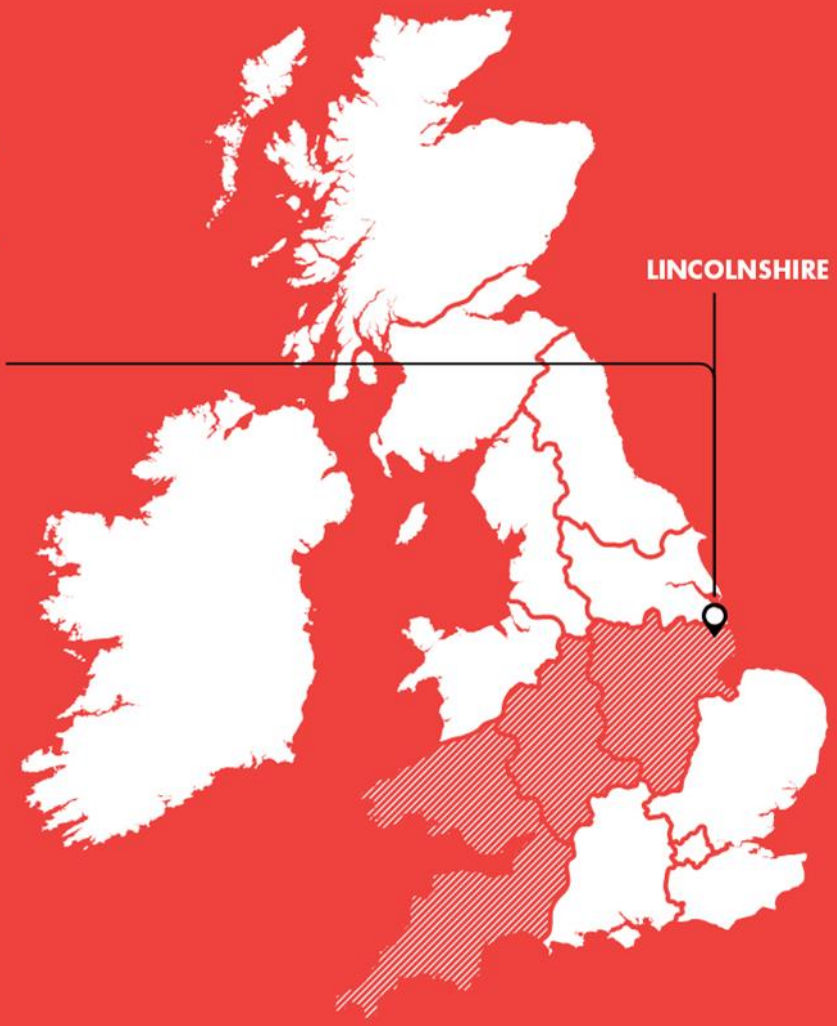
WESTERN POWER DISTRIBUTION

LOW CARBON HUB

CONNECTING RENEWABLE ENERGY IN LINCOLNSHIRE



Second Tier Reward Application

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LCN Fund
Low Carbon Networks

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Executive Summary

This Second Tier Reward submission for Low Carbon Hub provides Western Power Distribution with an opportunity to report on the progress made since the close down report was published at the end of 2015 and demonstrate the significant benefits the project has delivered to GB customers.

The Low Carbon Hub was designed to test a variety of new and innovative techniques for integrating significant amounts of low carbon generation on to electricity networks, in an effort to avoid the costs that would normally be associated with conventional methods.

The high number of both applications to connect generation to the distribution networks and the subsequent connections seen in East Lincolnshire in 2010 when the project was registered have started to be seen nationally. This has resulted in the network constraints addressed by Low Carbon Hub increasingly being seen across many other geographical areas.

The Low Carbon Hub developed and demonstrated six complementary innovative techniques together as an effective combination that had the potential to be rolled out across both WPD's and other DNOs' networks. Four of the project methods proved they could be used to unlock additional network capacity, one method required additional work before it could be used as a BaU technique and for one method the decision was taken not undertake any addition research within that area.

Low Carbon Hub Methods:

- Commercial Arrangements, now called Alternative Connections, are being rolled out into BaU, with significant scope to be the most cost-effective method across the network.
- FACTs, the Statcom device, was shown to be an effective method to unlock capacity (15MW) as an alternative to reinforcement on very long overhead lines.
- Network Enhancements were developed to a level that they could be used as an alternative to conventional network reinforcement when appropriate.
- The Active Network Ring can be used to unlock network capacity. However, its use is limited due its costs (£2m) and complexity for the capacity released (5-8MW).
- The Dynamic Voltage Control (DVC) method showed it could be a more cost-effective method than traditional network reinforcement. Additional work is required before it can be rolled out as business as usual. These were taken forward through the 2014 Network Equilibrium project (which completes in 2019).
- Dynamic Line Ratings for 33kV Wood Pole Overhead lines represented a significant risk in certain types of locality. Dynamic line rating is not being pursued for 11kV and 33kV lines.

As a direct result of the project learning, Alternative Connections was accelerated into Business as Usual with rollout across WPD to be completed by 2021. Statcoms and Network Enhancements can be used where required and where they provide more cost-effective options. GB DNOs who have received learning from the project are expecting to use Statcoms on 33kV networks within ED1.

As a result of the Low Carbon Hub project, over 1.2GW of generation connections have been offered, 244.6MW accepted and 86.4MW made. The project delivered benefits saving distributed generation customers £12.83m and, when measured against the Government Carbon Plan, produces 2.5TWh of renewable energy by 2050 through the connection of generation which previously could not have connected. The project has the potential to save significantly more for customers and defer additional carbon as additional connections are made to the network using the methods.

The considerable effort required to deliver the Low Carbon Hub and the additional investment of £280k made by WPD has represented value for money with the learning being documented and shared effectively to relevant customers across the industry.

1. Project Description

Western Power Distribution's (Central Networks at the time of funding) "Low Carbon Hub - Optimising renewable energy resources in Lincolnshire" LCNF project was also referred to as The Lincolnshire Low Carbon Hub and the Low Carbon Hub (LCH) at various times.

The Low Carbon Hub for East Lincolnshire was designed to test a variety of new and innovative techniques for integrating significant amounts of low carbon generation on to electricity distribution networks. The objective was to understand the opportunities presented by each, having regard to the characteristics of the generation output intermittency, and their viability in reducing costs compared with the use of the conventional the methods of network reinforcement that would normally be employed.

Distribution networks at all voltage levels, from 132,000V down to 415V, were predominately designed for uni-directional power flow demand connections and to operate passively. In 2010, when the project was registered, this passive design philosophy had historically proved to be the most appropriate and cost-effective method to operate distribution networks. When network reinforcement was required, such as for a proposed increase in either demand or generation, this was largely achieved through installing new overhead lines (OHL) and / or underground cables.

Low Carbon Hub was timely as it addressed the design and operational challenges that were expected to be created through UK de-carbonisation targets[1], which were expected to lead to major growth in the development of new low carbon, distributed generation installations requiring connection to distribution networks.

Geographic factors affect the performance of different sources of low carbon generation; for example, some areas have greater wind resources, whereas solar radiation tends to be greater in the south. However, site selection is also determined by the costs of connection and related factors such as consents. Consequently, this can lead to large areas of network becoming generation dominated. This leads to network issues on voltage and current control, reverse power ratings and, at times when the generated energy exceeds demand, power being exported back up the distribution network, ultimately to the transmission network.

This can cause problems on both the distribution and transmission networks, restricting further generation connections. Even at the time that Low Carbon Hub was conceived, it was becoming clear that voltage rise and reverse power flows were going to become a barrier to the UK's transition to a lower carbon economy.

