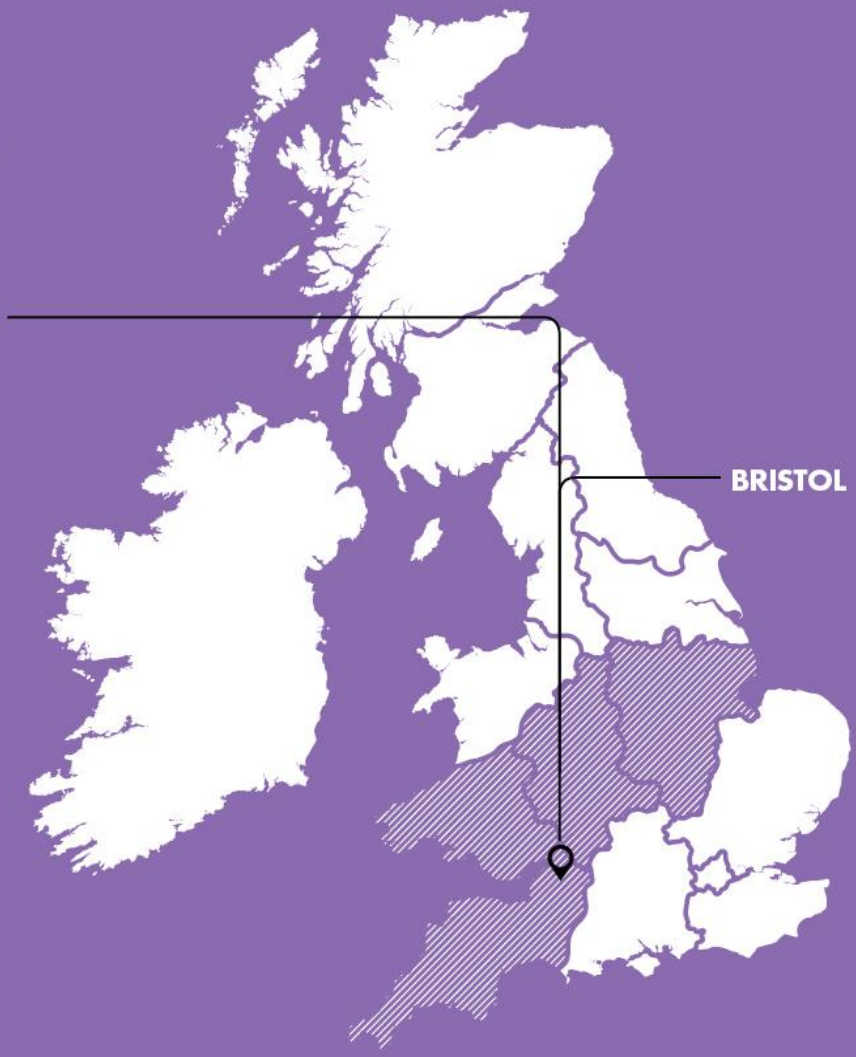
WESTERN POWER DISTRIBUTION

SOLA BRISTOL

# PROJECT SOLA BRISTOL




## Closedown Report

16th April 2016

LCN Fund Low Carbon Networks

BRISTOL CITY COUNCIL

UNIVERSITY OF BATH

KNOWLE WEST MEDIA CENTRE

SIEMENS

| | | |
|---|---|---|
| Report Title | : | Closedown Report |
| Report Status | : | FINAL |
| Project Ref | : | WPDT2003 – SoLa BRISTOL |
| Date | : | 14/06/2016 |

**Document Control**

| | Name | Date |
|---|---|---|
| Prepared by: | Mark Dale | 01/03/2016 |
| Reviewed by: | Roger Hey | 06/04/2016 |
| Recommended by: | Nigel Turvey | 07/04/2016 |
| Approved (WPD): | Phil Swift | 10/04/2016 |

**Revision History**

| Date | Issue | Status |
|---|---|---|
| 01/03/2016 | 0.1 | Draft |
| 18/03/2016 | 0.2 | Draft for Peer Review |
| 04/04/2016 | 0.3 | Draft Post Peer Review |
| 10/04/2016 | FINAL | |
| 09/06/2016 | Reissue | Updated post SDRC Application feedback |

## Contents

## 1. Project Title

BRISTOL (**B**uildings, **R**enewables and **I**ntegrated **S**torage, with **T**ariffs to **O**vercome network **L**imitations)

Throughout the project, it has more widely been referred to as SoLa Bristol and as such all references to previous documents at the time of the submission have been amended to reflect this.

