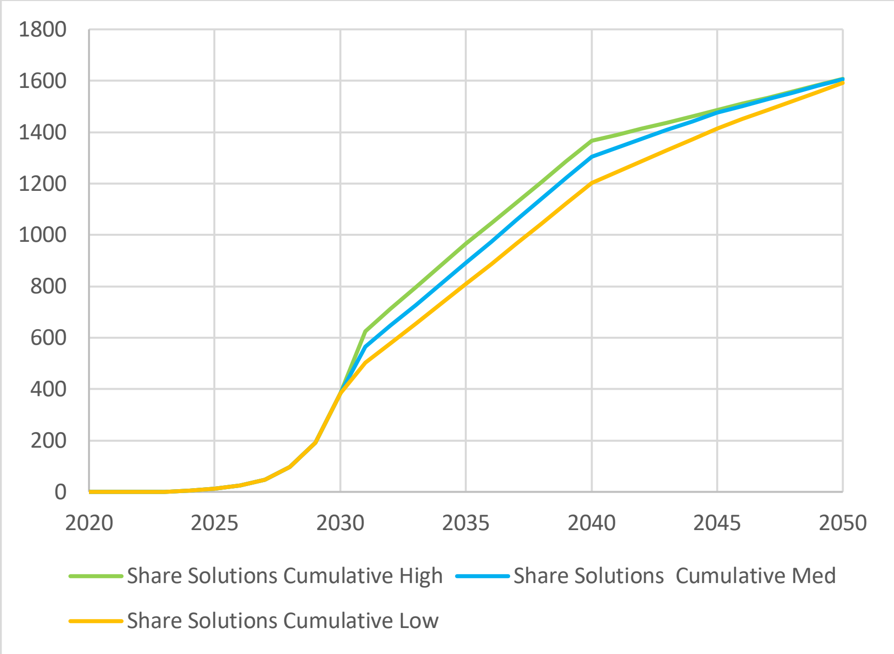


Figure 23. DC Share GB roll out profile

In order to determine the roll out profiles for Western Power Distribution and Electricity North West scale deployment, the urban populations served by each licensee was compared. This guided the process of predicting the split of deployed solutions between each licensee. Figure 24 shows the roll out assumptions for each licensee in GB up to 2050.

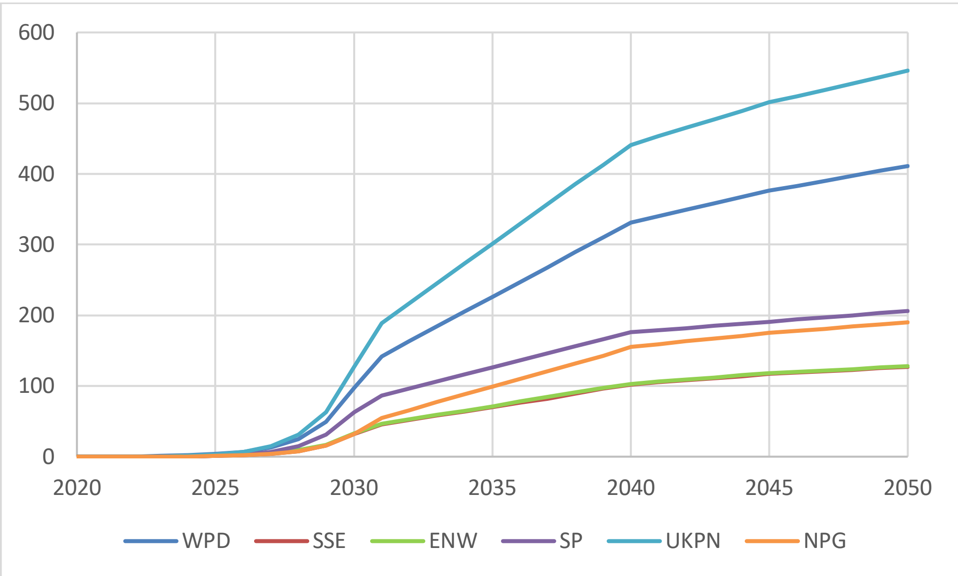


Figure 24. Roll out assumptions for each network licensee

10.2.2 Model results

Counterfactual model results

The three different counterfactuals were modelled as base cases in order to determine which was the most appropriate to use for the main business case. The most appropriate counterfactual is the one which would support the rapid charger hubs and provide comparable capability to the proposed DC Share solution for the lowest overall cost. Table 13 and Figure 25 below shows the modelling results using each of the counterfactuals. In each case, the 'medium' GB roll out assumptions were used. The roll-out costs shown include capital expenditure and operational costs, as well as replacement of equipment before the modelled duration.

	Traditional reinforcement	FUN-LV solution	LV Engine solution
Description	Traditional reinforcement: 3 new substations, AC fed Chargers, Cabling	FUN-LV solution: 3 off 2T, 1 off 3T, AC fed Chargers, LV Cabling	LV Engine solution: 3 off SST, AC Fed Chargers, LV Cabling
CAPEX	£xxxk	£xxxk	£xxxk
OPEX	£xk associated with charge point management	£xxxxk associated with charge point management and control systems	£xxxxk associated with charge point management and control systems
Replacement	£xxxk after 20 years associated with charge points	£xxxk after 20 years associated with converters and charge points	£xxxk after 20 years associated with SSTs and charge points
Equalisation Benefits	None	Same as method case	Half those of the method case
Single Deployment Costs	£992k	£1,069k	£1,120k
GB roll out costs	£943m	£964m	£1,013m

Table 13 The assumptions and results of modelling of the three counterfactual cases

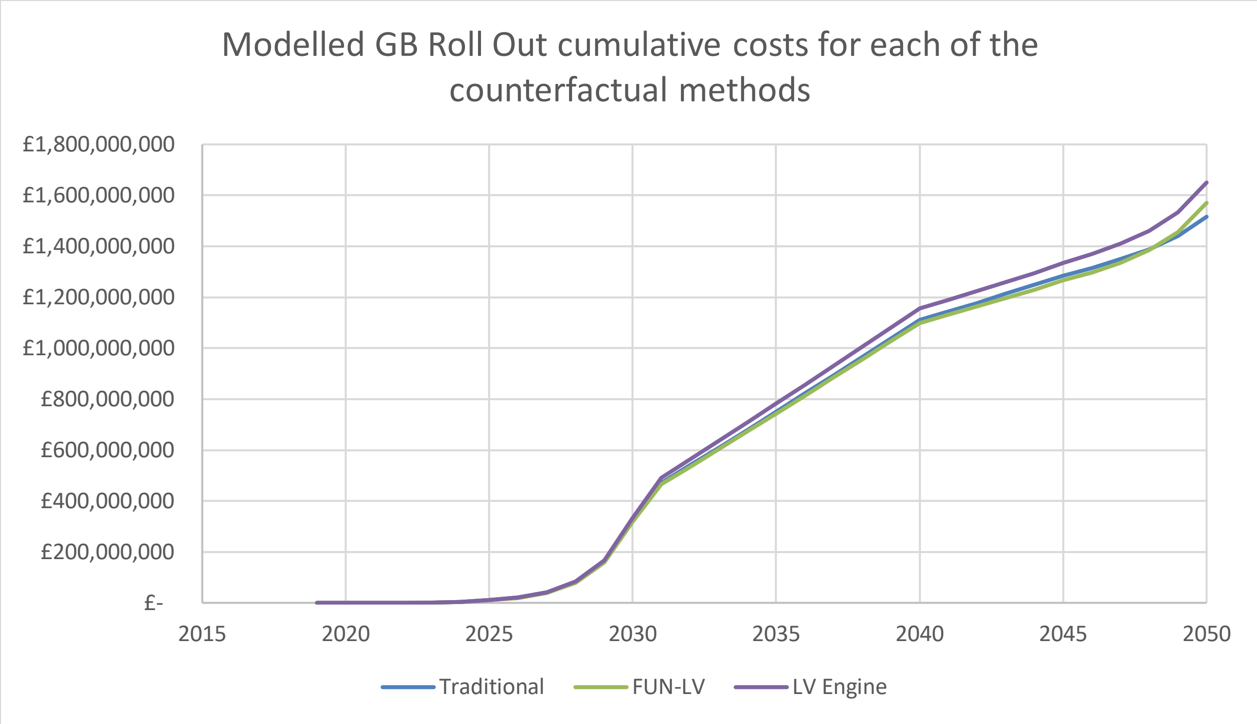


Figure 25. Cumulative costs for each counterfactual method to roll out across GB

Table 13 indicates that the lowest cost counterfactual is traditional reinforcement. This is expected, as though the other innovative solutions are beneficial in other applications, they were not designed to supply a significant point load such as a rapid charge point hub. Therefore, the traditional reinforcement solution was used in the remaining modelling.

The cost of traditional reinforcement is very close to that of the FUN-LV solution, and is only marginally more costly by 2050 due to the higher replacement costs of the power electronics with limited lifetimes. As the power electronic equipment improves, it is expected that the FUN-LV solution will become more beneficial and may provide the lower cost solution compared to traditional. A similar improvement would also benefit the LV Engine solution, though this is starting from a more costly starting point. These improvements in power electronic equipment will also benefit the DC Share solution.

Cost Benefits Model Results

The first step of the business case modelling included considering an individual deployment of the Method. This found that the cost benefits of a BaU deployment of the DC Share Method £134k.

The business case model considers the BaU deployment installation in the year 2023 (the deployment of the first BaU case) and operation up to 2050. All costs are in 2019 value, using a discount factor of 3.5% for the first 30 years and 3% thereafter, and with NPV calculation from when the installation programme begins (2023).

Figure 26 shows the cumulative cost of roll out for the DC Share solution, compared to each of the counterfactuals shown in Figure 25. These costs include capital expenditure and operational costs, as well as replacement of equipment before the modelled duration.

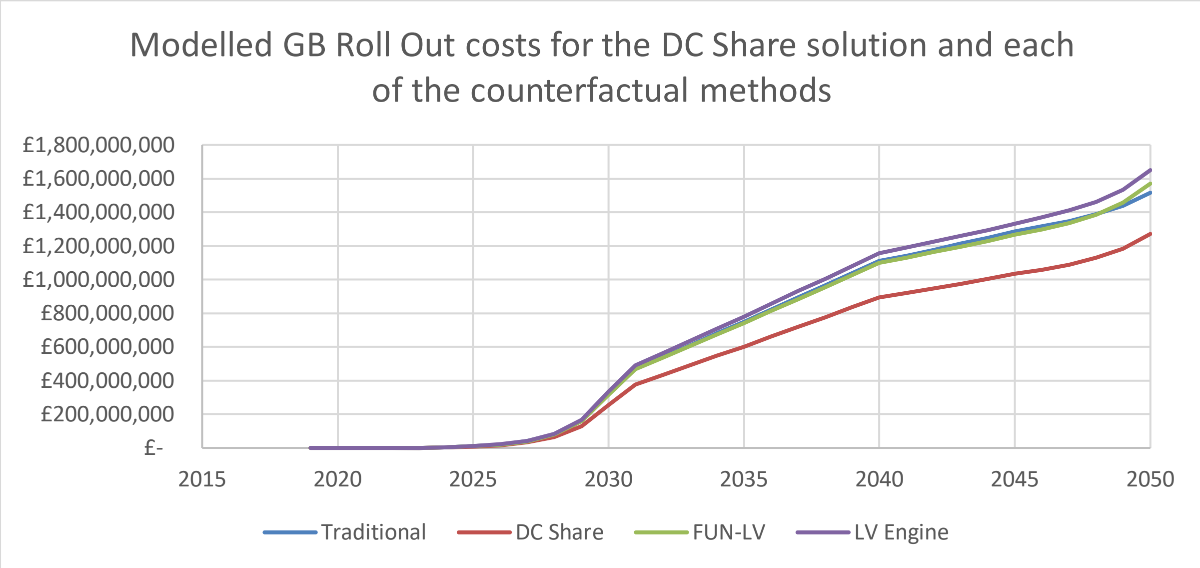


Figure 26. Cumulative costs for the DC Share solution and each counterfactual method to roll out across GB

Figure 27 and Table 15 show the forecasted financial benefits of the DC Share Method up to 2050 over all of GB. Again, the high, medium and low roll out cases are shown.