East Lincolnshire, being on the East coast, had a wide range of renewable generation types that were being adopted relatively early, compared to the rest of the UK, which made it an ideal testbed. These included onshore and offshore wind farms, large scale solar Photo Voltaic (PV) and energy from bio crops. However, many generators could not connect to the distribution network closest to them due to the effects their connection would have on the operation of the existing network. These generators thus tended to require costly, long, new underground cable installations to connect them to more

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47621/1358-the-carbon-plan.pdf

robust sections of the network. These costs created an economic barrier to the adoption of these sources of low carbon generation, frequently undermining the investment case.

Through the creation of the Low Carbon Hub, the project sought to explore how the existing electricity network could be developed ahead of need to support low carbon generation connections to customers at a significantly reduced cost when compared with conventional reinforcement. The project centred on the development of methods and the effective combination of six complementary project techniques detailed in Figure 1. Low Carbon Hub demonstrated these techniques, along with a telecommunications system, in East Lincolnshire and established the potential to release network capacity and facilitate additional generation connections. To facilitate this objective, the project received £2.8m of funding from Ofgem's Low Carbon Networks Fund Tier 2.

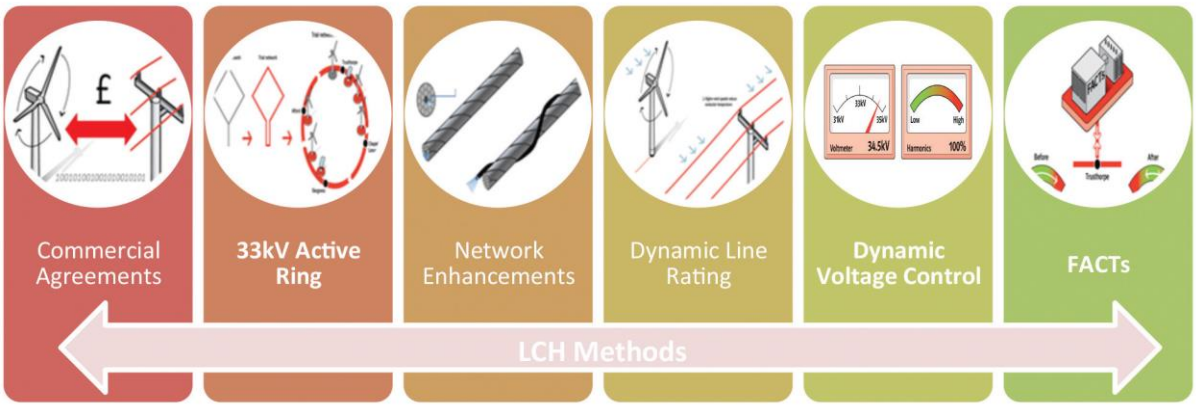

Figure 1 – Low Carbon Hub Methods

Western Power Distribution (WPD) has continued to receive high volumes of connection enquiries from developers in the East Midlands and Low Carbon Hub area in the last six years. This continued number in connection requests in the project area and the sustained high number of Distributed Generation connections across all four licence areas validates the original justification for this project and the decision to fund it.

The issues being seen within the Low Carbon Hub area were expected to be relevant to the issues that would be experienced in other areas across the UK.

	2012	2013	2014	2015	2016	2017
East Midlands Generation Connection Applications (MW)	766.3	1896.7	5938.6	7143.5	2682.8	5412
East Midlands Generation Connection Acceptances (MW)	234.9	544.4	1533	1593.9	1136.2	719.9

Table 1: A history of generation connections within the East Midlands in the last 6 years.

1.1 Criterion A: Exceptional Performance of the Project

The combined Low Carbon Hub project resulted in 48.8MW of new Distributed Generation connections being accepted within the Low Carbon Hub area, with a cost saving of £42m vs the conventional Business as Usual reinforcement costs that did not need to be funded by customers. To date, 8.8MW of Solar PV generation has connected to the Low Carbon Hub network saving an estimated £7.5m of the conventional network reinforcement costs.

WPD have in excess of 7,760MW of Distributed Generation (of all types) above 1MW connected to the network and an additional 5,870MW accepted connections. As the available capacity to support connections is taken up and conventional reinforcement costs increase, interest in alternative connections is growing.

The timely learning from the Low Carbon Hub project has resulted in the systematic roll out of one of the project methods across Western Power Distribution's four licence regions. Alternative Connections are available in four variants[2] (the most complex, ANM, was referred to as Commercial Agreements in the Low Carbon Hub project). Twelve of the twenty-three listed ANM zones already provide quotes based on the Solution developed by this project. By January 2021 the entire network across all Western Power Distribution's licence areas will be offering ANM Connections. The other variants of Alternative Connections are also based on learning from this project.

There have been 244.6MW of Alternative Connections based on ANM accepted across WPD's licence areas with 86.4MW of generation already connected. This avoided an estimated £12.83m in conventional network reinforcement as a result, also allowing significantly quicker connections avoiding delays which can be as much as 3-6 years.

The project learning from other areas of Low Carbon Hub are allowing other DNOs (including Scottish Power[3], UKPN[4] and Western Power Distribution) to consider Statcoms to resolve specific network issues as an alternative to more conventional reinforcement options.

The learning has been shared widely and regularly across the industry, especially to other DNOs and developers. WPD continue to disseminate the learning that continues to emerge as we roll the methods into Business as Usual across the company.

1.2 Criterion B: Additional Investment of DNO's Own Money

Western Power Distribution invested an additional contribution of £280k to the Low Carbon Hub, above the mandatory ten percent contribution. This was to ensure that the Low Carbon Hub's learning objectives were delivered despite a number of challenges locally within the community that could not have been reasonably predicted without the practical experience of undertaking the project and the effort required to ensure that the project delivered to time. Western Power Distribution considered this additional contribution to be value for money based on the learning the project was generating and the outcomes that are being adopted into Business as Usual.

1.3 Criterion C: Exceptional Efforts

For the reasons detailed in Criterion B, the Low Carbon Hub required exceptional effort to deliver the project and capture the learning, which was disseminated across the industry in a way which exceeded the dissemination plan detailed in the Final Submission Proforma. The learning dissemination was conducted through written reports, presentations, site visits, newsletters and one-to-one meetings. This was primarily due to the relevance and quality of the learning.

[2] https://www.westernpower.co.uk/Alternative-Connections.aspx
[3] The Scottish Power - Head of Engineering Design and Standards - email
[4] http://library.ukpowernetworks.co.uk/library/asset/06a37b73-e597-422e-b71f-7b79f42e4d2L/UKPN_Forecast_Outputs.pdf

Tier 2 Project Name	Licensee	Project summary (2 Sentences)	Tier 2 funding £k (nominal prices)	Licensee compulsory contribution £k (nominal prices)	Other contributions £k (nominal prices)	Link to Close-Down Report
Low Carbon Hub - Optimising renewable energy resources in Lincolnshire	Western Power Distribution (East Midlands)	Designed to test a variety of new and innovative techniques for integrating significant amounts of Distributed Generation, in an effort to avoid the costs that would normally be associated with more conventional reinforcement methods.	2,767	350	280	https://www.ofgem.gov.uk/publications-and-updates/wpd-s-low-carbon-hub-project-closedown-report

Table 2: Summary of Tier 2 Low Carbon Hub - Optimising renewable energy resources in Lincolnshire, widely known as Lincolnshire Low Carbon Hub.