## 2. Project Background

In the original submission we detailed the following as the rationale of the Method:

*"The UK's transition to a low carbon economy will require significant changes to the way we supply and use energy. Electrification of transportation and heating, combined with dense deployments of photo-voltaic panels, will give rise to additional constraints on electricity networks, particularly at low voltage (LV). These constraints cannot be ignored, and will ultimately adversely affect the customer and their own low carbon aspirations. To address this, networks can be strengthened using conventional reinforcement or by developing novel approaches.*

*The SoLa Bristol project is an innovative combination of energy storage in customer's premises, coupled with new variable tariffs and integrated network control to overcome generation or load related constraints at key times of the day. It will explore the use of direct current (DC) power in customer premises in conjunction with battery storage shared virtually between the DNO and customer, providing benefits to both parties.*

*Through batteries, the LV network will be operated more actively with additional capacity to manage peak load, control voltage rise and reduce system harmonics. The techniques trialled will, through reduction in constraints and need for network reinforcement, facilitate the connection of low carbon devices at reduced cost at over 40 locations in a range of premise types including homes, schools and a business."*

Based on this hypothesis the project included a couple of discrete pieces of work, the installation and operation of the technology, the customer engagement work(including the use of innovative tariffs to influence customer behaviour) and the analysis of the data to understand more about the dynamic of the Method in an operational setting. This was all supported by a Knowledge Capture and Dissemination workstream.

## 3. Executive Summary

The scope and objectives of the project were outlined within the Final Submission Proforma and in summary were that the project sought:

- To test the viability of integrating Low Carbon Technologies(LCTs) in a cost effective manner within the context of the Distribution Network
- To trial the use of DC as a method of encouraging consumer energy efficiency
- To determine whether or not the promotion of LCTs does place an additional strain on the LV distribution network and moreover whether this strain on the network could impede the overall transition to a low carbon economy
- To determine whether emerging smart gird technologies do offer a quicker and more cost effective solution to conventional reinforcement
- To examine the anecdotal view that as we do not under present arrangements utilise smarter grid solutions such as flexible demand to reduce peaks or to accommodate a rapid take up of generation on the LV network that this may be due to a lack of deployed suitable technology, unproven operating procedures and unknown costs, SoLa Bristol was a means to test this.

The outcomes at a high level were:

- SoLa Bristol could not prove the cost effectiveness of integrating LCTs within the distribution network
- There was some encouraging feedback from customers around DC usage and energy efficiency- although not conclusive
- The promotion of LCTs did not place additional strain on the network, but it is important to recognise that our sample was small
- The Smart Grid technologies trialled on SoLa Bristol do not currently appear to us to offer cost effective solutions to conventional reinforcement
- We do believe further opportunities do exist in this area, but we feel strongly that other parties may be better placed to explore and then exploit them.

It is our belief that SoLa Bristol fully met its objectives and SDRC's. This can be seen in the table below:

| SDRC | Status |
|---|---|
| 9.1 Successful initial engagement with customers | ✓ |
| 9.2 Confirmation of the SoLa Bristol design | ✓ |
| 9.3 Installation and commissioning of equipment | ✓ |
| 9.4 Early Operational Performance of SoLa Bristol | ✓ |
| 9.5 Measured the impact on the LV network | ✓ |

| | |
|---|---|
| 9.6 Customer Opinion | ✓ |
| 9.7 Keeping the lights on during power outages | ✓ |
| 9.8 Suitability of solution for mainstream adoption | ✓ |

Table 1: High level SDRCs and their status

The main learning points from the project are (further detail is provided within Section 9 and all learning is detailed within the Final Report, a link to which is provided in Section 14.1):

- a clear specification is critical and one which identifies a clear lead for each aspect of the project . This encourages ownership and allows for appropriate time and workload to be managed
- Contracts need to include some flexibility for unexpected tasks that emerge during the project lifecycle
- Understanding the type of relationship between partners is vital for project success
- All project members must understand the project and that understanding is not assumed.
- Customer engagement projects do require significant resources.