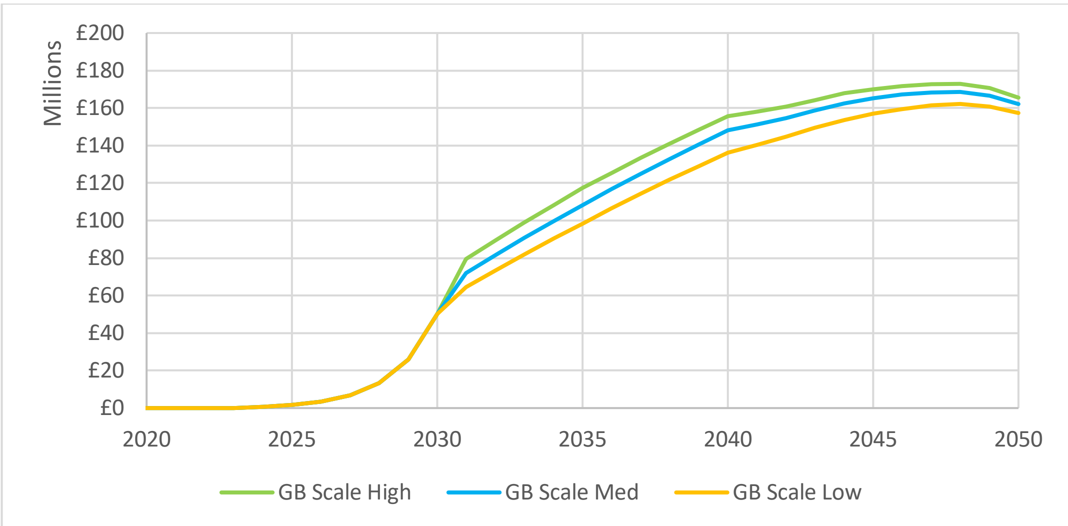


Figure 27. GB Scale deployment benefits (£m)

High Case	Base Costs (£m)	Method Costs (£m)	NPV (£m)
2030	251	201	50
2040	798	642	156
2050	960	795	165

Medium Case	Base Costs (£m)	Method Costs (£m)	NPV (£m)
2030	251	201	50
2040	758	610	148
2050	943	781	162

Low Case	Base Costs	Method Costs	NPV
2030	251	201	50
2040	698	561	136
2050	916	758	157

Table 15. NPV of DC Share solution across the high, medium and low cases (£m)

The shape of the benefits profile features a small dip towards the end of the model period up to 2050. This is due to the need to replace the power electronic equipment at the end of the asset lifetime; this requirement is higher in the method case, as there is more power electronics being deployed compared to the base case. The assumptions around this replacement are conservative, as it could be assumed that in the future power electronics may be built to be more robust, and the replacement costs may reduce.

The total customer funding required to implement the DC Share solution into BaU includes the project cost funding request of £4,716m, and any additional funding required to fully integrate the IT systems and processes, which is estimated at £500k.

DC Share will produce benefits that breakeven with customer funding in 2027, as shown in Figure 27.

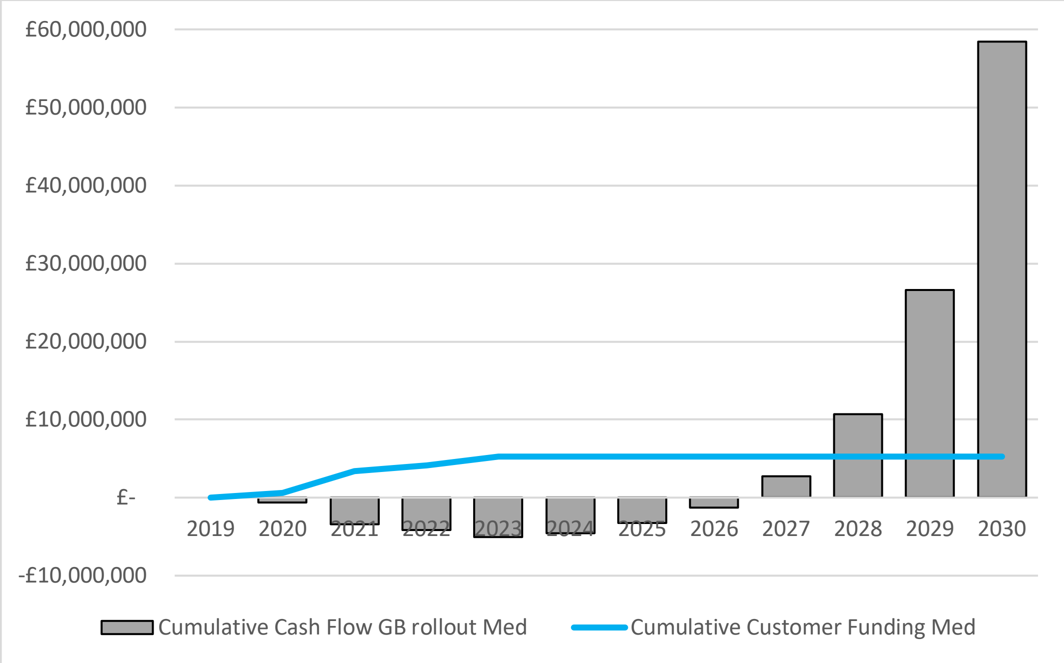


Figure 27. Breakeven analysis of the DC Share solution compared to customer funding. Analysis only up to 2030 is shown to highlight the breakeven year of 2027.

Capacity Benefits

The capacity released by the DC Share Method is derived through two main sources:

- Optimisation of charge point and DC system operation taking advantage of flexibility in charging time and minimising the peak demand on the network. This enables the release of 1,100 kVA per solution deployed.
- Additional capacity released through equalisation, beyond that required for the rapid charge points, to further support surrounding AC connected load growth. This enables the release of 110 kVA per solution deployed for the first 6 years of its lifetime (as this reinforcement is deferred rather than mitigated).

The capacity release figures were determined through modelling of the solution. Figure 27 and Table 14 below show the forecasted capacity benefits of the DC Share Method up to 2050 over all of GB.

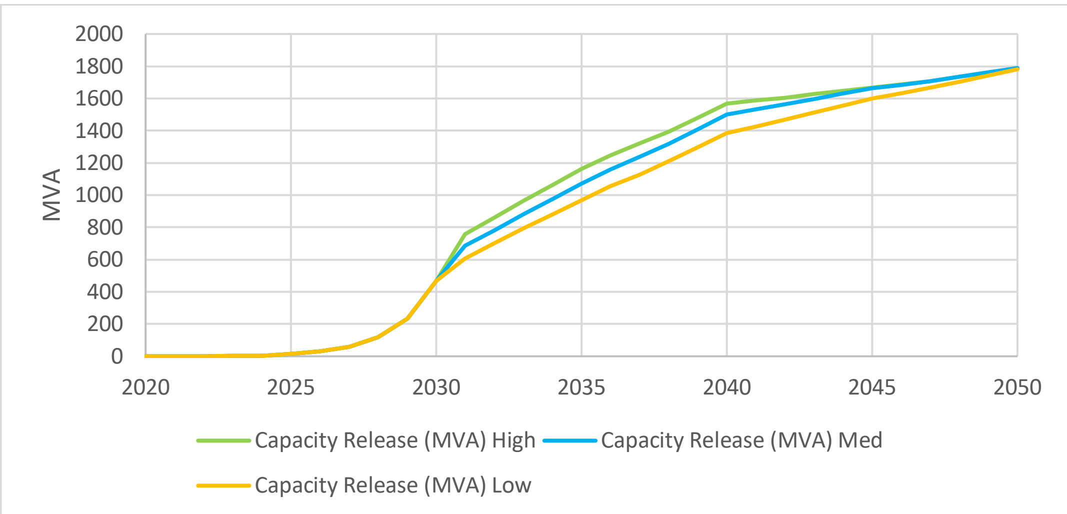


Figure 28. GB Capacity Release (MVA) from DC Share

Year	High Case	Medium Case	Low Case
2030	466	466	466
2040	1,567	1,501	1,384
2050	1,788	1,789	1,781

Table 15. Capacity Release across GB in the high, medium and low cases (MVA)

The capacity released by each deployment is assumed to be the same, 1.2 MVA, hence the differences in the scenarios is as a result of the roll out assumptions.

Direct Environmental Benefits

The direct carbon benefits of DC Share are driven by the creation of capacity for a lower carbon cost than the base case.

To quantify the carbon benefits in our model, we have researched the carbon emissions associated with the manufacture of the materials required in both Method and base solutions. The assumptions for carbon intensity of component material (steel, silicon carbide, transformer oil etc.), and that of transportation were gained through research. The carbon impact of the charge points and LV cabling is assumed to be the same in both the method and the base case, as similar volumes are required in both.

The results of our calculations are that the as installed carbon impact of the substation convertors is 0.41 tCO2eq, and for each secondary transformer it is 6.1 tCO2eq. The DC Share business case has been developed based on a solution comprising five substation converters, and deferring the replacement of three secondary transformers. On this basis the direct carbon benefits for each deployment is 16 tCO2eq. At GB scale using the assumed roll out the direct carbon benefits are as shown in Figure 29 and Table 16.

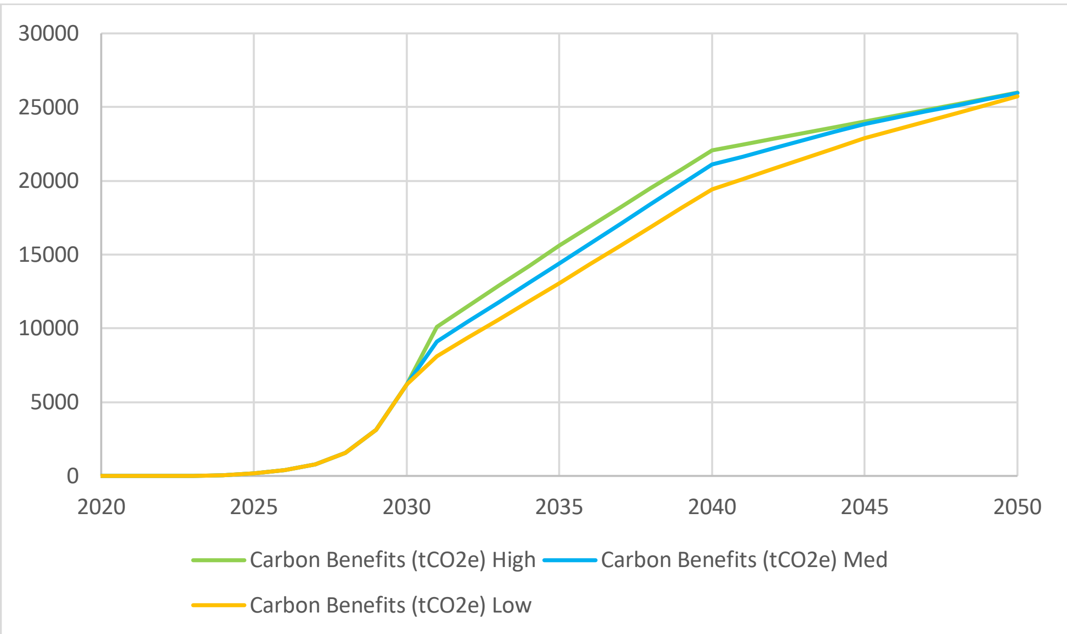


Figure 29. Direct carbon benefits across GB released through the DC Share solution (tCO2e)

Year	High Case	Medium Case	Low Case
2030	6,208	6,208	6,208
2040	22,075	21,100	19,422
2050	25,985	25,957	25,733

Table 16. Direct carbon benefits across GB in the high, medium and low cases (tCO2e)

Other DC Share Benefits:

- Minimise the impact of significant clusters of rapid charge points on the network - As part of the DC Share solution, rapid charging points can be managed and optimised as part of the wider DC solution, taking advantage of flexibility in charging time and minimising the peak demand on the network.
- Increased network flexibility – The provision of flexible methods enables increasing uncertainty to be managed more effectively, optimising power flow in real time to react to changing network demands and providing real-time controllable support to the wider AC network.
- Future-proofing of the network infrastructure and avoidance of stranded assets – The solution can provide future-proofing through enabling the connection of future DC loads, generation and storage to established DC Share solutions. The topology of a DC Share solution can expand and adapt over time to meet the changing future needs of the customers. Under-utilised substations can be connected to the DC network, allowing them to provide additional capacity to the system and enabling avoidance of stranded assets.
- Network control benefits – Additional network control benefits using Power Electronics may be enabled through the solution, such as the ability to actively manage network voltage and power flows, which can offer customers improved quality of supply which can be maintained through changing network conditions.
- Reduced Losses - Charger losses are lower in DC Fed EV charge points, by virtue of the simplified architecture of the devices. We estimate 97.5% efficiency for DC fed chargers, against 96.5% for AC fed. System losses are also lower in the DC Share case than in the "Soft Open Point" and "Solid State Transformer" cases, due to the reduction in conversions between AC and DC.
  Losses can also be minimised on the DC Share system, by actively managing power flows (when possible) to minimise current in the parts of the network most susceptible to losses, and by switching off converters when not required for use.

10.2.3 Sensitivity analysis

Sensitivity analysis was performed on the model to investigate the sensitivity of the results to small changes in the input assumptions, and to ensure that the case being modelled was a realistic conservative case. The findings of this analysis included:

- **The model produced positive business cases from a wide variety of Method and base case configurations** – Through analysis which included varying the DC network topology, number of converter units, and chargers used, it was found that a broad range of Method and base case configurations resulted in a beneficial business case, and the assumptions selected for the analysis results are a realistic, conservative middle ground.

- **Any requirement for HV reinforcement in the base case significantly improved the business case** – It is assumed that in the method case, HV reinforcement can be largely mitigated through the benefits for equalising across multiple substations, and therefore if the base case required HV reinforcement, there is a significant uplift on the business case. For the purposes of the business case, it is assumed that no major HV reinforcement is required in either case, making this a conservative assumption.
- **Any improvement in power electronics technology significantly improves the benefits case** – The business case modelling assumes that the lifetime of the power electronics is 20 years, and the cost of power electronics is constant. However, there is significant development being undertaken in the field of power electronics, and so it is reasonable to assume that these improvements will increase component lifeline and/or decrease component cost before the end of the model in 2050. These improvements will significantly improve the business case.

10.3 Technical Appendix

10.3.1 Benefits of the DC mesh network

The DC Share solution configuration has advantages over conventional AC network designs that will demonstrate benefits in the project trials. These advantages stem from three properties of the design.

1. Meshing

Distribution networks are typically of radial design in order to prevent circulating currents and excessive fault levels. This requirement to keep networks separated from each other creates electrical boundaries (e.g. at the 11 kV feeder boundary, the Primary Substation boundary etc.) that must be coordinated and managed to ensure safe and efficient operation.