2. Reward Criterion A: Exceptional Performance of the Project

Western Power Distribution, through the Low Carbon Hub, gained the necessary confidence to implement, via a staged roll out, one of the methods (Commercial Agreements / Alternative Connections) into business as usual across Western Power Distribution's four licence areas. This network wide roll-out will be completed by 2021.

The rollout of the project has already avoided conventional network reinforcement across nine different locations within Western Power Distribution, as detailed in Table 4, already delivering savings of £12.83m to customers and avoiding the disruption and delays associated with conventional network reinforcement, which can be as much as 3-6 years (including gaining the necessary permissions and consents).

This significantly exceeded the expected outcome, stated in the Full Submission Proforma, of deployment into two areas within each of WPD's four licence areas by 2020. There are similar roll outs of the Alternative Connections method now also underway or in the planning phase across all five other DNOs. WPD has offered in excess of 1.2GW of Alternative Connections across all four licence areas. It is recognised that, subsequent to Low Carbon Hub, other DNOs have conducted projects on numerous aspects of Alternative Generation Connections using Active Network Management. The combination of learning from Low Carbon Hub and the subsequent projects informed the publication of the Active Network Management Good Practice Guide, designed to support others rolling out the method. The Low Carbon Hub project had a clear focus on resolving the issues that would allow the technique to be rolled out into Business as Usual.

EXCEPTIONAL BENEFITS

- The Alternative Connections method focussed on the detail of both the technical and commercial method elements. Significant effort was made to engage with the relevant areas of the business to gain their understanding and commitment, and to resolve and proactively identify potential issues that could have resulted in barriers that delayed future adoption into Business as Usual.

  The successful demonstration and learning generated have been shared extensively during and after the project to help provide a roadmap, strategy and the tools for other DNOs to follow when adopting into BaU.

- The learning from this project has resulted in over 1.2GW of Alternative Connections being offered, 244.6MW of Alternative Connections being accepted and 86.4MW of Alternative Connections have been made to Western Power Distribution's networks. Customers inform us that these connections would not have gone ahead using conventional methods due to the prohibitive costs.

- 450MW of capacity has already been unlocked across Western Power Distribution's licence areas through active ANM areas as a result of the project. Additional capacity will be released through the future roll out of ANM within Western Power Distribution and across other DNOs' licence areas as they adopt Alternative Connections and ANM into Business as Usual.

2.1 Aspects of the Carbon Plan and/ or Clean Growth Strategy that have been facilitated

In 2010, East Lincolnshire was already experiencing significant network constraints, preventing the cost-effective connection of potentially high yield renewable generation projects due to the costs associated with conventional approaches to accommodating such connections through reinforcement. It was already foreseen at the time of developing the Low Carbon Hub project during 2009 and 2010 that the increasing levels in renewable generation could result in the same restrictions within different regions of the East and West Midlands as well as across other regions of the UK.

The Low Carbon Hub set out to test a suite of innovative techniques that, if successfully demonstrated, could be rolled out across the rest of Britain or to identify what additional works would be required to allow them to be rolled out nationally.

Each LCH method would help solve one or more of the distribution network constraint problems. The connection of renewable generation was, at the time Low Carbon Hub was conceived, central to the Carbon Plan[5] and is today relevant to the Clean Growth Strategy[6]. This can only be achieved if low carbon distributed generation can gain cost-effective access to the distribution network.

By solving this problem, the Low Carbon Hub has already achieved:

- The learning from this project has resulted in over 1.2GW of Alternative Connections being offered,
- The learning from this project has resulted in 244.6MW of Alternative Connections being accepted
- The learning from this project has resulted in 86.4MW of Alternative Connections being made to Western Power Distribution's networks, which would not have otherwise happened due to the costs associated with conventional methods.
- The learning from this project has resulted in an estimated additional 100,849MWh of low carbon generation output per year. This is predominantly from solar PV and wind schemes.

	2020	2030	2040	2050
MWh	403,000MWh	1,411,000MWh	2,420,000MWh	2,521,000MWh*

Table 3: Estimated cumulative MWh of renewable generation output the project 2020 – 2050 (Note connected projects assumed to have a 25-year life cycle)[7]

The Commercial Agreements Method provided the learning, knowledge and tools that have allowed WPD to commit to rolling out Alternative Connections as a Business as Usual[8] activity across all Western Power Distribution Grid Supply Points by 2021 with the areas identified by our customers and with the greatest requirements being developed first.

Table 4 shows the areas where Alternative Connections can be offered and made using Active Network Management. It also shows when it is scheduled to be implemented in all future Grid Supply Point groups.

[5] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47621/1358-the-carbon-plan.pdf
[6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf
[7] https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes (Appendix 6.5)
[8] https://www.westernpower.co.uk/Connections/Generation/Alternative-Connections/ANM-Further-Info.aspx

Supply Point Group	Live Bulk Supply Point Group	Quoting from	Building during	Approximate conventional reinforcement cost
Bicker fen	Skegness	Live	Live	£10m
Grendon	Corby Northampton	Live Live	Live Live	£20m
Bridgwater	All	Live	Live	£4m
West Burton	Horncastle	Live	Live	£5m
Indian Queens	Truro	Live	Live	£15m
Swansea North	Swansea	Live	Live	£14m
Pembroke	Pembroke	Live	Live	£11.5m
Cellarhead	Meaford	Live	Live	£4.5m
Rassau	Abergavenny	Live	November 2018	£15m
Feckenham	Feckenham	Live	April 2019	£5m
Aberthaw	All	Live	April 2019	£8.5m
Staythorpe	All	November 2018	November 2019	£10m
Berkswell	Warwick	April 2019	April 2020	tbc
Axminster	All	April 2019	April 2020	tbc
Shrewsbury	All	April 2019	April 2020	£2.4m
Bishops Wood	Hereford	November 2019	November 2020	£3.3m
Rugeley	All	November 2019	November 2020	tbc
East Claydon	All	November 2019	November 2020	tbc
West Burton	All	November 2019	November 2020	tbc
Pyle	Pyle	April 2020	April 2021	tbc
South Devon	Landulph - Abham - Exeter GSPs	January 2018	January 2020	tbc
Remaining GSPs requiring ANM		January 2021	November 2021	tbc

Table 4: Summary of Active Network Management roll out across Western Power Distribution.

In addition, learning generated by the Low Carbon Hub enabled the use of export limitation devices, soft intertrip and timed connections to be developed to support the use of the Commercial Arrangements

methodology. Learning from Low Carbon Hub gave Western Power Distribution the confidence to implement these approaches directly into Business as Usual without the requirement for additional innovation funding.

This unlocked additional capacity for customers where an optimised Active Network Management connection is not required. Without the learning from the Low Carbon Hub about the Commercial Arrangement Method (Alternative Connections) Western Power Distribution would not have had the confidence to move the integration of Alternative Connections into Business as Usual.

2.2 Releasing network capacity

The project methods demonstrated how they can unlock network capacity. Table 5[9] outlines the capacity increase in MVA per method. The project unlocked this capacity across the East Lincolnshire network.

Method	Cost (£)	Capacity increase (MVA)*	Comments/Other benefits/disadvantages
1. New Commercial Arrangements	≈£550k	≈50MVA[1]	[1] Based on East Lincolnshire capacity, another network will vary considerably depending on the existing network assets already installed. Significant benefits to DG developers with reduced network reinforcement costs.
2. 33kV Active Network Ring	≈£2,000k[2]	≈5-8MVA[3]	[2] Based on East Lincolnshire network. The costs will vary dependent on design, space, complexity [3] Very dependent on the location of new generators, the Active Network Ring provides a much greater security of supply and reduction of constraints associated with abnormal network operation.
3. Network Enhancements	≈£8k/km	≈12MVA[4]	[4] Based on the LCH standard design with a 300mm^2 Hard Drawn Aluminium with long span lengths and without optical fibre installed. The alternatives being the installation of 150mm^2 Aluminium Conductor Steel Reinforced on medium span lengths. This is very dependent on the location of new generators.
6. FACTs	≈£775k	≈15MVA[5]	[5] Very dependent on the location of new generators and the step change restrictions.