As stated above, these do represent a small snapshot of the overall project learning. A lot more information can be found in the final report. The link to the final report is in Section 14.1.

The main learning from the Method was:

- there is little benefit currently for customers and DNOs to pursue the method without some significant changes
- we saw significant variation in response to the technologies deployed, some customers liked it, some were less positive
- Integrating LCTs can work in theory, in practice in this environment they were not cost effective
- They do not offer, currently, an alternative to conventional reinforcement
- There appears to be little reason why a DNO would utilise these types of solution to manage demand flexibly in the current arrangements, with equipment costs as they are.
- Time of Use tariffs can work to an extent (although the benefits were small in our trial), but significant effort is required to maintain the connection with the customer to ensure their sustained commitment to the desired outcome.

Setting aside the main learning, we do think that the results of SoLa Bristol could, and should, be taken up by suppliers/builders and building management companies.

## 4. Details of the work carried out

The Method trialled was a rollout of PV Panels and Batteries at a series of domestic homes and a series of commercial sites (local schools predominantly). The location selected was Bristol, the reasons for selecting Bristol were that housing occupation was roughly in line with the national average and there was a large base of socially rented and council owned properties that were more typical of common UK property construction types.

As detailed within the final report, the overview of the SoLa Bristol system was as follows:

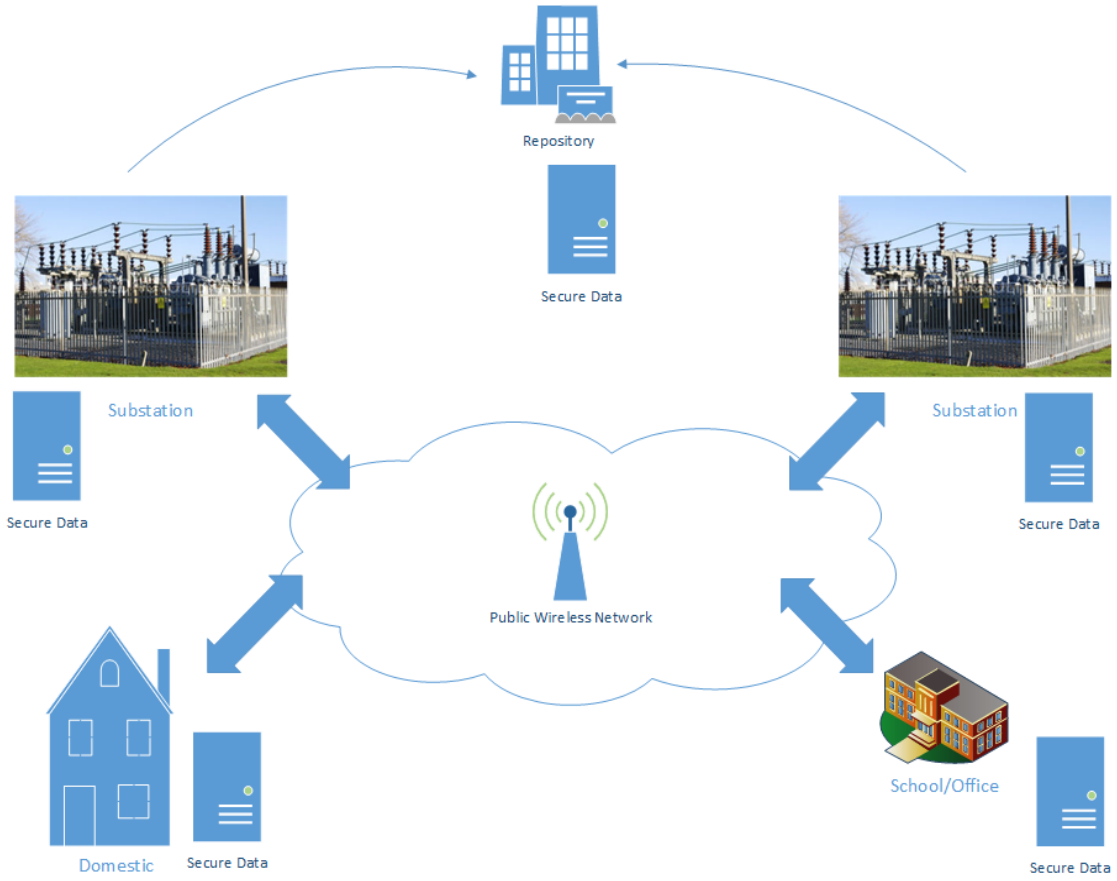



Figure 1 – SoLa Bristol System

As well as the installation of the equipment there was also the construction of the most appropriate communications network in order to obtain reliable data back from the trial sites. More information on the exact nature of this is provided within Section 11, but at a high level the communications network required for the team to be able to receive load data back from the equipment, provide information to the customers as well as provide for the remote control of the battery devices. This was of course not an insubstantial

undertaking as house types can vary, signal strength is always a challenge and at the same time we were attempting to trial new technologies and use innovative tariffs to see if these could be used to enable customers to modify their behaviour.

As the fundamental deliverable of the trial was to quantify the benefit (if applicable) of behavioural change a key focus of the project team was customer engagement. We believe that the project has gained some significant insights because of this.