The meshed DC Share network will allow connections across these electrical boundaries, without increasing fault levels or causing circulating currents. This means that demand can be met from transformers that have available capacity, and support provided to others, equalising demands between the connected transformers in proximity to each other, irrespective of the boundaries between them. This allows a greater degree of aggregation of the demand profiles to be obtained and more effective use of the available capacity.

2. Diversity

The current required by a Rapid EV Charger is large, for example a 100 kW charger equates to 140 A at 415 V. This means that only a small number can be connected to the supply cable, before the rating would be exceeded. For example; a typical 350 A cable could supply two 100 kW chargers, as if both were utilised at the same time 280 A would be required.

By using a higher voltage connection of 800 V, and connecting the chargers directly to a meshed ring, rather than to radial circuits, a higher number can be connected. Consequently, a greater degree of diversity in the charging demand can be assumed, as with the higher number of chargers in a group it is less likely that all will be in use at the same time.

3. Control of Power Flows

In conventional AC networks, the power flows from the generation source to the demand via the path of least resistance, and there are very limited ways of providing any control of these flows. Conversely, a power electronic converter fed DC network affords a large degree of control, as the direction and magnitude of the power flows can be set. The DC Share network will make use of this capability to equalise the demand profiles at the connection substations, and also ensure that the charger demand is maintained within the rating limits of the equipment.

10.3.2 DC Share hardware description

The DC Share network comprises four core hardware components:

1. Grid Tied Inverters (GTI);
2. DC/DC convertors for rapid EV chargers:
3. The charge point themselves; and
4. The control system.

GTIs are required to connect the scheme to the LV AC distribution network. These devices create a fixed voltage DC cable bus which forms a common link to all of the GTIs in the network, each GTI being connected to a separate substation. This enables transfer of power either between substations to equalise demands, or from substations to the EV chargers themselves whilst balancing charging load across the multiple infeeds.

Connected to the DC bus are the chargers themselves, comprising a DC/DC converter which provide a controllable, variable voltage output, suitable for charging EV batteries. The DC/DC converters are each housed in a charge point, the on-street device which transfers the output power of the converter to the EV, each having in-built charge monitoring and metering.

The control system will provide integrated management of the whole DC Share network.

Each component is described in more detail below:

Grid Tied Inverter (GTI)

The GTIs used in the scheme, whilst being of a 3-phase standard inverter architecture, are unique for the following reasons:

- A fourth leg converter is used to enable balancing of voltage or power across each individual phase of each LV connection. This maximises the benefit of the scheme to the distribution network relative to commercial off the shelf solutions formed from conventional motor drive inverters.
- The Inverters deploy new generation Silicon Carbide (SiC) semiconductor switching devices. This approach enables high switching frequencies to be used in order to achieve silent and efficient operation in a compact footprint. This is made possible through the inherently low conduction and switching losses associated with the technology. For DC Share the inverters will operate at 20 kHz to ensure no audible noise.
- The inverter construction comprises individual leg modules enabling ease of service and maintainability in the event of a device or component failure.

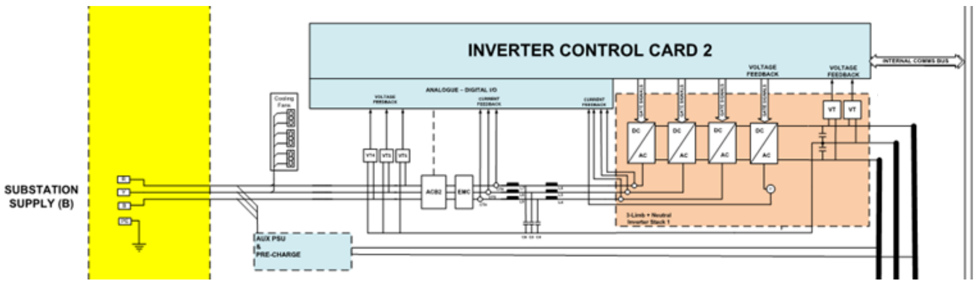


Figure 29, Grid Tied Inverter configuration

The project will not investigate back feeding of substation LV boards through the DC network under transformer outage conditions, as the converters will not be able to provide enough fault current to operate the conventional fuse protection employed on LV networks. However, techniques to allow this could be investigated in subsequent work to allow increased network resilience.

DC/DC Converters for Rapid Vehicle Charging

For safety it is critical that any EV charger is isolated to prevent potentially fatal electric shock from the necessary high DC voltages in the system. This requirement dictates the need for an isolated architecture, this being an electronic converter with either high or low frequency transformer. In using a high frequency transformer architecture, a compact charging unit can be achieved.

The converter to be used for DC Share deploys a three-stage conversion process. In the first stage the high voltage created by the GTIs for the DC supply bus is regulated to a controlled DC voltage using a buck/boost chopper, this needs to be controllable to set the battery charge level. The resulting voltage is then converted in the second stage to high frequency AC, using a single-phase inverter, which is supplied to the primary winding of a high frequency transformer. In the third stage the secondary winding of the high frequency transformer is connected to an output rectifier which converts the high frequency AC back to DC which, once filtered, is suitable for EV battery charging.

Like the GTIs, Silicon Carbide switching technology is deployed to create a silent, efficient and compact unit. Conventional rapid chargers are designed for AC supply; hence this dedicated and unique DC/DC converter is required to enable charging from the DC cable bus of the DC Share network.

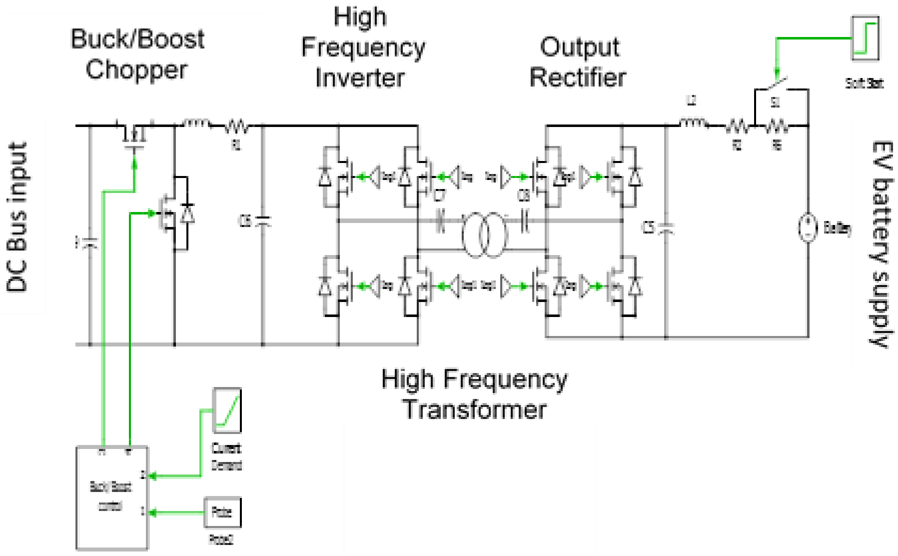


Figure 30. DC/DC charging converter architecture

Charge Point

A dedicated charge point will be developed as part of DC Share, this is necessary to accommodate the DC/DC charging converter whilst controlling the power delivery to the EV using the CHADeMO (Charge de MOve) and CCS (Combined Charging System) charging protocols. The high currents associated with rapid charging demand the need for integrated cooling systems to ensure the vehicle connection cables do not overheat. Creating a compact and ergonomic integrated charge point that that can be distributed around the DC cable bus demands a unique and currently unavailable integrated charger unit.

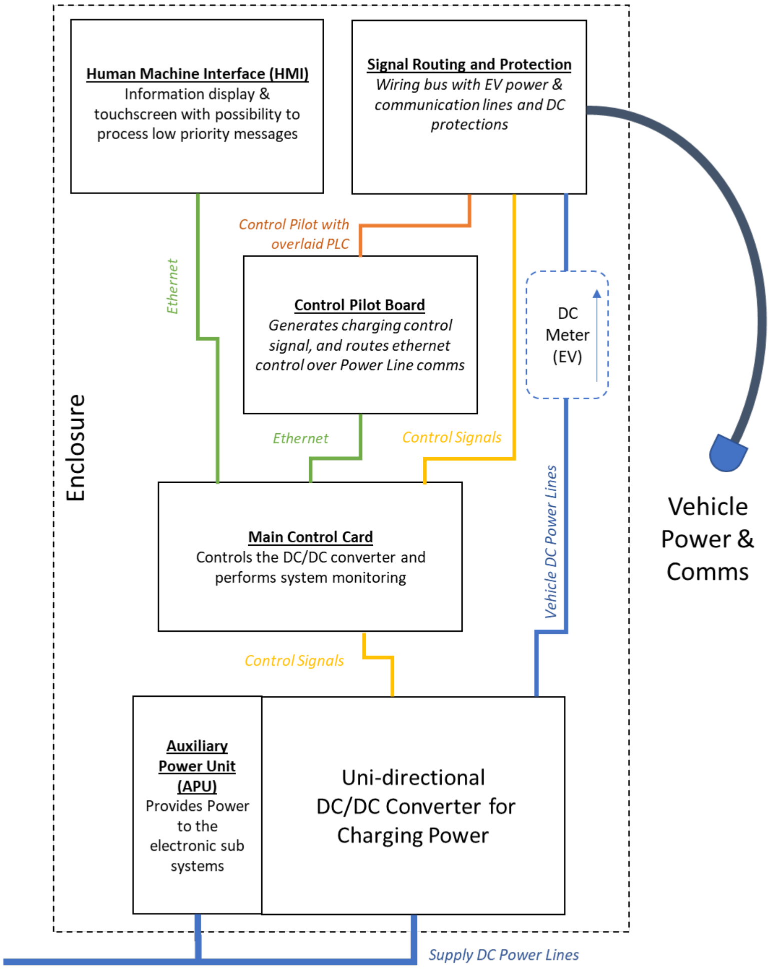


Figure 30, Charge point architecture.

Control System

The control scheme will ensure the GTIs share the load between them according to their relative load capability and provide support to heavily loaded transformers. Should the total load approach the available power capability then the chargers will be instructed to reduce their demand.

To establish these control features it will be necessary to have a control application in each substation that:

- Receives real time data on the power capacity available from the AC power transformation process within the substation; and
- Issues set points to the local inverter, exchanges data with a similar application in each of the other substations, and with the associated EV charging posts.

The control scheme will also have to set up to provide a safe and "graceful" response to the loss of primary plant or data.

To implement a control system that provides this functionality and performance a Remote Terminal Unit (RTU) will be required in each substation that:

- receives data from the AC plant at the substation,
- hosts the control application,
- issues set points to the inverter,
- communicates with the other substations via a router with optical interfaces connected via fibres running between the substations, laid with the power cables.

We propose to use a passive optical network for communications with the street charging posts. This would require a control box in each substation, a fibre to the first street charging post in a group where a passive optical splitter would be installed, and single fibres taken from the splitter to an optical network terminal installed in each charging post in the group. Communications would be based on ethernet protocol.

When the solution transfers to BaU the RTUs could also be connected to the network management system, though for the trial installation a standalone control system will be used.

10.4 Other international projects

Many manufacturers of EVs are integrating fast charging technology into their latest EVs on the market. There is an interest and ambition from the European Commission to enable consumer confidence in purchasing an EV with fast charging (20 – 99 kW) capability. As car manufacturers continue development into faster charging (up to 350 kW), EV charging stations around the world are beginning to prepare for the introduction of faster charging EVs, with examples such as EVgo[11] in northern California and IONITY[12] in Kent which both have 350 kW charging capability. PG&E in California has recently invested $20.1 million in a Fast Charge program, which has approval for DC fast-charging stations along highways and at park-and-ride locations, and for chargers for medium- and heavy-duty trucks, school buses, forklifts and other commercial and industrial EV.

There are a growing number of consortiums, such as "FastCharge", which is a project investigating the increase in charging capabilities to 450 kW.[13] The consortium consists mainly of manufacturers of EVs with the aim to increase charging capacity to 450 kW, which will enable a substantial reduction in charging times for consumers.

One of the largest fast charge projects in Europe was "fast E", which installed 307 fast 50 kW chargers across Belgium, Germany, Czech Republic and Slovakia.[14] The project consisted of 10 project partners, with charging stations located spread along highways, intermodal locations and retail locations. The aim of the project was to enable a comprehensive study of user behaviour and technical and business considerations ahead of a larger roll out of charging infrastructure in Europe.

Another project investigating fast charging is "Ultra E", which is installing 25 ultra-fast 350 kW charging stations across Austria, Belgium, Germany and the Netherlands.[15] The aim of the project is to facilitate long distance and cross border driving between major cities in Europe. The average distance between the ultra-fast charging stations is between 120 – 150 km.