Table 5: LCH Methods which resulted in a capacity increase.

[9] Low Carbon Hub Closedown Report, 2015. Extract from Table 5, Page 45

At the submission stage in 2010, the project estimated that up to 1,400MW of additional distributed generation capacity could be unlocked across the UK before 2020 using all the techniques demonstrated by the Low Carbon Hub.[10]

At the time of writing this report, it has been conservatively calculated that an additional 450MW of network capacity has already been released solely in Western Power Distribution's network areas across the nine active ANM zones. With the combination of the nine live ANM zones and the future 13 additional ANM zones that will be live by 2020, it is estimated that the Commercial Arrangements (Alternative Connections) alone will to unlock 1,100MW of additional generation connections solely on Western Power Distribution's networks (compared with the submission estimate of 1,400MW across the UK as a whole) that would otherwise not have been cost effective to connect. Other DNOs will unlock additional capacity though the Commercial Agreements (Alternative Connections) and the other techniques that are used between now and 2020.

It was recognised by Ofgem that the roll out of the Commercial Arrangements method (as Alternative Connections) was one of the key enablers for releasing network capacity[11]. Ofgem's challenge to DNOs recognised that Western Power Distribution is leading the way in this field. The rates of connection requests and actual network connections indicate that the forecasts for renewable generation connections from 2010 will be significantly exceeded as every Distribution Network Operator has committed addressing the cost barrier to connections by rolling out Alternative Connections. This demonstrates the exceptional role that Low Carbon Hub has played in achieving the release of network capacity through Alternative Connections, especially by enabling the identification of the potential future issues at the demonstration stage and enabling them to be addressed so Alternative Connections is now offered as a Business as Usual option.

The demonstration of the power electronic shunt connected FACTs device, also known as a Statcom, unlocked 15MW within this the project area alone. The learning showed that the method is very specific to the network on which the device in installed. The Statcom will unlock the most benefits on very long overhead lines to solve steady state and transient voltage issues.

ScottishPower have confirmed they are expecting to use several Statcoms within both of their licence areas to unlock additional capacity on their 33kV network.

Western Power Distribution is now actively considering the use of a Statcom for several locations in West Midlands, including the Feckenham network. This network has very long 66kV circuits and Statcoms provides a potential method to unlock an estimated 30MW+ of network capacity for connection of additional load and will deliver benefits for generation within a future ANM zone. For very remote networks, the learning from Low Carbon Hub can inform investment decisions and help ensure the most cost-effective options for customers are implemented.

[10] CNT2-2002 Addendum and Proforma, Page 20, Third Paragraph
[11] https://www.ofgem.gov.uk/publications-and-updates/ofgem-challenges-power-grid-companies-connect-more-renewables

2.3 Delivering Financial Benefits

The Low Carbon Hub established that three of the trialled methods had the capability, when replicated, to deliver a more cost-effective way of making capacity available when compared to the traditional approach of increasing capacity through reinforcement.[12]

Method	Cost (£)	Comments
1. New Commercial Arrangements	≈£550k	[1] Based on East Lincolnshire capacity, another network will vary considerably. Significant benefits to DG developers with reduced network reinforcement costs.
3. Network Enhancements	≈£8k/km	[4] Based on the LCH standard design with a 300mm^2 Hard Drawn Aluminium with long span lengths and without optical fibre installed. The alternatives being the installation of 150mm^2 Aluminium Conductor Steel Reinforced on medium span lengths. This is very dependent on the location of new generators.
6. FACTs	≈£775k	[7] Very dependent on the location of new generators and the step change restrictions.

Table 6: LCH Methods which resulted in a more cost efficient method that could be used in BaU[13].

The costs of the new Commercial Arrangements (Alternate Connections) have continued to improve. With the further nine locations across WPD's network locations now accepting Alternative Connections using Active Network Management, the average cost is captured at £550k per system for all network locations. The traditional alternatives will cost between £1m - £30m per location and include new transformers (Primary, Grid and Super Grid), new 33kV and 132kV overhead lines, new 33kV and 132kV underground cables).

	Costs Per Unit / Per km	Delivery Timescales Order, design, installation and commissioning
Primary Transformer	£395k	12 - 24 Months
Grid Transformer	£915k	18 - 24 Months
Super Grid Transformer	£12,000k	36 Months
33kV OHL	£65k*	24-36 Months
132kV OHL	£490k*	24 – 60 Months
33kV Underground Cable	£215k	12-24 Months
132kV Underground Cable	£1,200k	12-24 Months

Table 7: Traditional network reinforcement unit costs and typical delivery timescales[14]. *Excludes consenting and wayleaves

As detailed above, these traditional solutions often have substantial cost, design and delivery timescales that are significantly higher than Alternative Connections and Active Network Management. The continual level of learning has further advanced the confidence that the Commercial Arrangements /

[12] Low Carbon Hub Closedown Report, 2015. Extract from Table 5, Page 45

[13] Low Carbon Hub Closedown Report, 2015. Extract from Table 5, Page 45

[14] WPD Costs

Alternative Connections methods can provide benefits above the conventional reinforcement alternatives.

The project showed that FACTs devices have the potential to unlock considerable network capacity both on their own and as part of an Active Network Management network on networks where they have proved to work most effectively. The costs of delivering FACTs devices remains as outlined in the close down report. This is based on the current costs from FACTs manufacturers as well as the more traditional activities required to integrate a Statcom into the distribution network. This is why the project has shown that Statcom's will be best suited to very rural locations where the costs of conventional network reinforcement options are significant.

2.4 Rollout across the DNO's system and across GB

The Commercial Arrangement section of the project developed "Alternative Connections" using Active Network Management. This is in the approach of being rolled out across GB.

There is now a commitment by all the GB Distribution Network Operators to roll out Alternative Connections, meaning the solution will be adopted across Great Britain. The Low Carbon Hub was the first mainstream application of Active Network Management technology outside of an island network and created the first full suite of documents and tools needed to offer Alternative Connection arrangements in a mainstream activity. These were first shared across the industry in October 2013 at the Low Carbon Hub dissemination event. The shared documents included the template for offer documents and new constraints analysis tools were demonstrated at the event.

On 4th March 2016 Ofgem detailed how they recognised that Western Power Distribution was successfully using creative approaches through Alternative Connections to speed up the connection of renewables. In their challenge to the DNOs, Ofgem stated, "Ofgem is challenging local electricity grid owners to follow Western Power Distribution's lead by squeezing more capacity out of their grids to connect renewables." Ofgem called on other DNOs to take measures also to replicate the roll out, unlocking capacity on their network.[15]

The learning from this project was well publicised with Western Power Distribution providing a significant contribution, on behalf of the industry, to the development of a Good Practice Guide for Active Network Management[16], which was published by the ENA in 2015. There have been 9 separate installations of ANM systems across Western Power Distribution's networks, with installations to occur across all Western Power Distribution's networks so any connection can apply for an Alternative Connection using ANM. These approaches have been embedded within Business as Usual through Western Power Distribution producing policies to support these approaches:

- POL:SD10 Managing Processes for Alternative Connections
- ST:SD10A Process for Offering a timed Alternative Connection
- ST:SD10B Process for Offering a Soft-Intertrip Connection
- ST:SD10C Process for Offering an Active Network Management (ANM) Connection

There have been further Business as Usual adoptions of ANM within Scottish and Southern's networks where there are two active zones, which are closed to new customers, and one active zone which is

[15] https://www.ofgem.gov.uk/publications-and-updates/ofgem-challenges-power-grid-companies-connect-more-renewables
[16] http://www.energynetworks.org/assets/files/news/publications/1500205_ENA_ANM_report_AW_online.pdf

open to new customers. UK Power Networks have seven open ANM zones, Northern Powergrid have one active zone and other DNOs are committing to rolling out ANM connections.