The Methodology used was a waterfall based project plan with distinct phasing of the work. The work was divided into a number of workstreams as follows:

- Domestic Customer Recruitment,  Installations and Trials
- Commercial Customer Recruitment, Installations and Trials
- Data Collection
- Knowledge Capture and Dissemination

Each workstream lead was responsible for the delivery of the work packages within their workstream. The original bid had a detailed project plan for the overall delivery of the project.

The final summary plan looked like this:


Fig 2 High level project plan

The work carried out was relatively straightforward insomuch as there was some design work up front, running in parallel with customer recruitment and once these tasks were completed it was then a matter of installing the equipment , running the trials and then analysing the data. So from a practical point of view SoLa Bristol was a relatively straightforward project. The whole plan was underpinned by a Knowledge Capture process and more information on this can be found within the Final Report.

Of course some aspects of this work were harder to achieve than others, in particular the design piece coupled with customer recruitment did hamper progress. A lot of this was not predictable and as such it provided some valuable learning for WPD and stakeholders. The full detail of the learning from these pieces of work can be found in the Final Report(a link to this is within Section 14.1).

In terms of the delivery methodology, as mentioned previously, it was a waterfall plan in the main with some parallel working where SDRCs or other key deliverables occurred within the same phase. Some SDRCs had a significant lead time as they required extensive data analysis in order to meet them and this explains the parallel running within the high level plan.

# 5. The outcomes of the Project

The project had a number of key areas, the installation of the technology, the customer engagement experience and the trials and analysis.

We will take each area in turn and explain the outcomes in more detail and where appropriate give sufficient information to enable other DNOs to use the solutions as may be required. It is however our view that at this stage, these solutions do not present value for money in their current form and as such we have not gone into too much technical detail for the purpose of this report. We are though happy to provide whatever information another DNO may reasonably require.

## 5.1 The Installation Process

The project required the design, build and testing of a new system that allowed the customer and DNO to utilise, as required, the solar panels and storage facilities for mutual benefit. In order to facilitate this, the customer had a storage device installed in the roof space, solar panels on their roof and the relevant accompanying devices for the control of both. They also had the use of a tablet PC which provided information on their energy usage and savings.