There is a list of further fast charge projects within the report: "Roll out of public EV charging infrastructure in the EU".[16] The focus of the majority of the fast charge projects outlined in the report is user interaction when driving between different countries with the reduced charging times. There is also a project between National Grid and Pivot Power which is installing 50 MW of battery storage at substations connected directly to the transmission network to support 150 – 350 kW fast charging in the GB.[17]

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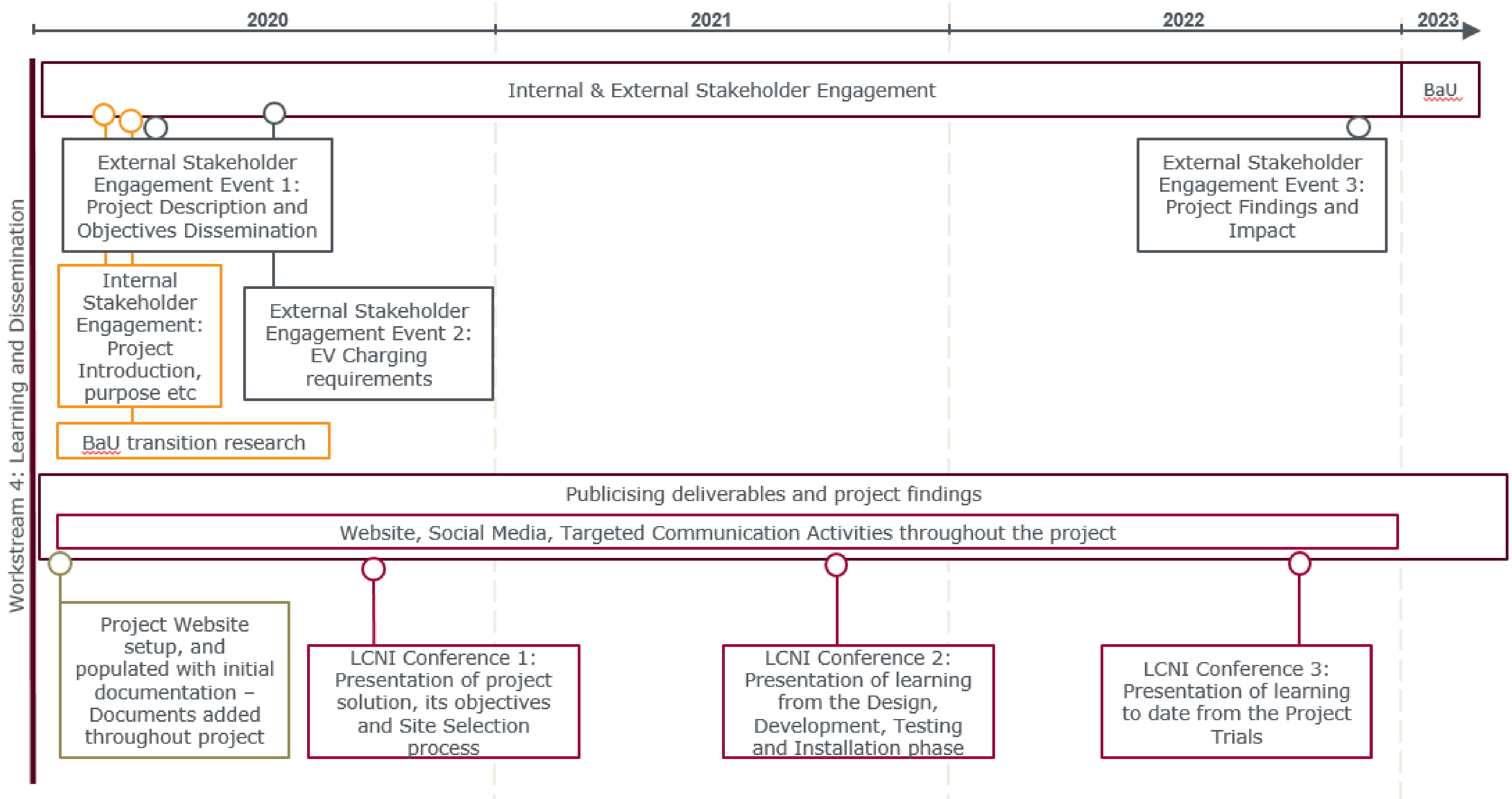
[11] https://www.greencarreports.com/news/1120518_evgo-launches-first-public-350-kw-fast-charger
[12] https://www.autoexpress.co.uk/car-news/101586/uk-s-first-350kw-ev-charging-station-opens-in-kent
[13] https://www.press.bmwgroup.com/global/article/detail/T0288583EN/research-project-%E2%80%9Cfastcharge%E2%80%9D:-ultra-fast-charging-technology-ready-for-the-electrically-powered-vehicles-of-the-future
[14] http://www.fast-e.eu/be-de/
[15] https://www.ultra-e.eu
[16] https://www.euractiv.com/wp-content/uploads/sites/2/2018/09/Charging-Infrastructure-Report_September-2018_FINAL.pdf
[17] https://www.pivot-power.co.uk/pivot-power-work-national-grid-future-proof-energy-system-accelerate-electric-vehicle-revolution/

Our research suggests that the challenge of meeting the demand for hubs of rapid chargers from the distribution network using a DC solution is not being considered elsewhere and apart from the use of storage and local PV generation, conventional reinforcement solutions would be adopted in a similar way to the Milton Keynes hub described in Section 2.

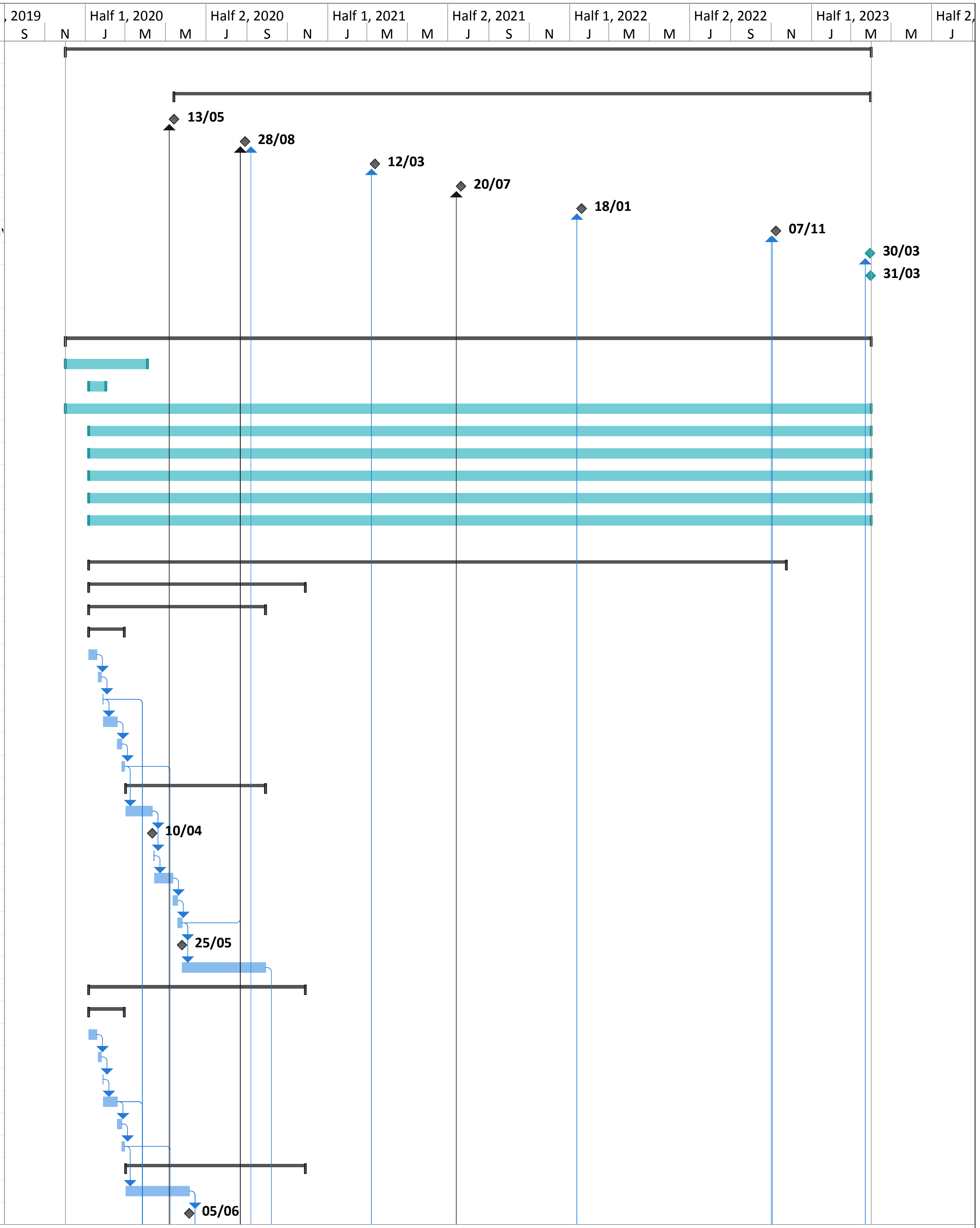
10.5 Dissemination time table



10.6 Programme, Risk Register/Contingency Plan

Programme

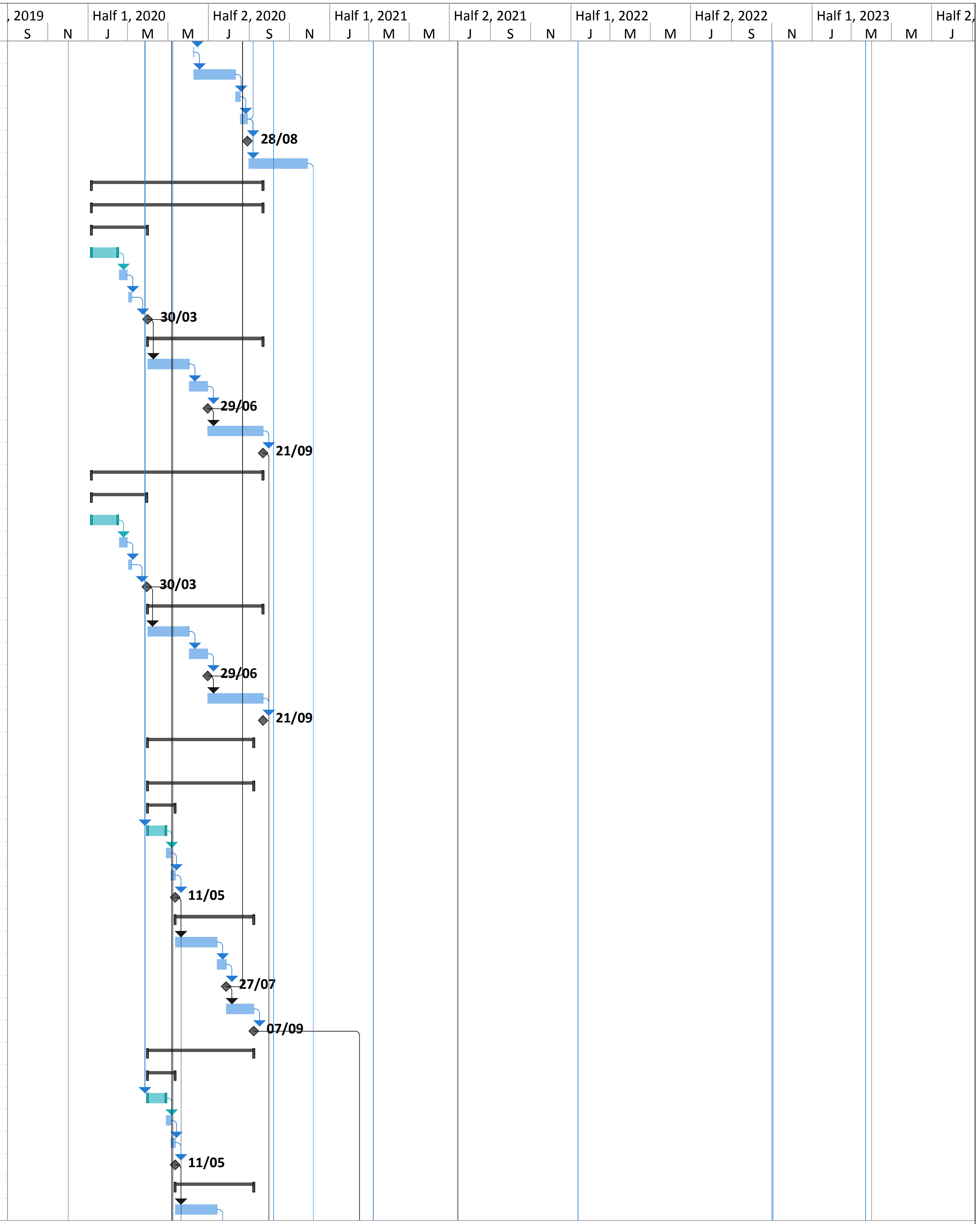
ID	Task Name	Duration	Start	Finish	Predecessors
1	**DC Share Project Plan**	**870 days**	**Mon 02/12/1**	**Fri 31/03/23**	
2					
3	**Project Milestones**	**751 days**	**Wed 13/05/2**	**Fri 31/03/23**	
4	Deliverable 1. Site Selection Completed	0 days	Wed 13/05/2	Wed 13/05/2	143FS+5 wks
5	Deliverable 2. Final System Design Report	0 days	Fri 28/08/20	Fri 28/08/20	39,56,69,81,94
6	Deliverable 3. Factory Acceptance	0 days	Fri 12/03/21	Fri 12/03/21	114FS+10 days
7	Deliverable 4. Installation Completion	0 days	Tue 20/07/2	Tue 20/07/2	121FS+45 days
8	Deliverable 5. Trial Interim Report	0 days	Tue 18/01/2	Tue 18/01/2	150FS+45 days
9	Deliverable 6. Trial Results Report and EV Charging Customer Experienc	0 days	Mon 07/11/2	Mon 07/11/2	152FS+45 days,164FS+10 da
10	Deliverable 7. Final Conclusions and BaU recommendation	0 days	Thu 30/03/2	Thu 30/03/2	201
11	Mandatory: Comply with knowledge transfer requirements of the Governance Document.	0 days	Fri 31/03/23	Fri 31/03/23	
12					
13	**Project Management**	**870 days**	**Mon 02/12/1**	**Fri 31/03/23**	
14	Contract Negotiation	90 days	Mon 02/12/1	Fri 03/04/20	
15	Mobilisation	20 days	Mon 06/01/2	Fri 31/01/20	
16	Ricardo Project Management	870 days	Mon 02/12/1	Fri 31/03/23	
17	WS1 Lead	845 days	Mon 06/01/2	Fri 31/03/23	
18	WS2 Lead	845 days	Mon 06/01/2	Fri 31/03/23	
19	WS3 Lead	845 days	Mon 06/01/2	Fri 31/03/23	
20	WS4 Lead	845 days	Mon 06/01/2	Fri 31/03/23	
21	WS5 Lead	845 days	Mon 06/01/2	Fri 31/03/23	
22					
23	**Workstream 1: Hardware Development and Deployment**	**753 days**	**Mon 06/01/2**	**Wed 23/11/2**	
24	**Specification, Design and Development of Novel hardware**	**235 days**	**Mon 06/01/2**	**Fri 27/11/20**	
25	**Interface Convertors**	**191 days**	**Mon 06/01/2**	**Mon 28/09/2**	
26	**Specification**	**40 days**	**Mon 06/01/2**	**Fri 28/02/20**	
27	Develop initial requirements	10 days	Mon 06/01/2	Fri 17/01/20	
28	Internal Review	5 days	Mon 20/01/2	Fri 24/01/20	27
29	Specification workshop	1 day	Mon 27/01/2	Mon 27/01/2	28
30	Draft specification production	15 days	Tue 28/01/2	Mon 17/02/2	29
31	Review	5 days	Tue 18/02/2	Mon 24/02/2	30
32	Finalised Specification	4 days	Tue 25/02/2	Fri 28/02/20	31
33	**Design and Development**	**151 days**	**Mon 02/03/2**	**Mon 28/09/2**	
34	Initial Design	30 days	Mon 02/03/2	Fri 10/04/20	32
35	Initial Component Order	0 days	Fri 10/04/20	Fri 10/04/20	34
36	Design Review workshop	1 day	Mon 13/04/2	Mon 13/04/2	34
37	Updates to Design	20 days	Tue 14/04/2	Mon 11/05/2	36
38	Review	5 days	Tue 12/05/2	Mon 18/05/2	37
39	Finalised Design	5 days	Tue 19/05/2	Mon 25/05/2	38
40	Follow up Component Order	0 days	Mon 25/05/2	Mon 25/05/2	39
41	Manufacture	90 days	Tue 26/05/2	Mon 28/09/2	39
42	**Charge Points**	**235 days**	**Mon 06/01/2**	**Fri 27/11/20**	
43	**Specification**	**40 days**	**Mon 06/01/2**	**Fri 28/02/20**	
44	Develop initial requirements	10 days	Mon 06/01/2	Fri 17/01/20	
45	Internal Review	5 days	Mon 20/01/2	Fri 24/01/20	44
46	Specification workshop	1 day	Mon 27/01/2	Mon 27/01/2	45
47	Draft specification production	15 days	Tue 28/01/2	Mon 17/02/2	46
48	Review	5 days	Tue 18/02/2	Mon 24/02/2	47
49	Finalised Specification	4 days	Tue 25/02/2	Fri 28/02/20	48
50	**Design and Development**	195 days	Mon 02/03/2	Fri 27/11/20	
51	Initial Design	70 days	Mon 02/03/2	Fri 05/06/20	49
52	Initial Component Order	0 days	Fri 05/06/20	Fri 05/06/20	51