Another example where learning and outputs from Low Carbon Hub have been adopted by other DNOs includes Northern Powergrid, who are using the same constraints analysis process and data displays that were originally generated from the Low Carbon Hub constraints analysis tool to display information to customers.[17]

ScottishPower's Head of Engineering Design and Standards confirmed that "across ScottishPower Distribution and Manweb, a couple of projects are in the pipeline which we [Scottish Power] expect will be using 33kV Statcoms as a solution. The projects are still being designed and developed but it is looking promising". Western Power Distribution has further offered their support to ScottishPower with these initial projects, confirming the learning generated from the Low Carbon Hub. The same offer has been made to all of the DNOs, should they require our assistance.

2.5 Value for money to Customers

The Low Carbon Hub proved to be an extremely valuable programme of work, with a significant amount of activities completed over a wide area. The project received £2,767k funding from the Low Carbon Network Fund. This funding was used to achieve the best outcomes for customers, resulting in quicker and more cost effective innovative solutions that enabled customers to connect schemes that would previously not have been economic to progress. As a direct result of Low Carbon Hub and the six innovative techniques that it demonstrated:

- Alternative Connections (Commercial Arrangements) are being rolled out across Western Power Distribution and all other DNOs have committed to roll out the method to solve problems on their networks.
- Statcoms (FACTs) are a proven technique that is now available to DNOs to be used in long rural distribution networks. It provides both the steady state and transient network voltage support. Subsequent to the close down report, additional benefits that help address reactive power flows at the transmission interface have been identified.
- Network Enhancements are a design standard that can be installed for new 33kV overhead lines in rural areas where both high future capacity, communications capability and long span lengths are required.
- Dynamic Voltage Control was demonstrated and areas requiring additional work before being suitable for Business as Usual were identified. These were taken forward through the 2014 Network Equilibrium project (which completes in 2019).
- Criteria were developed to identify where the use of the 33kV Active Ring can be economic in unlocking additional capacity. This included understanding the costs and challenges associated with modifying existing substations safely whilst not creating barriers to their future development. This was learnt from the Low Carbon Hub design and installation activities.
- Risks with Dynamic Network Rating for 33kV overhead lines were identified. Specifically, risk of OHLs becoming sheltered from the wind, which could result in safety concerns due to lower levels of convective cooling reducing the potential for capacity release. The sheltering of OHLs

[17] http://www.northernpowergrid.com/asset/0/document/2944.pdf.

could be as a result of planting of fast-growing trees or the installation of new industrial and commercial buildings, which can be installed quickly can have a significant effect on the wind patterns around 33kV Overhead Lines.

The funding received from the LCN Fund generated the learning above, has demonstrated where each of the Low Carbon Hub methods could provide cost effective connections to future customers and has helped establish the steps that need to be taken first to assess the appropriateness of a method. Alternative Connections (Commercial Arrangements) have already been rolled out with significant customer savings and other techniques can be assessed for when they can be used cost effectively. As stated in the SDRC application, the project demonstrated value for money due to the effectiveness of the Low Carbon Hub[18]. The techniques that have been taken forward into Business as Usual since the close down report and the benefits being realised by customers further evidence the value for money delivered by Low Carbon Hub.

The Low Carbon Hub project further sought to ensure value for money for our customers by running competitive tenders for the products and services required to deliver the project where ever it was possible and appropriate to do so. This included for the Statcom devices, 33kV switchboards and the Active Network Management scheme. This approach of using competitive procurement as a means of delivering value for money for customers became common practice in LCN Funded projects and continues to be good practice in Network Innovation Stimulus projects.

Situation at Time of Project Scoping

At the time of scoping of Low Carbon Hub in 2010, no DNO was considering any of the trialled methods for implementation into Business as Usual because there were significant risks and uncertainty associated with the techniques due to the lack of evidence about their performance. The Low Carbon Hub delivered that evidence by demonstrating these methods and sharing the learning across the industry to provide value for money and support the roll out across GB.

2.6 Relevance and timing of project

The Low Carbon Hub was an ambitious project delivered at a time when the amount of Distributed Generation connections was growing rapidly. By December 2015 8.6GW of solar capacity had been installed in the UK, which was 15 years ahead of forecasts made in 2012[19]. By the end of the project, and continuing today, the issues that were predominantly being seen in East Lincolnshire were starting to be seen in other network locations across WPDs licence areas as the number of connections increased.

[18] LLCH-Knowledge-SDRC-V1.pdf , Page 10, second paragraph.

[19] https://www.ofgem.gov.uk/publications-and-updates/ofgem-challenges-power-grid-companies-connect-more-renewables

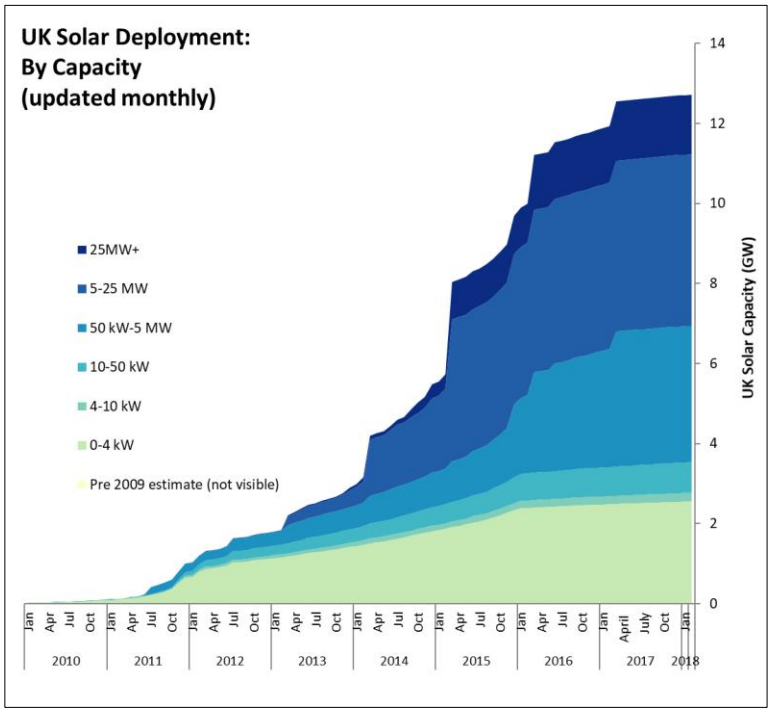

Figure 2 – UK Solar Deployment up to 2018[20]

In 2016, Ofgem commended Western Power Distribution for using both conventional and innovative techniques, which were developed through the Low Carbon Hub, to resolve issues and get some of the accepted 7.6GW of generation connections across all of its licence areas that were ready to connect to the network quicker.[21]

Through the Low Carbon Network Fund innovation funding, it was the first time that DNOs had undertaken larger coordinated projects with lower Technology Readiness Levels. The initial approach for the project had some obstacles which required exceptional efforts to resolve.