The full list of equipment is provided within Section 11, and this phase of the project produced the following outcomes:

- Whilst the installation process did throw up some issues, it was generally well received by the end customer.

- It was important we found, to use the same people throughout the installation and decommissioning processes.

- The storage devices worked well and broadly in line with what was expected , we do feel however that there is some work to do to make this mode of market operation work effectively for DNOs and more important an attractive proposition.

## 5.2 The Customer Engagement Process

SoLa Bristol was a long project and throughout, it was important to maintain a consistent dialogue with the customers. This in itself was a considerable lesson for WPD, in that the amount of effort required was considerably more than we had anticipated. However the main outcomes that other DNOs can take from the project in this regard were:

- Customers were generally positive about the project.
- There were some significant lessons for the industry we feel about engaging with customers in innovation projects.
- It is extremely time consuming to engage with customers and maintain the level of engagement required for this type of initiative and whilst we have gained valuable insights , we have to consider the wider value for money aspects of these solutions.

## 5.3 Trials and Analysis(including calculation of benefits)

Obtaining good quality data was a key factor of success for SoLa Bristol. The design phase was predicated on the achievement of a robust, but viable, design that could deliver the requirement in the timescales. We believe that this was a considerable achievement given the complexity of the requirement. Therefore to get good data we see as a particularly strong message for SoLa Bristol.

The analysis of the data has been another challenge because of the volume of data and the amount of analysis required in order to test the hypothesis. However, this has been completed and the full results are detailed within the Final Report, a link to which is provided within Section 14.1.

The high level results from the analysis were as follows:

- Network Benefits- there were some observed benefits that were seen from the project. Further work is required, however indications are that although the penetration of battery and PV was relatively low in the trial network and there was some demand uncertainty, the network demand change was not reflected in the measured data and therefore the corresponding network investment deferral was small. When the penetration level is theoretically increased, the network investment deferral is increased to thousands of pounds. However, clearly this is not material enough to justify the considerable investment.
- Domestic Customer Benefits- The average saving of the 11 houses on substation 3 was £52.10 during the trial, and the average saving per month equated to £7.43.
- Commercial Customer Benefits- In the schools, only the battery was taken into account for calculating benefit,. The schools implemented the new EMS strategies at the end of November 2014. Therefore, the school's ToU benefit was calculated from December 2014 through to May 2015. The six months benefit received by the school was c. 0.9%. As the weekday and weekend EMS strategies were different, the benefit of weekdays and weekends was consequently different. The average benefit received per month was £5.83.

The full analysis can be found within the Final Report, Sections 7 & 8.

Given these results, it is absolutely clear that change is needed and we discuss more on this later in this report.

## 6. Performance compared to the original Project aims, objectives & SDRCs

The problems that SoLa Bristol was attempting to address were around the connection of LCTs and how these might be a useful tool to DNOs in the future. We could not prove this assertion and whilst this is disappointing, it did provide fascinating insights into the challenges that the industry as a whole faces.

This was a long and at times, challenging project. The effort from the project team to get the results we needed was immense and the data analysis has been useful in establishing what needs to happen in order to make the transition to a low carbon economy as effective as we can, but it is absolutely clear to us that there is considerable work to do to make the aspiration a reality.

In terms of the projects aims, objectives and success criteria, we believe that despite the challenges and the inability to prove the hypothesis, that SoLa Bristol has been extremely successful. We detail below all of the SDRCs and other aims of the project and their completion status.