Project: DC Share Project Plan v2.
Date: Fri 26/07/19

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline			
Split		External Tasks		Inactive Summary		Manual Summary		Progress			
Milestone		External Milestone		Manual Task		Start-only		Manual Progress			
Summary		Inactive Task		Duration-only		Finish-only					

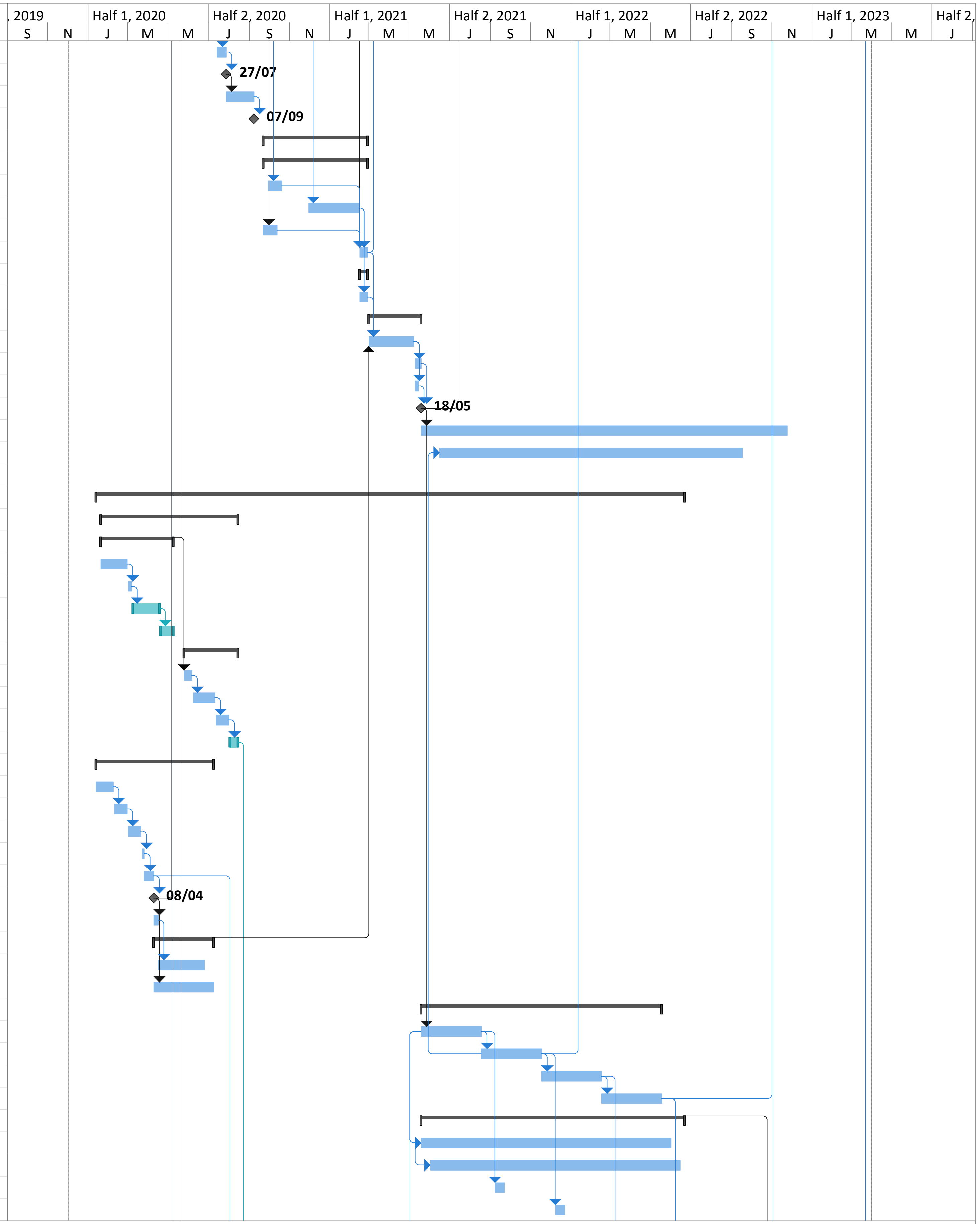
ID	Task Name	Duration	Start	Finish	Predecessors
53	Design Review workshop	1 day	Mon 08/06/2	Mon 08/06/2	51
54	Updates to Design	45 days	Tue 09/06/2(	Mon 10/08/2	53
55	Review	5 days	Tue 11/08/2(	Mon 17/08/2	54
56	Finalised Design	9 days	Tue 18/08/2(	Fri 28/08/20	55
57	Follow up Component Order	0 days	Fri 28/08/20	Fri 28/08/20	56
58	Manufacture	65 days	Mon 31/08/2	Fri 27/11/20	56
59	**Specification, Procurement and Manufacture of Control System**	**186 days**	**Mon 06/01/2**	**Mon 21/09/2**	
60	**Control System**	**186 days**	**Mon 06/01/2**	**Mon 21/09/2**	
61	**Specification**	**61 days**	**Mon 06/01/2**	**Mon 30/03/2**	
62	Develop initial requirements and system design	30 days	Mon 06/01/2	Fri 14/02/20	
63	Internal Review	10 days	Mon 17/02/2	Fri 28/02/20	62
64	Updates to Specification	5 days	Mon 02/03/2	Fri 06/03/20	63
65	Finalised Specification	0 days	Mon 30/03/2	Mon 30/03/2	64
66	**Procurement, Manufacture and Delivery**	**125 days**	**Tue 31/03/2(**	**Mon 21/09/2**	
67	Tender issue and response period	45 days	Tue 31/03/2(	Mon 01/06/2	65
68	Tender Review	20 days	Tue 02/06/2(	Mon 29/06/2	67
69	Contract award	0 days	Mon 29/06/2	Mon 29/06/2	68
70	Manufacture	60 days	Tue 30/06/2(	Mon 21/09/2	69
71	Equipment Complete	0 days	Mon 21/09/2	Mon 21/09/2	70
72	**Communication network**	**186 days**	**Mon 06/01/2**	**Mon 21/09/2**	
73	**Specification**	**60 days**	**Mon 06/01/2**	**Mon 30/03/2**	
74	Develop initial requirements and system design	30 days	Mon 06/01/2	Fri 14/02/20	
75	Internal Review	10 days	Mon 17/02/2	Fri 28/02/20	74
76	Updates to Specification	5 days	Mon 02/03/2	Fri 06/03/20	75
77	Finalised Specification	0 days	Mon 30/03/2	Mon 30/03/2	76
78	**Procurement, Manufacture and Delivery**	**125 days**	**Tue 31/03/2(**	**Mon 21/09/2**	
79	Tender issue	45 days	Tue 31/03/2(	Mon 01/06/2	77
80	Tender Review	20 days	Tue 02/06/2(	Mon 29/06/2	79
81	Contract award	0 days	Mon 29/06/2	Mon 29/06/2	80
82	Manufacture	60 days	Tue 30/06/2(	Mon 21/09/2	81
83	Equipment Delivery	0 days	Mon 21/09/2	Mon 21/09/2	82
84	**Specification, Procurement and Manufacture of DC Cable System and Ancillary equipment**	**115 days**	**Tue 31/03/20**	**Mon 07/09/20**	
85	**Cable System**	**115 days**	**Tue 31/03/2(**	**Mon 07/09/2**	
86	**Specification**	**30 days**	**Tue 31/03/2(**	**Mon 11/05/2**	
87	Develop initial requirements and system design	20 days	Tue 31/03/2(	Mon 27/04/2	29,47
88	Internal Review	5 days	Tue 28/04/2(	Mon 04/05/2	87
89	Updates to Specification	5 days	Tue 05/05/2(	Mon 11/05/2	88
90	Finalised Specification	0 days	Mon 11/05/2	Mon 11/05/2	89
91	**Procurement, Manufacture and Delivery**	**85 days**	**Tue 12/05/2(**	**Mon 07/09/2**	
92	Tender issue and response period	45 days	Tue 12/05/2(	Mon 13/07/2	90
93	Tender Review	10 days	Tue 14/07/2(	Mon 27/07/2	92
94	Contract award	0 days	Mon 27/07/2	Mon 27/07/2	93
95	Manufacture	30 days	Tue 28/07/2(	Mon 07/09/2	94
96	Equipment Delivery	0 days	Mon 07/09/2	Mon 07/09/2	95
97	**Ancillary Equipment (Switchgear, connectors etc)**	**115 days**	**Tue 31/03/2(**	**Mon 07/09/2**	
98	**Specification**	**30 days**	**Tue 31/03/2(**	**Mon 11/05/2**	
99	Develop initial requirements and system design	20 days	Tue 31/03/2(	Mon 27/04/2	29,47
100	Internal Review	5 days	Tue 28/04/2(	Mon 04/05/2	99
101	Updates to Specification	5 days	Tue 05/05/2(	Mon 11/05/2	100
102	Finalised Specification	0 days	Mon 11/05/2	Mon 11/05/2	101
103	**Procurement, Manufacture and Delivery**	**85 days**	**Tue 12/05/2(**	**Mon 07/09/2**	
104	Tender issue and response period	45 days	Tue 12/05/2(	Mon 13/07/2	102



Project: DC Share Project Plan v2.
Date: Fri 26/07/19

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline					
Split	External Tasks	Inactive Summary	Manual Summary	Progress					
Milestone	External Milestone	Manual Task	Start-only	Manual Progress					
Summary	Inactive Task	Duration-only	Finish-only						