One of the key areas of learning from the project was about the need to address the softer, non-technical behaviours encountered from certain DNO stakeholders. This experience gave rise to significant learning about stakeholder engagement, which is today embedded in Western Power Distribution's culture and is, we believe, reflected in us consistently being ranked at the top of Ofgem's Stakeholder and Customer Vulnerability Incentive.

A new learning point was the tactical use of planning objections by landowners to new overhead lines as a means of preventing the construction of new generation facilities that needed the connection. The learning from this period was captured and documented in detail and represented valuable learning, but this learning was additional to the original project aims[22].

Through this learning it became apparent that there were no options to continue with the Active Ring method as originally planned. Therefore, the project was redesigned and a change request was

[20] https://www.gov.uk/government/statistics/solar-photovoltaics-deployment#history
[21] https://www.ofgem.gov.uk/publications-and-updates/ofgem-challenges-power-grid-companies-connect-more-renewables
[22] https://www.westernpower.co.uk/docs/Innovation/Closed-projects/Lincolnshire-Low-Carbon-Hub/4-LCH-Project-Progress-Report-Dec-2011-WPD.aspx - Page 5, Section 2.2, Second Paragraph.

submitted[23]. The project continued using the alternative method and significant sustained effort was required with additional internal and external staff assigned to deliver the project and learning within the original timescales of the project[24].

The only way the project was able to deliver the successful learning with the delays caused by the land owner objections was with significant additional effort and the backing from all areas of Western Power Distribution's business[25]. This commitment from the business was gained because the learning from this project was judged to have significant potential value for the way low carbon technologies could be supported in the future.

The project successfully delivered learning, both positive and negative, that has resulted in a programme being established to roll out Active Network Management across all Western Power Distribution's networks by 2021. This programme will deliver Active Network Management capability to further resolve the issues our customers face to all grid groups.

The learning about stakeholder engagement has been taken forward in the way that Western Power Distribution engages with our stakeholders. The way this has embedded in our culture is evidenced by Western Power Distribution being consistently ranked at the top of Ofgem's Stakeholder Engagement and Customer Vulnerability Incentive.

The use of Statcoms remains an option that will be used across the distribution network. Within the ED1 period, the use of Statcoms are continually assessed by the planning teams with policies having been implemented that embed the project specific learning from the Low Carbon Hub into Business as Usual:

- ST:OC31A Process for Statcoms Design
- ST:OS1Y/1: Process for Statcoms safe installation
- ST:SP2CY: Process for Statcoms Maintenance
- POLGE:25: Policy for Statcoms Operation

These policies enable planners to consider where they could provide a more cost-effective option than traditional approaches. The use of a Statcom continues to be assessed for a WPD project in Feckenham and ScottishPower have confirmed their use on a number of schemes.

Policy changes

- As a result of the learning from the Low Carbon Hub, there were Western Power Distribution policies for Active Network Management and Statcoms implemented, embedding the learning in our working practices.
- Alternative Connections were rolled out across Western Power Distribution.
- Western Power Distribution contributed towards the Industry Good Practice Guide for Active Network Management, sharing the key learning gathered through the Low Carbon Hub.

[23] https://www.westernpower.co.uk/docs/Innovation/Closed-projects/Lincolnshire-Low-Carbon-Hub/Low-Carbon-Hub-Design-Justification-v2-2.aspx
[24] https://www.westernpower.co.uk/docs/Innovation/Closed-projects/Lincolnshire-Low-Carbon-Hub/LCH-Project-Progress-Report-May-2014.aspx - Page 6, Section 1.3.2
[25] https://www.westernpower.co.uk/docs/Innovation/Closed-projects/Lincolnshire-Low-Carbon-Hub/LCH-Project-Progress-Report-May-2014.aspx - Page 6, Section 1.3.2

2.7 Methodology robustness and project readiness

The project was conducted with the intention of exceeding the deliverables of the methodologies contained in the submission. In the case of the 33kV active network ring, the proposed approach had to be modified in the light of construction consent issues caused by protest action. This protest action was not specifically against the overhead line but as a tactical means of preventing the development of the generation that needed the connection. In order to overcome the objections and deliver the required connections, this led to the development of techniques to adapt existing radial networks run in a ring configuration without the need for new linear assets. This, in turn, led to the development of an innovative protection scheme for the new Active Network Ring network beyond what would normally be installed on a rural 33kV network[26]. The learning about the key factors that need to be considered in detail before committing to the Active Network Ring method was shared with the DNO community. This work went substantially beyond the original committed deliverables and delivered learning that should be considered as exceptional.

Whilst the adaption of the Active Network Ring had a substantial impact on the design phase and delivery of the project[27], the Low Carbon Hub project methods (Commercial Agreements, Dynamic Line Ratings, FACTs and Dynamic Voltage Control) were developed and delivered as expected and identified within the Full Submission, whilst generating significant additional learning.

The project demonstrated how the combination of innovative techniques (Commercial Arrangements, Network Enhancements and the use of Statcoms) could best be selected for deployment, established where the learning showed individual techniques could not successfully be rolled out in particular circumstances but showed particular promise in others. In the latter case, where techniques showed promise but the necessary threshold to implement into Business as Usual was not achieved, additional work was scheduled to ensure the industry learning could be generated and shared.

2.8 Other Benefits

The project identified that use of Dynamic Line Ratings for 33kV Wood Pole Overhead lines represents a significant risk in certain types of locality. The risk arises from the unforeseen impact that structures, in particular industrial and commercial buildings (which can be constructed within short time periods), can have on the wind flows and the convective cooling of a line. As a result, no additional research activities have gone into dynamic line ratings on 11kV and 33kV wood pole lines on this project. The early identification of this issue meant that additional effort, and the associated costs, were avoided, to the ultimate benefit of the consumer.

[26] https://www.westernpower.co.uk/docs/Innovation/Closed-projects/Lincolnshire-Low-Carbon-Hub/Low-Carbon-Hub-Design-Justification-v2-2.aspx Section 7.
[27] https://www.westernpower.co.uk/docs/Innovation/Closed-projects/Lincolnshire-Low-Carbon-Hub/PPR_WPD_LINCS_LC_HUB_MAY2013_PUBLIC.aspx Page 3 - Section 1.

3. Reward Criterion B: Additional Investment of DNO's Own Money

To ensure successful delivery of the project it was necessary for Western Power Distribution to make an additional contribution to the project. This was due to the project being impacted by protest action against connection of renewable generation. This protest manifested itself through objection to the proposed new overhead lines required to deliver the connections. This was a scenario that, at time that Low Carbon Hub was being scoped in 2010, could not have been reasonably predicted. These challenges generated additional learning around stakeholder engagement.

Activity on the 33kV Active Network Ring method was delayed as a result of such action, and had a consequential impact on the other project methods that were dependent on the Active Ring design.

After the redesign and subsequent the need for delivery of the project within a truncated period, the costs did increase. The project was truly innovative, being delivered as one of the earliest innovation projects and delivering significant learning. Therefore, Western Power Distribution was prepared to invest £280k of its own money to ensure the project could be successfully delivered, generating learning of true value to the DNO industry and customers.

As a result of some of the non-technical learning from this project around stakeholder attitudes, the use of cables for the connection of a new distributed generator to an existing network asset is now considered as a default. This addresses the scenario where Western Power Distribution is unable to gain a wayleave for a new overhead line in a particular area for renewable projects. This ensures that other Business as Usual projects can avoid the potential barriers in scenarios similar to those encountered by the Low Carbon Hub project.

3.1 Details and significance of DNOs additional contribution

The Low Carbon Hub went over budget in some areas and this was reported through the six-monthly project reports[28]. The project faced a number of unforeseen challenges, especially in respect of the electricity connection planning consent process being used by the community as a means of preventing or disrupting unpopular generation schemes. No additional funding was requested for the project, with Western Power Distribution covering the additional expenditure and some funds were handed back to customers as part of the change request in 2013.