| Criterion | Proposed Evidence | Completion Status |
|---|---|---|
| **9.1 Successful initial engagement with customers**: This criterion corresponds to successfully holding a workshop with Bristol City Council, potential trial participants and interested parties before 30th April 2012. Holding the workshop on or before this date will demonstrate the project is on schedule to recruit trial participants' in line with the project plan. Prior to the workshop the customer communication plan will have been submitted and accepted by Ofgem. WPD will work with our partner, Bristol City Council and the trial participant recruitment specialist to engage with target domestic audiences and the selected schools from the Solar PV for schools scheme. | •The Customer Communication plan will be sent to Ofgem at least two months before any intended contact with customers, the final version will be shared with customers Energy Retailer when the trial participants have been selected, published on the Western Power Distribution website and on the project SoLa Bristol website.<br>•The recruitment plan, copies of material used to recruit trial participants and locations targeted will be recorded.<br>•Minutes and notes captured from the workshop will be stored for future use during knowledge dissemination outputs. Feedback from the event and recruitment | The Customer Communications Plan was written, sent to Ofgem and approved on 18th December 2013. A link to the document is provided here:<br><br>http://www.westernpowerinnovation.co.uk/Document-library/2016/Sola-Bristol-customer-engagement-Final-(2).aspx<br><br>These were all recorded and the findings form part of our learning.<br><br>These were all recorded and the findings form part of our learning. Feedback was an integral part of the learning process within SoLa Bristol, especially given the considerable amount of customer engagement that was required. |

| | | |
|---|---|---|
| The workshop will be used to explain the purpose of the project, provide a guide to the installations, detail the project timeline and gather customer feedback. It will be an opportunity for customers to learn more about the project first hand and ask any questions they may have. | process will be gathered through a post event questionnaire where any outstanding questions can be collated.<br>•An overview of the workshop and feedback will be posted on the SoLa Bristol website for interested parties within a month of the event. | All feedback was disseminated as part of early learning and the final report. Extensive analysis of the findings has been undertaken and we detail our thoughts elsewhere in this report. |
| **9.2 Confirmation of the BRISTOL design**: This criterion corresponds to signing off the design of the installations by 30th September 2012 for homes, schools and office after the trial participants and locations have been confirmed. The design will confirm the capability of the equipment being installed; details which equipment will be connected to the DC network, how the equipment will be connected together and the location of equipment in a typical home, school and the selected office.<br>The design will be developed with our partners, Siemens and the University of Bath. It will build upon the Technical Overview outlined in Appendix C and use the outputs from the detailed survey and planning, participants wiring and structural reviews. The final design will be published through the BRISTOL website. The designs will be reviewed and modelled to predict the performance of the solution, customer | •Regular meetings will be held between WPD, Siemens and the University of Bath to develop the SoLa Bristol design. Summaries of the meetings and design decisions will be captured and recorded.<br>•The results of the surveys, inspections and reviews will be recorded and stored by the University of Bath<br>•The predicted performance and benefits will be recorded and stored. The predicted performance will be compared against the actual performance.<br>•The final design will be signed off by WPD senior engineering managers and subsequently shared through the SoLa Bristol website. | All deliverables were met and can be seen through the depth of detail captured throughout on learning.<br><br>The final designs were disseminated via this report:<br><br>http://www.westernpowerinnovation.co.uk/Document-library/2012/Confirmation-of-the-SoLa-BRISTOL-design-v1-0.aspx<br><br>All documents have been stored and as part of closure are being transferred to WPD.<br><br>All documents have been stored and as part of closure are being transferred to WPD.<br><br>The final designs were published on the WPD Innovation website the link is here:<br><br>http://www.westernpowerinnovation.co.uk/Document-library/2012/Confirmation-of-the-SoLa-BRISTOL-design-v1-0.aspx |