ID	Task Name	Duration	Start	Finish	Predecessors
105	Tender Review	10 days	Tue 14/07/2(	Mon 27/07/2	104
106	Contract award	0 days	Mon 27/07/2	Mon 27/07/2	105
107	Manufacture	30 days	Tue 28/07/2(	Mon 07/09/2	106
108	Equipment Delivery	0 days	Mon 07/09/2	Mon 07/09/2	107
109	**System Testing**	**114 days**	**Tue 22/09/2(**	**Fri 26/02/21**	
110	**Factory Testing**	**114 days**	**Tue 22/09/2(**	**Fri 26/02/21**	
111	Interface Convertors	15 days	Tue 29/09/2(	Mon 19/10/2	41
112	Charge Points	55 days	Mon 30/11/2	Fri 12/02/21	58
113	Control System	15 days	Tue 22/09/2(	Mon 12/10/2	71
114	Integrated System Testing	10 days	Mon 15/02/2	Fri 26/02/21	111,112,113,96
115	**Certification**	**10 days**	**Mon 15/02/2**	**Fri 26/02/21**	
116	Certification of compliance with relevant standards	10 days	Mon 15/02/2	Fri 26/02/21	112
117	**Installation & Commissioning**	**57 days**	**Mon 01/03/2**	**Tue 18/05/2**	
118	Installation of Trial Network	10 wks	Mon 01/03/2	Fri 07/05/21	114,145,116
119	Commissioning of Trial Network	7 days	Mon 10/05/2	Tue 18/05/2	118
120	Configuration of Communications Network and Data Historian	5 days	Mon 10/05/2	Fri 14/05/21	118
121	Completion of Commissioning	0 days	Tue 18/05/2	Tue 18/05/2	119,120
122	Ongoing Development and Support	396 days	Wed 19/05/2	Wed 23/11/2	121
123	System Modifications	328 days	Wed 16/06/2	Fri 16/09/22	150SS-45 days
124					
125	**Workstream 2: Trials and Analysis**	**637 days**	**Mon 13/01/2**	**Tue 21/06/2**	
126	**Detailed Use Case development**	**150 days**	**Mon 20/01/2**	**Fri 14/08/20**	
127	**High Level Use Cases development**	**80 days**	**Mon 20/01/2**	**Fri 08/05/20**	
128	Develop Initial Use Cases	30 days	Mon 20/01/2	Fri 28/02/20	
129	Internal Review	5 days	Mon 02/03/2	Fri 06/03/20	128
130	Stakeholder Review	30 days	Mon 09/03/2	Fri 17/04/20	129
131	Complete Initial Use Cases	15 days	Mon 20/04/2	Fri 08/05/20	130
132	**Detailed Use Case development**	**60 days**	**Mon 25/05/2**	**Fri 14/08/20**	
133	Stakeholder Workshops	10 days	Mon 25/05/2	Fri 05/06/20	127FS+10 days
134	Develop Detailed Use Cases	25 days	Mon 08/06/2	Fri 10/07/20	133
135	Stakeholder Review of Use Cases	15 days	Mon 13/07/2	Fri 31/07/20	134
136	Complete Detailed Use cases	10 days	Mon 03/08/2	Fri 14/08/20	135
137	**Site Selection & Trial Design**	**128 days**	**Mon 13/01/2**	**Wed 08/07/2**	
138	Produce Site Selection process	20 days	Mon 13/01/2	Fri 07/02/20	
139	Gather data	15 days	Mon 10/02/2	Fri 28/02/20	138
140	Analysis	15 days	Mon 02/03/2	Fri 20/03/20	139
141	Produce Short List of Sites	3 days	Mon 23/03/2	Wed 25/03/2	140
142	Site Engagement and Visits	10 days	Thu 26/03/2(	Wed 08/04/2	141
143	Site Selected	0 days	Wed 08/04/2	Wed 08/04/2	142
144	Site Survey	5 days	Thu 09/04/2(	Wed 15/04/2	143
145	**Trial Design work and applications**	**65 days**	**Thu 09/04/2(**	**Wed 08/07/2**	
146	Design installation requirements	50 days	Thu 16/04/2(	Wed 24/06/2	144
147	Planning Permission Process	13 wks	Thu 09/04/2(	Wed 08/07/2	143
148	**Trial**	**260 days**	**Wed 19/05/2**	**Tue 17/05/2**	
149	Trial (Phase 1)	13 wks	Wed 19/05/2	Tue 17/08/2	121
150	Trial (Phase 2)	13 wks	Wed 18/08/2	Tue 16/11/2	149
151	Trial (Phase 3)	13 wks	Wed 17/11/2	Tue 15/02/2	150
152	Trial (Phase 4)	13 wks	Wed 16/02/2	Tue 17/05/2	151
153	**Trial Analysis and Review**	**285 days**	**Wed 19/05/2**	**Tue 21/06/2**	
154	Data Collection	270 days	Wed 19/05/2	Tue 31/05/2	149SS
155	Analysis	270 days	Wed 02/06/2	Tue 14/06/2	154SS+10 days
156	Phase 1 result document	10 days	Wed 08/09/2	Tue 21/09/2	149FS+15 days
157	Phase 2 result document	10 days	Wed 08/12/2	Tue 21/12/2	150FS+15 days

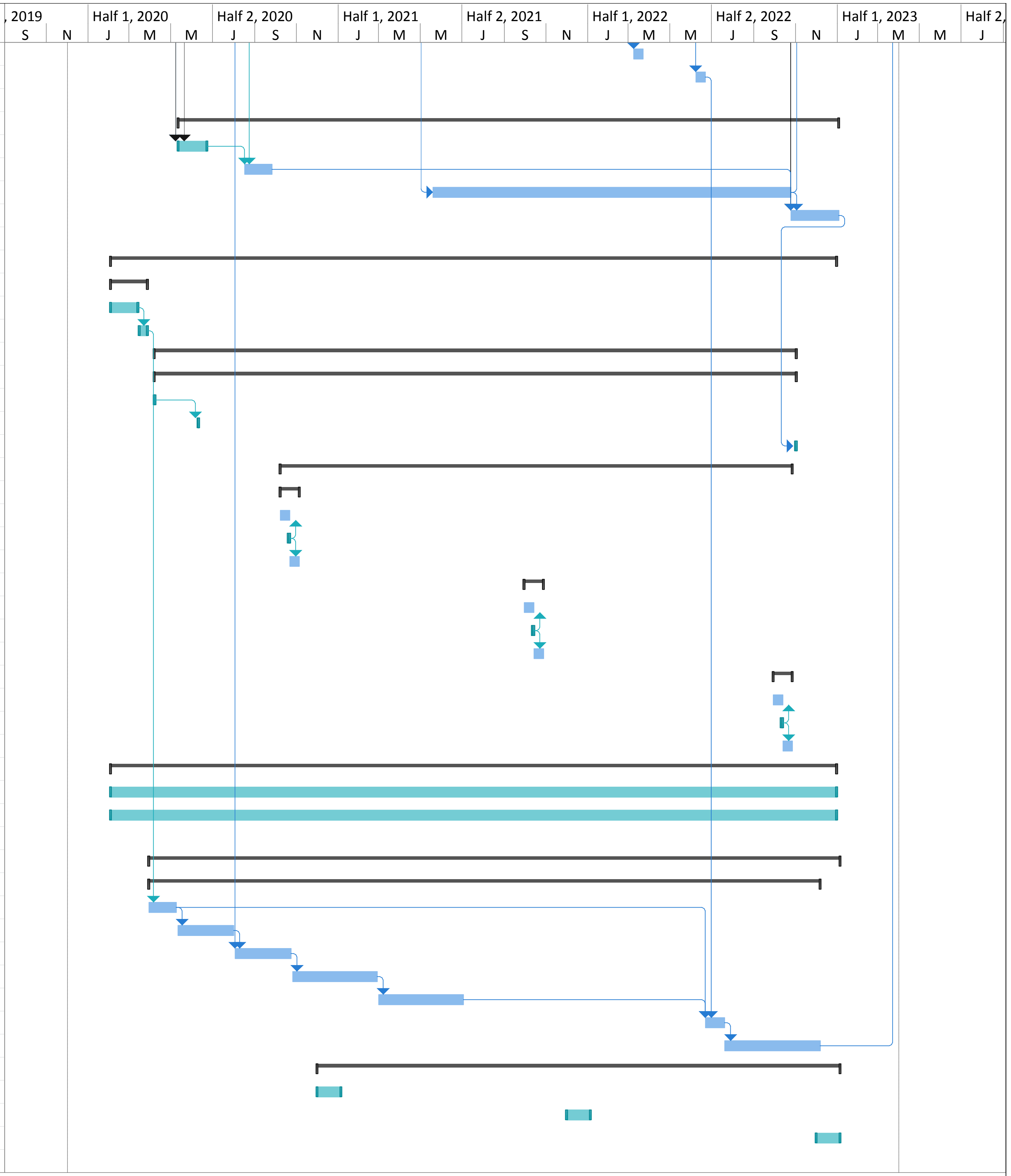


Project: DC Share Project Plan v2.
Date: Fri 26/07/19

Task	Project Summary	Inactive Milestone	Manual Summary Rollup
Split	External Tasks	Inactive Summary	Manual Summary
Milestone	External Milestone	Manual Task	Start-only
Summary	Inactive Task	Duration-only	Finish-only

Deadline
Progress
Manual Progress

ID	Task Name	Duration	Start	Finish	Predecessors
158	Phase 3 result document	10 days	Wed 09/03/2	Tue 22/03/2:	151FS+15 days
159	Phase 4 result document	10 days	Wed 08/06/2	Tue 21/06/2:	152FS+15 days
160					
161	**Workstream 3 : System Benefits and Limitations**	**690 days**	**Tue 12/05/2(**	**Mon 02/01/2**	
162	System Benefits and Limitations Definition	30 days	Tue 12/05/2(	Mon 22/06/2	32,49,65,77,90,102
163	Business Case assumptions and scenario review	30 days	Mon 17/08/2	Fri 25/09/20	162,136
164	EV Charging Customer Survey and Results	374 days	Wed 19/05/2	Mon 24/10/2	149SS
165	Business Case Review	50 days	Tue 25/10/2:	Mon 02/01/2	163,153,164
166					
167	**Workstream 4: Learning & Dissemination**	**760 days**	**Mon 03/02/2**	**Fri 30/12/22**	
168	**Internal Stakeholder Engagement (WPD and ENW)**	**40 days**	**Mon 03/02/2**	**Fri 27/03/20**	
169	General Engagement (Project Introduction, purpose, etc.)	30 days	Mon 03/02/2	Fri 13/03/20	
170	BaU transistion research	10 days	Mon 16/03/2	Fri 27/03/20	169
171	**External Stateholder Engagement**	**671 days**	**Tue 07/04/2(**	**Tue 01/11/2:**	
172	**Project Events**	**671 days**	**Tue 07/04/2(**	**Tue 01/11/2:**	
173	Engagement Event 1: Project Description and Objectives Dissemin	1 day	Tue 07/04/2(	Tue 07/04/2(	
174	Engagement Event 2: EV Charging requirements	1 day	Wed 10/06/2	Wed 10/06/2	173FS+45 days
175	Engagement Event 3: Project Findings and Impact	1 day	Tue 01/11/2:	Tue 01/11/2:	165FS+45 days
176	**LCNI Conferences**	**535 days**	**Thu 08/10/2(**	**Wed 26/10/2**	
177	**LCNI Conference 2020**	**20 days**	**Thu 08/10/2(**	**Wed 04/11/2**	
178	Prepare Material	10 days	Thu 08/10/2(	Wed 21/10/2	179FS-10 days
179	Attendance and Presentation	2 days	Tue 20/10/2(	Wed 21/10/2	
180	Follow up actions and engagement	10 days	Thu 22/10/2(	Wed 04/11/2	179
181	**LCNI Conference 2021**	**20 days**	**Thu 30/09/2:**	**Wed 27/10/2**	
182	Prepare Material	10 days	Thu 30/09/2:	Wed 13/10/2	183FS-10 days
183	Attendance and Presentation	2 days	Tue 12/10/2:	Wed 13/10/2	
184	Follow up actions and engagement	10 days	Thu 14/10/2:	Wed 27/10/2	183
185	**LCNI Conference 2022**	**20 days**	**Thu 29/09/2:**	**Wed 26/10/2**	
186	Prepare Material	10 days	Thu 29/09/2:	Wed 12/10/2	187FS-10 days
187	Attendance and Presentation	2 days	Tue 11/10/2:	Wed 12/10/2	
188	Follow up actions and engagement	10 days	Thu 13/10/2:	Wed 26/10/2	187
189	**Publicising deliverables and project findings**	**760 days**	**Mon 03/02/2**	**Fri 30/12/22**	
190	Website and Social Media activities	760 days	Mon 03/02/2	Fri 30/12/22	
191	Targeted Communications	760 days	Mon 03/02/2	Fri 30/12/22	
192					
193	**Workstream 5: Project Reporting, BaU Recommendations and Close out**	**723 days**	**Mon 30/03/2**	**Wed 04/01/2**	
194	**Business as Usual Handover**	**702 days**	**Mon 30/03/2**	**Tue 06/12/2:**	
195	Existing Process Mapping	30 days	Mon 30/03/2	Fri 08/05/20	170
196	Stakeholder engagement	60 days	Mon 11/05/2	Fri 31/07/20	195
197	Process design	60 days	Mon 03/08/2	Fri 23/10/20	196,142
198	Procedure and Specification production	90 days	Mon 26/10/2	Fri 26/02/21	197
199	Review period	90 days	Mon 01/03/2	Fri 02/07/21	198
200	Updates	20 days	Wed 22/06/2	Tue 19/07/2:	199,159,195
201	Handover	100 days	Wed 20/07/2	Tue 06/12/2:	200
202	**Project Reporting**	**547 days**	**Tue 01/12/2(**	**Wed 04/01/2**	
203	2020 Annual Progress Report	25 days	Tue 01/12/2(	Mon 04/01/2	
204	2021 Annual Progress Report	25 days	Wed 01/12/2:	Tue 04/01/2:	
205	Closedown Report	25 days	Thu 01/12/2:	Wed 04/01/2	
206					



Project: DC Share Project Plan v2.
Date: Fri 26/07/19

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only		Manual Progress	
Summary		Inactive Task		Duration-only		Finish-only			

Risk Register/Contingency Plan

During planning of this proposal for NIC funding we have produced a comprehensive Risk Register which is updated frequently as a living document, even in the period between proposal submission and Ofgem award decision. Below is a summary of that Risk Register.