As stated in the SDRC award document[29], Western Power Distribution believes that the project exceeded the anticipated requirements, delivered significant learning that (a) has been implemented into Business as Usual through investment in ANM and (b) we are exploring further through LCNF Funding via the Network Equilibrium project. Moreover, the rollout of Alternative Connection Agreements adds further to the significant legacy of the Low Carbon Hub. This demonstrates the return on the additional investment by Western Power Distribution and justifies the spend as value for money.

Western Power Distribution made an additional contribution of £280k, which allowed the execution of the project to be conducted and the valuable learning to be generated. The funding specifically covered the telecoms design, IT costs, new commercial agreements with DG customers with increased

[28] https://www.westernpower.co.uk/docs/Innovation/Closed-projects/Lincolnshire-Low-Carbon-Hub/Lincs-LCH-Nov-14-PPR-V1-0.aspx - Page 17 section 4.
[29] LLCH-Knowledge-SDRC-V1.pdf, Page 13, 14th Paragraph.

capabilities, the Active Ring method and the FACTs integration[30]. Western Power Distribution was focussed on delivering a successful project, safely and effectively, whilst generating the maximum amount of learning for all DNOs and customers.

3.2 Issues that justified the additional contribution

As detailed in Section Six of the close down report[31] there were a number of modifications to the project that could not have been reasonably foreseen at the application stage of the project. This was because of the low level of understanding of stakeholder needs and customer engagement approaches that existed in DNOs at that time. Some of these resulted in additional costs which were covered by Western Power Distribution.

- The implementation approach for the Active Network Ring method had to be completely redesigned following protest action relating to a connection for onshore wind turbines meaning the planned route was not viable. There was significant additional effort associated with engaging with the affected customers, the redesign work and in ensuring that Low Carbon Hub delivered to the agreed timescale.
- The requirement to amend the design of the Network Enhancements following feedback from landowners.
- The changes to the delivery of the Low Carbon Hub as a result of the purchase of the East and West Midlands by PPL. The project had to comply with the new policies and procedures within the new company as well as being delivered within the new company structure which changed significantly, the costs for which were considered part of the business integration.

There were limited additional options open to WPD that would have resulted in the learning still being generated by the project. Therefore, the decision was taken to fund the additional costs due to the value coming from all areas of the project.

3.3 Demonstrable benefits to customers

As detailed throughout the report, the Low Carbon Hub generated substantial learning in all areas, from Business as Usual ready methods, to methods that required additional work before they were suitable to be applied across the network, to approaches that Low Carbon Hub has proven are not appropriate for roll out into Business as Usual.

Low Carbon Hub has resulted in lower cost and quicker connections as Alternative Connections for Distributed Generation customers.

The additional funding made towards the delivery of the Low Carbon Hub was considered necessary to deliver this vital industry learning and demonstrates Western Power Distribution's commitment to innovation and delivering on our promises to customers. The learning from Low Carbon Hub has enabled Alternative Connections (Commercial Arrangement) to be adopted into Business as Usual and there is an established programme to roll out across Western Power Distribution. Other DNOs are adopting similar programmes.

[30] LLCH-Knowledge-SDRC-V1.pdf , Page 11-12.
[31] CNT2002-LLCH-Close-Down-Report_v1-0-Final.pdf, Page 39, Section 6.

4. Reward Criterion C: Exceptional Efforts

The earlier sections of this submission have described the challenges that emerged during the delivery of the project, and the significant measures that Western Power Distribution had to undertake for its successful completion. As a consequence, substantially greater learning was delivered than was anticipated when Low Carbon Hub was developed in 2010.

Western Power Distribution took wide ranging steps to ensure that knowledge has both been captured, shared and brought into standard use. These steps have included;

- Taking a key contributing role in the production of national guidance, Active Network Management Good Practice Guide[32]
- One to one discussions with other DNOs
- Facilitation of site visits

More specific details are included in the following section. These serve to demonstrate that Western Power Distribution has made great effort to ensure widespread and effective dissemination of the project findings.

4.1 Demonstrate where the project has delivered more learning than was expected

In relation to its scale, the project, as stated above, has delivered a disproportionately high level of learning, greater than anticipated at time of submission;

- Alternative Connections (Commercial Arrangements) has been developed to Business as Usual[33]
- Additional learning has been gained on use of Statcoms (FACTs) about its applicability, proximity to residential customers and mitigation actions[34]
- On Active Network Ring, learning generated on alternative approaches, development of innovative protection, and delivery risk mitigation

More specifically - The project learning was more than expected in the following areas:

4.1.1 Commercial Arrangements methods (Alternative Connections)

Section 3.2.2, 3.3.2 and 3.4.4 from the Knowledge Dissemination Report[35] articulates the detailed knowledge generated, captured and disseminated as part of the Low Carbon Hub commercial arrangements section. The key learning included:

- The additional support required by Generation Developers to understand the Alternative Connections, the risks and the potential scenarios that could affect their connection.
- The learning on how to design Alternative Connection Offers and Alternative Agreements in such a way that they could be rolled out as a Business as Usual solution. This included interactivity, the steps for customers to secure a merit order place, the validity of an offer and transferring from an

[32] http://www.energynetworks.org/assets/files/news/publications/1500205_ENA_ANM_report_AW_online.pdf
[33] LLCH-Knowledge-SDRC-V1.pdf , Page 13, 14th Paragraph.
[34] LLCH-Knowledge-SDRC-V1.pdf – Page 54, Section 8.3
[35] LLCH-Knowledge-SDRC-V1.pdf

alternative connection to a standard offer. All the learning has been retained, used to inform the rollout of Alternative Connections into Business as Usual and disseminated to other DNOs.

- How Active Network Management can be adopted by a DNO as a Business as Usual solution, including where servers are located, who maintains them and who resolves any issues.
- The importance of a DNO owning their own constraints estimation tool; how the tool must be flexible to account for changing requirements and scenarios as a project's constraints evolve.
- The extensive knowledge generated has been disseminated through the Commercial Arrangements Knowledge Capture Document (August 2014), setting out the details of the method and the knowledge captured on all aspects when developing Alternative Connection Documents.
- The additional learning captured and disseminated 20/11/2014[36], including a customer's view to accepting an Alternative Connection with significant project development costs.

4.1.2 Network Enhancements

- Sections 5.1.3 and 5.2.3 from the Knowledge Dissemination Report[37] document the detailed knowledge generated, captured and disseminated as part of the Low Carbon Hub Network Enhancements section.
- Low Carbon Hub established that land owners are unwilling to consent for the shorter overhead line spans required to support the larger cross section conductors associated with the reinforced network. Designs to support these larger conductors almost doubled the number of poles required, reducing spans from the existing 150m-160m to 85m.
- Low Carbon Hub Network Enhancements could reduce voltage rise by 24% over the traditional solution and increase thermal capacity from 16MVA to 41MVA.
- There was significantly more learning in these specific areas due to the challenges that Low Carbon Hub had to overcome during the design and delivery phase. Specifically working with external stakeholders who have existing overhead lines on their land[38].

4.1.3 Ring Method

- Section 4.3 from the Knowledge Dissemination Report details the detailed knowledge generated, captured and disseminated as part of the Low Carbon Hub Ring Method. Due to the change in approach, the method generated significantly more learning than originally envisaged.
    - How public perception of new renewable generation in the area changed very quickly in between the final submission and the detailed design of the project. The change in public opinion had a considerable impact on the ability to secure agreements.
    - The increased amount of detailed design that is required before this technique could be considered in a new area and the requirements for site visits and alternative delivery solutions.
    - How the use of new assets such as 33kV switchboards can be more economic and advantageous than having Air Insulated Switchgear (AIS) or a hybrid of AIS solutions.