| | | |
|---|---|---|
| benefits and distribution network benefits of the final design. | | |
| **9.3 Installation and commissioning of equipment**: This criterion corresponds to installing and commissioning equipment in 30 domestic properties before 30th April 2014, 10 schools before 31st August 2014 and an office before 30th April 2014.<br>Prior to the installations WPD and our partners will Factory Acceptance Test the BRISTOL solution, provide training for the installation team, form method statements for installation, risk assessments for installation and operation, an appointment booking process, re-booking process, complaints procedure and operation guide. | •A test specification will be completed prior to the factory acceptant test and the commissioning of equipment; this will be signed off by the WPD project manager. The results from the factory acceptance tests will be analysed by Siemens and the University of Bath with final acceptance by WPD.<br>•Project documents will be peer reviewed by the WPD Project Manager before they are issued. Copies of the project documentation will be stored by the University of Bath.<br>•Regular installation progress reports will be posted on the SoLa Bristol website for interested parties to view.<br>•A review of the installation and commissioning activities will be carried out, capturing any lessons learnt. If required, the method statements and other related documentation will be updated and stored. | This criterion was completed and a report developed on the FAT process, this was disseminated as part of the Final Report.<br><br>All documents are peer reviewed internally before any dissemination. Moreover, key documents are reviewed wherever possible by partners and other stakeholders as well. All project documentation was stored at the University of Bath and is now being transferred to WPD as part of project closure.<br><br>Installations progress was detailed within the PPRs and the final installation report was disseminated as below: http://www.westernpowerinnovation.co.uk/Document-library/2013/Sola-Bristol-Installation-report.aspx<br><br>This was completed and forms part of the Installations report published in December 2014.<br><br>http://www.westernpowerinnovation.co.uk/Document-library/2013/Sola-Bristol-Installation-report.aspx |
| **9.4 Early Operational Performance of BRISTOL**: This criterion corresponds to successfully operating an integrated DC network with storage in homes, schools and an office. The operational performance from the data captured | •An operations report will be produced and shared through the SoLa Bristol website, Stakeholder Dissemination symposia, and the project board.<br>•The actual data will be collected and stored by | The early learning report disseminated:<br><br>http://www.westernpowerinnovation.co.uk/Document-library/2014/Sola-Bristol-Operational-early-learning-report-fin.aspx<br><br>All documents and data have been stored and as part of closure are being transferred to WPD. |

| | | |
|---|---|---|
| through the LV Connection Manager will be analysed to provide an early snapshot of the BRISTOL performance since commissioning.<br>We will capture and share the early learning from deploying and running DC networks and battery storage in customer premises. Data will be captured up to 30th November 2014; the learning will be released by 31st December 2014. No customer sensitive data will be released, and any data relating to customers will be completely anonymous.<br>A review of the early learning will be undertaken to determine if any changes are required in the operation of the LV Connection Manager, including the battery use and charging algorithms to improve the future performance of the SoLa Bristol solution. | the University of Bath. The performance data including system availability, battery usage and data rates will be analysed and compared to the pre installation predictions.<br>•If required, the method statements and other related documentation will be updated and stored.<br>•Notes from the project meetings discussing operational performance in homes, schools and the office will be recorded and stored. | All documents have been stored and as part of closure are being transferred to WPD.<br><br>All documents have been stored and as part of closure are being transferred to WPD. |
| **9.5 Measured the impact on the LV network:** This criterion corresponds to measuring the impact of the SoLa Bristol solution on the trial distribution substations operation, compared to the operation prior to the installation and commissioning of equipment in homes, schools and the office. The long term operation of the distribution network will be captured through the LV Network Manager located in distribution substations, the data recorded will be analysed to monitor any | Findings shall be shared through a summary report published through the SoLa Bristol website by 31st May 2015.<br>Notes from the project meetings discussing operational performance (changes to the LV voltage profiles, feeder demand profiles and power quality) will be recorded and stored.<br><br>The actual data will be collected and stored by the University of Bath. The performance data recorded by the LV | The measured impact was shared within the Measure Impact on the LV Network December 2014 report which can be found here:<br><br>http://www.westernpowerinnovation.co.uk/Document-library/2015/SDRC-9-5-REPORT-Final.aspx |