Ref	Description	Impact	Probability	Severity	Rating	Mitigation/Comments
R1	Technology development and/or deployment issues. Delays or technical barriers to development of power electronics (converters, chargers) and/or control/communications systems	Outputs delayed, potential overspend could require additional partner and/or Ofgem contributions.	2	3	6	Detailed discussions with all partners and some potential suppliers during ISP and FSP stages. TPS converters and chargers are developments of existing products. TPS manage risk around the supply and cost of SiC in the converters for a number of their projects and can source the SiC on project commencement. The communication and control system for the trial will be standalone and will be able to be tested offline and so represents low risk.
R2	Delays caused by town planning	Outputs delayed	2	3	6	Partnering with Vectos transport planners who are very experienced in transport planning. Vectos will act as an expert interface between the charger designers (TPS) and local authority Town Planners, resulting in a high level of empathetic cooperation to ensure all parties' needs are met in good time

Ref	Description	Impact	Probability	Severity	Rating	Mitigation/Comments
R3	Poor engagement with public and commercial operators. Low usage of charging points. Low responses to surveys	Risk of lack of engagement with the target users would result in lower quality of learning data than expected	2	3	6	Commercial operators may be encouraged by licence issuers (e.g. local authorities). We have developed site selection criteria which will focus on small commercial van fleet operators and taxis to ensure we get the usage during the trial. General public engagement could be slightly more difficult or present a false demographic of potential users. Although the target demographics will certainly be interested, will they probably not purchase an EV at this stage until fast charging is more commonplace. The general public users are therefore more likely to be existing EV users who have their own charger at home and are attracted by "free/convenient power" while doing another activity such as shopping. Obtaining survey responses from users can sometimes present problems but Ricardo have extensive experience in such activities in many sectors including EV usage surveys.
R4	Solution does not meet UK standards (CE marking, Harmonic limits etc.)	System unavailable for use outside of laboratory conditions. Outputs delayed, potential overspend	1	4	4	TPS are developing chargers and develop other equipment so have experience of being compliant with CE and other standards.

Ref	Description	Impact	Probability	Severity	Rating	Mitigation/Comments
R5	Injury to the public, damage to public property, DNO property or local authority property. Caused by malfunction of equipment (power electronics, DC ring or chargers) or civil works	Serious impact on DNO and/or Customers	1	5	5	Both the charger and the converter to be developed and supplied by TPS who have extensive experience in protecting users and adjacent systems. For the civil engineering works, Western Power Distribution will employ known contractors familiar with GB safe working practices. Control system will be specified with safety as number-one criteria. The control system will monitor the substation transformer loading.

10.7 Project Team

DC Share will be organised with a Western Power Distribution Project Sponsor who will have overall accountability for the project. The project sponsor will ensure that DC Share delivers to our customers and to Ofgem the technical and learning benefits described in this proposal.

The Project Management function will be responsible for day to day running of DC Share and will comprise a person from Western Power Distribution and a person from Ricardo. The function includes but is not limited to reviewing the project progress against plan, presenting the project progress report to the Project Steering Group, updating the project plan, monitoring project risks and project budget. Western Power Distribution will manage DNO related day to day issues and Ricardo will manage delivery of the Workstreams.

Advising the Project Management function will be a Design Authority and a Project Steering Group.

The Design Authority will comprise Stakeholders from the DNOs, Ricardo, TPS, Vectos and other key partners as they are brought into the project. The Design Authority reviews and approves all key project deliverables.

However, ultimate responsibility for the delivery of the solution rests with the project delivery team. On the DC Share project this role will be fulfilled by a partnership of key staff from Western Power Distribution, Electricity North West, Ricardo, TPS and Vectos.

The Project Steering group will comprise senior technical staff from the DNOs and Ricardo. This group is ultimately responsible for the project and will make decisions that have an overall impact on the benefits and outputs that the project will deliver. Currently we have identified three key figures but we plan to include a wider expertise base, potentially including other DNOs, energy consultants/policy experts (Ricardo and elsewhere), local authority planners and EV manufacturers. Several candidates have been identified during preparation of this FSP and discussions will continue as Ofgem consider the proposal.

Each of the five identified Worksteams will be allocated a leader and will have key staff with specific technical expertise, although obviously each of the partner companies have many other staff who will also contribute as needed.

Please refer to the full organogram in Figure 18.

Western Power Distribution

Western Power Distribution is the DNO responsible for electricity distribution in the Midlands, South West and Wales. Western Power Distribution will be project sponsors for DC Share and will be responsible for delivering the full benefits to their customers and to Ofgem.

Key Western Power Distribution Staff

Carl Ketley-Lowe is the Engineering Policy Manager within Western Power Distribution and has been working in the electricity distribution industry for over 20 years. He joined the company as an overhead lines apprentice in 1994 and has had various operational and non-operational roles within the business. He has had regulatory reporting responsibilities for two licence areas, team management responsibility for geographical operational teams as well as fault management and contingency planning experience. He is presently responsible for Engineering Policy within Western Power Distribution and the formal training programmes including craft apprenticeships.

Ricky Duke has worked in the electricity distribution industry and for Western Power Distribution for the last 11 years, and is currently an Innovation and Low Carbon Network Engineer within the Future Networks team. Joining the company in 2008 as an apprentice cable jointer based at Taunton, he completed an apprenticeship and took up a role as a craftsmen jointer working up on systems up to 33kV in the Sedgemoor team. Ricky then progressed to Training engineer, teaching underground systems and operation at Western Power Distribution's Taunton training centre, before joining the innovation team in 2018 where he now project manages EV innovation projects such as Electric Nation.

Jonathan Berry is Innovation Team Manager at Western Power Distribution and has worked in the electricity distribution industry since 2006, where he previously focussed on a number of technical areas including re-generation infrastructure planning and renewable generation integration. He now leads a team investigating innovative technologies, commercial methodologies and applications through research, development and demonstration projects, principally funded through GB's energy regulator, Ofgem's Network Innovation Allowance and Competition mechanisms.

Andrew Reynolds is the Policy Engineer for Transformers within Western Power Distribution and has worked in the industry from 2003, he has had several roles from Project Managing asset replacement projects from LV link boxes up to 33KV network reinforcement, to failure investigation of network assets, his current role covers specification of all transformer related assets and their maintenance tasks, he also covers noise assessments and plays a vital role in the practical solving of noise related problems for Western Powers Customers. He is still active on the company's standby rota and deals with external bodies and suppliers.

Electricity North West

Electricity North West is the DNO responsible for electricity distribution in the North West England. Electricity North West will provide valuable consultancy from the point of view of another DNO to complement the knowledge brought by Western Power Distribution. The Electricity North West region has a wide variety of customers in areas of heavy industry, high-tech industry, major cities and rural areas.

Key Electricity North West Staff

Paul Turner is Innovation Manager at Electricity North West. Paul has nearly 20 years of experience in the electricity industry. He has a degree in electrical and electronic engineering from Nottingham University and is an authorised control engineer. Since joining United Utilities (subsequently Electricity North West) as a graduate engineer in 1999, he has carried out a variety of roles in the control environment such as outage planning manager and automation development manager. After joining the innovation team in 2012 as technical manager, Paul became innovation manager in 2014 and is now responsible for the delivery of our multi-million pound portfolio of innovation projects.

Dr Geraldine Paterson is the Innovation Strategy & Transition Engineer at Electricity North West. Geraldine joined United Utilities (subsequently Electricity North West) as a graduate engineer in 1998. She has a BEng in electrical and electronic engineering and a PhD in design of generators from Queen's University, Belfast. After a role in the policy and standards team, Geraldine joined the innovation team in 2012 to provide technical expertise for our portfolio of low carbon projects. Geraldine also project manages a range of NIA projects and helps transition all of our projects into business as usual. She provides technical input to the development and submission of our flagship innovation projects and was part of the team which gained funding to deliver CLASS, Smart Street, Respond and Celsius.

Ricardo Energy & Environment

Ricardo is a global strategic, technical and environmental consultancy, and a specialist niche manufacturer of high-performance products. The company employs over 2,000 professional engineers, consultants and scientists who are committed to delivering outstanding projects focused on class-leading innovation.

Ricardo has significant experience of working on NIC projects, including leading work streams, and it has relevant skills in each of the key project roles. Ricardo have been an active project partner and taken lead roles in the development and implementation of a number of Low Carbon Network Fund and NIC projects such as Distribution Network Visibility, Smart Urban LV Networks, Flexible Urban Networks -LV, Celsius and Active Response. Areas where Ricardo have led are the design and management of technical trials on electricity networks, the have developed data storage and management platforms and the collection, management, visualisation and analysis of large data sets. Ricardo have experience in developing input and recommendations into business as usual practices and processes.

Ricardo will have several key roles within the project consisting of both technical and project management across all work streams. Ricardo will act as project manager and will lead four of the five work streams:

- ***Workstream 2: Trials and Analysis***
- ***Workstream 3: System Benefits and Limitations***
- ***Workstream 4: Learning & Dissemination***
- ***Workstream 5: Project Reporting, BaU Recommendations and Close out***

Ricardo will participate in the following technical activities:
- Hardware and software specification and design
- Specification, tendering and procurement of software, communication system, DC cabling and ancillary equipment
- Site Selection
- Trial design and management
- Technical analysis
- Development of recommendations
- Dissemination of learning and results

Key Ricardo Personnel

Nick Ash is a Chartered Engineer with 13 years of experience in the energy sector and Masters studies in energy economics and policy. Nick has experience in multiple energy subsectors, with an emphasis on electricity generation, markets and regulation. Nick has worked on projects involving renewables, biomass, natural gas, coal, hydro, waste-to-energy, district cooling, sustainable heat and smart grids. Clients and partners have included regulators, utilities, developers, NGOs and public-sector agencies across the full range of the project lifecycle from strategic planning through implementation to operation. He has also lectured on project management, electricity generation technologies and electricity markets. Nick is currently the Ricardo project manager for the NIC Active Response project.

Simon Terry is a Chartered Electrical Engineer with 20 years of industry experience within both Utilities and Consultancy. He has led and worked within teams responsible for a broad range of Electricity projects, from identification of the need case and establishing viability to the detailed design and commissioning phases. Simon has extensive experience of various aspects of Power Systems, specialising in Protection and Control on Transmission and Distribution Networks. Simon holds authorisations to National Grid TP141 in Protection & Control Design, Commissioning and Protection Settings. He has an excellent working knowledge of HV Plant, Power Systems Design and Operation, Project Management, and was previously an "Authorised Person" for National Grid affording an in depth understanding of the Operational and Safety procedures used in the UK Electricity Supply Industry. Simon has been involved in a broad range of activities, including the scoping and delivery of Network Innovation Competition/Allowance projects with Distribution Network Operators and is currently the Ricardo technical lead on the NIC Active Response project.

Olivia Carpenter-Lomax is a Chartered electrical engineer who specialises in innovation within energy networks and future energy systems with a particular focus on business benefits modelling and BaU adoption, a recent example being the Celsius project. She has held the role of bid lead, project manager, and technical lead for several significant projects including technical network innovation projects, and future energy system projects. Olivia is the Ricardo project manager of the NIC Celsius project.

Sarah Carter is a Chartered Engineer with over 25 years of experience in power consultancy and project management. Sarah has had responsibility for and been involved with a wide variety of projects associated with smart networks for UK Distribution Network Operators. These include the Smart Grid Forum Distribution 2030 study; several Low Carbon Network Innovation projects including consideration of the development of network visibility tools to enhance technical and commercial decision making by system operators and planners; as well as projects involved with condition monitoring of equipment and the consideration of future power supply options. Sarah is currently the Ricardo Project Director for the Active Response and Celsius NIC projects and is assisting the Energy Networks Association (ENA) with the implementation of the European Network Codes and their integration with the existing GB distribution documents. Prior to joining the Energy Practice in 2005, Sarah worked for Parsons Brinkerhoff where she gained considerable experience in power system studies to plan and analyse transmission, distribution and industrial power systems across the world.

Trevor Glue is a qualified (BA Hons Marketing) and experienced marketing professional who has been responsible for strategic marketing and brand development, as well as tactical delivery. He has been responsible for marketing delivery through direct and indirect channels around the world. Particular skills include: web design, build and management, collateral development, copy writing, lead generation, data management and marketing analytics. Trevor has held a number of management roles within marketing; managing both local and international marketing professionals.