[36] https://www.westernpower.co.uk/docs/Innovation/Presentations/Balancing-Act- -Combined-V0-16-Redacted-2.aspx
[37] LLCH-Knowledge-SDRC-V1.pdf
[38] CNT2002-LLCH-Close-Down-Report_v1-0-Final.pdf – Section 12 Learning dissemination.

- The challenges of protecting very rural networks with low fault levels and high levels of embedded generation with low fault level contributions and the impact of new connections on the protection systems, preventing them from becoming too complex.

4.1.4 Statcom

- Section 8.3 from the Knowledge Dissemination Report records the detailed knowledge generated, captured and disseminated as part of the Low Carbon Hub FACTs method. Significant efforts were undertaken to resolve issues and enhance the learning from the project, including the retrofitting of noise attenuating filters added to the Statcom demonstrating a > 10dB reduction in noise[39].
  - The requirements to consider audible noise from both fans and power electronic switching, the proximity to customers and how cost-effective noise cancelling solutions can be used.
  - The requirement for long term service plans and access to spares, especially if the solution is unlocking additional network access for customers.
  - The requirement to procure both a Statcom and step up transformer together as a combined solution.

4.1.5 Dynamic Voltage Control

- The demonstration of dynamic voltage control (DVC) showed there was a capability to deliver a more cost-effective method than the traditional network reinforcement approach. By using remote measurement data and an algorithm, there was a potential to amend voltage profiles and power flows across the network, unlocking network capacity by changing ANM set points.
- However, it was identified that the DVC method had to optimise the network under both normal and abnormal network conditions. The method had to cope with communications outages. If this was a default to the nominal settings, it could not unlock DG capacity as an alternative to traditional network reinforcement.
- As such it was clear that additional work was required to cater for abnormal conditions, in order to calculate how much capacity would be unlocked in each network locations it was identified that, after additional development to resolve these issues, this technique could also deliver considerable financial benefits to customers. As such this was taken forward as one of the methods for the LCNF Tier 2 Network Equilibrium project, which was awarded funding in 2014.

4.2 Additional learning as a result of exceptional effort of the DNO

The successful delivery of the Low Carbon Hub resulted in some key learning that was not envisaged when the project was developed, this included:

- The project had a coordinated programme of works across six different primary network substations[40] to deliver the Active Network Ring method, associated with the first two years of the project. Exceptional effort was required to successfully deliver the project and the associated learning. This was completed safely and without the work causing additional interruptions in supplies to customers, especially whilst a number of innovative techniques were also being

[39] LLCH-Knowledge-SDRC-V1.pdf – Page 54 and 55.
[40] CNT2002-LLCH-Close-Down-Report_v1-0-Final.pdf Section 9.2

demonstrated across the same network. Section 9.2 of the Close Down Report focusses on the additional learning that would not have been achieved without the exceptional effort to redesign the solution and deliver within the shortened time period.

  - The project aimed to show how the existing network could be altered rather than rebuilt to enhance capacity. With the project delays associated with not receiving permission for the new overhead line, it was recognised that the use of 33kV switchboards would have been an economically advantageous alternative to an AIS or hybrid AIS solution. They would have reduced network risk due to an offline build, required a shorter construction phase, and result in a simpler network to operate.
  - The delays in the first two years of the project resulted in a shortened period for both design and delivery; this made the construction phase more challenging. If looking to replicate this technique again in a new area, it is now recognised that a minimum of 3 months for design works per substation and 6–12 months for construction per substation depending on the length of the works needs to be allowed.

- When meshing radially designed and protected substation circuits, additional circuit breakers and protection equipment is required. The following factors need to be taken into account:
  - The safety of staff during delivery of complex construction activities as an online build risks being compromised.
  - Using a hybrid of existing air insulated assets and new gas insulated switchboards connected with cables can lead to the operation of sites being more complex.
  - The inclusion of an additional primary substation (Ingoldmells) and the associated circuits significantly increased the number permutations for both normal and abnormal running arrangements leading to delays in selecting an acceptable Low Carbon Hub design that could be adequately protected.
  - The design of an active ring using sites with additional circuits retrofitted to them is more complex due to additional space constraints when trying to connect new switchgear.
- The project delivered learning from the Alternative Connections / Commercial Agreements focussed on ensuring that a solution was delivered that could be offered to customers and that was ultimately financeable. The project created constraint analysis software to support customers in their analysis of the potential constraints, provided network data and explanations so they could conduct their own due diligence and supported them through their understanding of the Alternative Connections approach. This generated significant additional learning that is supporting the approach to the Business as Usual rollout of Alternative Connections.
- The project went to great lengths with the FACTs manufacturer to resolve a noise issue which would have, if not rectified, prevented the method being used to solve network issues when a substation is within close proximity to customers. The additional learning and mitigation has proven how this device could be used by DNOs within more built-up areas. This was outside of the scope of the initial requirements, but forms a key requirement for the future roll out of the method.
- Significant learning was gained by Western Power Distribution about the original issue where land owners would not grant the wayleave to construct a new 5km interconnector. As result of this

factor, which could not have been reasonably anticipated when the project was designed, significant additional effort was required and significant additional learning was generated about how to engage with stakeholders. This has led to Western Power Distribution modifying its approach in delivering new linear circuits.

4.3 Exceptional capture and dissemination of learning in a way that maximises value for all customers

The excellent capture of learning by the Low Carbon Hub has allowed Western Power Distribution to roll out Alternative Connections as a Business as Usual method. The learning being gained from the Business as Usual rollout is also being disseminated to other DNOs. As project learning was captured it was successfully shared with the industry. This was done both as the project was running and at the end of the project. Learning continued to be shared and disseminated in the most appropriate ways to support the development of the industry, such as through the publication of the ANM Good Practice Guide[41].

The knowledge capture and dissemination is articulated in Section 11 of the close down report[42]. This included both the written capture and dissemination of learning and the presentation of learning to the industry. Western Power Distribution believes we have demonstrated exceptional commitment to the dissemination of learning across the industry in the following areas:

- Three project specific dissemination events were held for the wider industry and DNOs, including on Alternative Commercial Arrangements and FACTs devices.
- Press and magazine articles were written about the project and associated learning to raise awareness of the project to the wider stakeholder community.
- The project has disseminated learning at numerous industry wide conferences. Over and above the LCNI events, learning has been disseminated at ACI Smart Grid: Vision, Strategy Implementation conference; the CE Smart Customer Response Trials workshop; The Realisation of the Future Smart Grid conference; a Solar Trade Event and to >90 local authority planners across the East Midlands.
- The project offered to disseminate learning directly to other DNOs in 1-to-1 meetings at their offices, some of which have taken up our offer.
- WPD held a licence Network Operators event, detailing the plans to deploy Alternative Connections to Generation Customers in the Midlands, South West and Wales, further sharing the learning generated that supported this rollout.

As detailed above, Western Power Distribution has supported ScottishPower[43] and shared learning to help them assess where Statcom could be used to solve network issues ScottishPower as a whole.

[41] http://www.energynetworks.org/assets/files/news/publications/1500205_ENA_ANM_report_AW_online.pdf
[42] CNT2002-LLCH-Close-Down-Report_v1-0-Final.pdf Page 54
[43] LLCH-Knowledge-SDRC-V1.pdf, Page 56, Section 8.4.1