Denis Naberezhnykh is a Technical Director Sustainable Transport in 2018. His focus is on vehicle technologies and alternative fuels, including electric vehicles, and connected and automated vehicles. Prior to joining Ricardo Energy and Environment, Denis worked at Transport Research Laboratory (TRL) for over 9 years where he was the Head of Ultra Low Emission Vehicles and Energy since 2016, overseeing the development and execution of TRL Ultra Low Emission Vehicles and Energy strategy and ensuring TRL thought leadership in this area. Prior to that Denis was the Head of ITS and Ultra Low Emission Vehicle Technology. Notable areas of Denis' work include research into EV adoption and related modelling, the distribution of charging infrastructure and the costs and benefits of ULEVs in fleets. Denis was involved in world-leading demonstrations of the feasibility and potential benefits of smart EV charging, as well as in-depth research into EV consumer and user attitudes and charging behaviour. He was also the technical lead for the monitoring and evaluation of the UK Low Emission Bus Scheme programme, being undertaken on behalf of the Department for Transport, to evaluate the performance and impact of different low emission bus technologies including, electric, hydrogen fuel cell, gas and hybrid.

Tim Skelton, MSc is an Associate Technical Director at Ricardo with over 30 years of relevant experience in the field. He spent the early portion of his career supervising the Electrical and C&I aspects of power plant installation and commissioning including gas, steam and diesel generating plants. More recently Tim has produced feasibility studies, conceptual designs, requirements specifications, tender documents, and tender evaluation reports for SCADA, EMS and DMS systems. He has a good knowledge of the electrical power industry and the operational and management structures and processes involved in running a power network. These projects have provided Tim with an in-depth appreciation of the functionality and performance that can be delivered by modern SCADA, EMS and DMS systems and is familiar with the products of the main vendors in the field. Tim has overseen the successful delivery of many control and monitoring projects associated with the production transmission and distribution of electrical energy including the delivery of three national control centre schemes for managing country wide electrical transmission networks.

Nathaniel Bottrell, MEng, PhD joined Ricardo having previously worked on innovation projects with UK Power Networks while as a post-doctoral researcher at Imperial College London. Nathaniel has been involved with the Smart Urban Low Voltage and Flexible Urban Networks-LV projects and is currently a key team member in the Active Response NIC project. His competences are in power electronics hardware and their controllers, modelling and analysis of power electronics, modelling and analysis of microgrids, integration of power electronics into the distribution network and technical analysis for distribution projects. Nathaniel is project manager for the technical workstream assisting UKPN's V2G Transpower project.

Turbo Power Systems Ltd (TPS)

TPS design and manufacture world class power conversion systems using cutting edge technology. They have relevant experience in the delivery of power converters for use on public LV distribution networks through their role on the UKPN's FUN-LV and Active Response projects. Furthermore, they have experience of developing and manufacturing High Voltage products in the form of power supplies for laser cutting with operating voltage ranges of 35 to 50kV. TPS will provide the power converters and associated electrical equipment for use on DC Share.

TPS will lead Workstream 1: Hardware Development and Deployment.

Key TPS Personnel

Dr Nigel Jakeman is Engineering and Business Development Director at TPS. Nigel is responsible for the delivery of custom design power converters to market sectors including Rail, Industrial and Energy. After qualifying with PhD from the University of Sheffield, he worked for Cummins Generator Technologies as both Electromagnetic Design Engineer and Design for Six Sigma Black Belt before co-founding the start-up company GenDrive Ltd where under his watch as Managing Director the company delivered to market a range of unique Grid Tied Converters for Wind Turbines.

Dr Artur Krasnodebski is Engineering Manager for Energy at TPS. Artur is responsible for the technical execution of Smart Grid programs. Holding PhD from University of Warsaw, he worked at Cummins Generator Technologies delivering Variable Speed Generator converters for Military applications before joining GenDrive Limited as Technical Director taking responsibility for technical execution of Grid Tied converters for wind turbine applications. After several years working for Ecotricity, he joined TPS in 2018 to lead the engineering energy team who have a number of active project programs in the fields of Smart Grid, Electric Vehicle charging, Energy Efficiency and Energy Infrastructure.

Graeme Thompson is Chief Power Electronics Engineer at TPS. Graeme has a wealth of industrial experience and has overseen the introduction of numerous complex technology programs at TPS including, as a lead engineer, the development of our flagship aerospace drive now deployed in the Boeing Dreamliner. Holding first class Honours degree in Electrical Engineering from University of Newcastle and with over 30 years industrial experience at companies including Rolls Royce and NEI, Graeme also heads up our newly formed Engineering Product Development team who take responsibility for delivery of new technology into the business.

Dr Fainan Hassan is Principle Engineer at TPS. Fainan actively leads the technical execution of Smart Grid and Energy Infrastructure programs. Prior to joining TPS, she worked for companies active in smart grid including Alstom Grid and Smarter Grid Solutions as both power systems and network analysis engineer. Working for the energy team at TPS, Faye is currently leading the implementation of second generation Soft Open Point converters as part of the Active Response program and will play an active role in DC share to deliver the Grid Tied converters required for managing the grid interface.

David Charlton is Chief Embedded Systems Engineer at TPS. David has over 20 years of experience and oversees the company strategy for embedded solutions. He has been an active member of numerous new product implementation teams across all active market sectors, most notably as part of the FUN-LV team which developed ground breaking Soft Open Point converters for UK Power Networks. David holds honours degree in electrical engineering from the University of Newcastle and has expertise in implementing hardware and software solutions for numerous micro-processor control platforms including DSP, PIC and PLC.

Ian McDonald is Chief Systems Engineer at TPS. Ian worked in the Oil and Gas industry before joining Intelligent Power Systems, the forerunner to TPS, as Technical Director. With over 35 years of experience, Ian's expertise with systems engineering and product packaging have been central in the delivery of numerous TPS products including 50kV laser power supplies, high speed air blower motor drives and more recently the Soft Open Point converter for FUN-LV, all of which he delivered as lead engineer. Ian continues to work on energy projects in TPS, defining electronic architecture, packaging requirements and concepts in the early stages of program execution.

Vectos

Vectos is a transport planning, infrastructure design and flood risk, hydrology and sustainable drainage consultancy specialising in assisting the property development industry to maximise the commercial value of land/assets through the planning process. We have gained an enviable reputation for master planning and securing planning consents and Development Consent Orders for complex and challenging schemes.

With 130 staff based in London, Cardiff, Birmingham, Manchester, Bristol, Exeter, Leeds, Perugia and Bonn, we have a proven track record in dealing with large scale redevelopments and contribute to sustainable transport planning initiatives across the UK and wider Europe.

Vectos' involvement in state-of-the-art European programmes such as CIVITAS enables the intelligence learned to be fed directly into the company's UK portfolio; ensuring Vectos advice and solutions remain at the international leading edge.

Key Vectos Personnel

Paul Curtis is the Associate Director for the International group with 13 years' experience in developing and delivering innovative European sustainable urban mobility projects. This includes successful public and private stakeholder engagement in the trialling of new electric vehicle services, the analysis of EV user needs and deploying incentives and behaviour change programmes.

Patrick West is an Associate with 12 years' transport planning experience. Patrick is proficient in detailed capacity assessments and the production of large scale Transport Assessments and Travel Plans for all land uses. He has expertise in negotiating with planning and highway authorities and successfully gaining planning permission for a range of interventions, including electric vehicle charging infrastructure.

10.8 Letters of Support

Letters of support have been received from a number of local authorities:

- Coventry City Council
- Somerset West and Taunton Council
- Transport for Greater Manchester

Coventry City Council

Place Directorate
Transportation and Innovation

One Friargate,
Floor 10
Coventry
CV1 2GN

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Ref: DC Share/letter of support

22 July 2019

Dear Sarah,

Letter of Support for DC Share, Electricity/Gas Network Innovation Competition bid 2019

At its Council meeting in June 2019, Coventry City Council debated the climate change emergency and declared the Council's intention that Coventry will become a carbon-neutral city. Councillors have pledged to reach net zero carbon emissions before the government's target of 2050, building on the good work already taking place in the city to encourage the uptake of electric vehicles, improve air quality and promote sustainable travel. The Government's Clean Growth Strategy sets out the importance of accelerating the shift to Low Carbon Transport (LCT) and we believe that the EV market is emerging strongly, demanding a quick, low cost charging solutions with a future proofing availability.

The power of our DNO to accommodate the new demand to charge electric vehicles relatively easily is a major key to facilitating the decarbonisation of transport. Coventry could be the UK's climate change city and lead the change, through work including encouraging electric vehicles, cleaner buses, and major investment in Coventry Railway Station to support public transport use.

It is important that the users have a choice and availability for a range of EV charging to boost confidence in the uptake of EV's. However, this will have a substantial impact on the distribution network operator's current infrastructure.

This project looks to address the more costly and difficult undertakings of increasing the capacity of the local substation requirements to accommodate the additional load on the supply required for EV charging by releasing unused capacity specifically for EV rapid charging.

The DC Share equalisation project is particularly relevant to Coventry City Council as a Local Authority as it will help give confidence to its citizen on the uptake of EV's. If successfully trialled, it will provide an alternative flexible solution to the network capacity and the learnings will inform the provision of the next generation charging solutions. The learning in terms of the benefits of the user requirements and experience will be valuable to enable us with our decarbonisation planning.

We look forward to working with you on this project and exploring how we can support it.

Yours Sincerely

John Seddon
Head of Transport and Innovation
Coventry City Council

Somerset West and Taunton

Mr R. Duke
Innovation and Low Carbon Engineer
Western Power Distribution
Feeder Road
Avonmouth
BS2 0TB

Our Ref:
Your Ref:
Date: 22 July 2019

Dear Ricky,

Somerset West and Taunton Council recognise the opportunity that the DC Share Infrastructure Scheme represents and see it as a significant step in decarbonising transport to enable net zero carbon emissions by 2050 and our Council's target of 2030.

Our Liberal Democrat administration have set a clear direction and shown leadership within their manifesto on the importance of these issues for the local community, both in terms of future direction and air quality.

Our challenges to date have been the ability to lead this in isolation and we pledge our support as a Host Authority bringing together the distribution network, the Council, with our provision of possible charging sites within the public car parks, and the technical innovators that will make this enhancement available for our residents and visitors.

Whilst charging points could be installed by the Council we have concerns that the EV market is moving at such speed we risk being behind the curve without the links identified above. This scheme allows us to be part of a partnership at the forefront of technology and sustainable network supply.

The benefits of our involvement are that we have control of the Council owned and operated car parks across the district area and can work with the provider to ensure space is made available in a format that works for them and the public. We also hold a recently approved Garden Town Status and feel that this project fits well with our ambitions.

We have a desire to move our own fleet to EV and are exploring the options to do this alongside the charging point needs and network capacity. We see this project as a catalyst for this progression.

We support the DC Share infrastructure project which is looking at an alternative, flexible solution to provide the network capacity and believe the learning will inform the provision of the next generation rapid charging solutions. The learning in terms of the benefits of the equalisation solution, the future flexibility and the user requirements and experience will be valuable to enable us with our decarbonisation planning.

Yours sincerely

Cllr Federica Smith-Roberts
Leader

James Hassett
Chief Executive
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Dr Geraldine Paterson
Innovation Strategy & Transition Engineer
Electricity North West
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Our ref RC18072019

18th July 2019

Dear Geraldine

Letter of support to DC Share Application

On behalf of Transport for Greater Manchester, I am pleased to provide our Letter of Support to Ricardo's **'DC Share'** application for funding through the Networks Innovations Competition (NIC) being submitted in partnership with Western Power Distribution and Electricity North West.

Transport for Greater Manchester has ambitious plans to significantly expand its EV charging infrastructure with a target to be carbon neutral by 2038. We are conscious of the significant challenges that accelerating the shift to low carbon transport brings and the importance of understanding the options available that can help us make this happen.

The objectives of 'DC Share' are fully in line with our strategic roadmap and activities in terms of looking at an alternative, flexible solution to provide the network capacity and believe the learning from this project will inform the provision of the next generation rapid charging solutions. The learning in terms of the benefits of the equalisation solution, the future flexibility and the user requirements and experience will be valuable to enable us with our decarbonisation planning.

In this context, we are see great opportunities and benefit of the DC share proposal and look forward to a positive evaluation and successful submission.

Yours sincerely

Rafael Cuesta
Head of Innovation
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10.9 Glossary of Terms

AC	Alternating Current
BaU	Business and Usual
CE	Conformite Europeenne
CT	Current Transformer
CHADeMO	Charge de Move
CLASS	Customer Load Active System Services
CCC	Committee on Climate Change
CCS	Combined Charging System
DC	Direct Current
DMS	Distribution Management System
DNO	Distribution Network Operator
DSR	Demand Side Response
EMS	Energy Management System
ENA	Energy Networks Association
ENWL	Electricity North West Ltd
EU	European Union
EV	Electric Vehicle
FES	Future Energy Scenario
GB	Great Britain
GTI	Grid Tied Inverter
HGV	Heavy Good Vehicle
HV	High Voltage
ICE	Internal Combustion Engine
IPR/IP	Intellectual Property Rights / Intellectual Property
ISP	Initial Submission Proforma
IT	Information Technology
kVA	Kilovolt Amps (apparent power)
kWh	Kilowatt Hour (energy)
LCNF	Low Carbon Network Fund
LCT	Low Carbon Technology
LV	Low Voltage
MPAN	Meter Point Administration Number
MVA	Mega Volt Amps (apparent power)
MW	Mega Watts
NIC	Network Innovation Competition
NPV	Net Present Value
PV	Photovoltaic
QA	Quality Assurance
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SOP	Soft Open Point
SST	Solid-State Transformer
tCO_2e	Tonnes of Carbon Dioxide Equivalent
TPS	Turbo Power Systems
TRL	Technology Readiness Level
UK	United Kingdom
ULEV	Ultra-Low Emission Vehicle
WPD	Western Power Distribution