| | | |
|---|---|---|
| changes in the voltage profile, load profile and power quality of the network as a result of the installation in homes, schools and the office. In substations with SoLa Bristol installed on one LV feeder, another similar LV feeder will also be monitored and used as a reference.<br><br>Through this criterion we will be capturing and sharing the early learning, measuring the network benefits of the BRISTOL solution, sharing the analysis before 31st May 2015. | Network Manager will be analysed and compared to the pre installation predictions. If required, the method statements and other related documentation will be updated and stored. | |
| **9.6 Customer Opinion**: This criterion relates to learning about customer acceptance of a SoLa Bristol solution. We will specifically report on how they feel about virtual asset sharing, taking up space in their home, the energy savings, how disruptive the equipment has been, how easy it is to operate and if there opinion of the SoLa Bristol solution has changed over time. WPD will work with the trial participant recruitment specialist and the University of Bath to design a process and subsequently capture customers' feelings on the project in line with the customer communication plan. The assessments will be completed before 31st March 2014 to capture customers' opinions before the trial starts, before 31st March 2015 | •The Customer Communication Plan, detailing customer contact will be on the website<br>•Knowledge will be captured using a mixture of questionnaires and interviews with results published two months after each assessment is completed.<br>•Any customer complaints will be resolved within 14 days and the responses will be stored.<br>•Analysis will be shared with all trial participants, Bristol City Council and GB DNOs through the BRISTOL website. The learning from the customer opinion will be used to update the customer communication plan. | As detailed previously this is available on the WPD innovation website.<br><br>Knowledge has been captured and analysed throughout and has been detailed within the Final Report with some key lessons learnt. In this report, we have taken this to the next level by detailing how we are taking the lessons forward.<br><br>No complaints were received throughout the project lifecycle, but a process was in place to ensure that complaints received were process expediently.<br><br>All learning was documented in order to develop and inform the Customer Communications Plan throughout the project. |

| | | |
|---|---|---|
| to capture customers' opinions during the trial and before 31st November 2015 to capture customers' opinions after the trial. | | |
| **9.7 Keeping the lights on during power outages**: This criterion corresponds to testing the domestic BRISTOL solution during an AC power outage. WPD will ask selected domestic customers to test the energy security section provided by the battery storage between 1st June 2014 and 1st June 2015. The performance of the DC network and batteries will be monitored, through the LV Connection Manager. Customers' behaviour and use of energy during the short outage will also be captured through the LV Connection Manager and a survey. This test will inform us of the capability of the SoLa Bristol system during a power outage and the potential value to customers. The trials will be scheduled at different times of the day with different weather conditions and battery capacities to maximise the learning. Selected customers will be invited to undergo this test only once during the trial. | The data from the LV Connection Manager and responses from the domestic questionnaire will be stored by the University of Bath. The power outage test plan and communication methods used will be designed and stored by the University of Bath and will be signed off by the WPD Project Manager. The learning generated by analysing the data will be shared with all stakeholders and interested parties through the end of project report on 15th January 2016.<br><br>Customers' energy demands during the short power outage test will feed into the battery size review at the end of the project (SDRC 9.8 (5)). | All deliverables contained within this SDRC were disseminated on 15th January 2016 via the WPD Innovation website. The report covered all aspects of the project and detailed the learning throughout.<br><br>The link is here:<br><br>http://www.westernpowerinnovation.co.uk/Document-library/2016/WPDT2003_SoLa-Bristol_SDRC9-8-resubmissionv2-0.aspx |
| **9.8 Suitability of solution for mainstream adoption**: This criterion corresponds to writing a comprehensive end of project report summarising the project | The end of project report will review the detail knowledge generated from the design and operation of the BRISTOL project. The report will include | Disseminated on 15th January 2016 via the WPD Innovation website. This report details all learning, summarises the design and details the benefits analysis of the ToU tariffs and networks.<br><br>More information should it be required can be obtained by contacting WPD. |

| | | |
|---|---|---|
| findings. The report will contain sufficient information to advise other UK DNOs: (1)If the SoLa Bristol trial demonstrates solar PV can be integrated into the distribution network using battery storage and DC networks. (2)How the measured results compared to the predictions made in the set up and development period (SDRC 9.2). (3)How the solution could be used to incorporate other LCTs into the distribution network (4)What customer benefits where recorded throughout the trial. (5)The significant lessons learnt during the trial, how these would be reflected in a future roll out of the BRISTOL solution if used as an alternative to conventional network reinforcement. (6)Which policies and standards would need to be modified to allow a BRISTOL solution and (7)What impact the inclusion of SoLa Bristol will have on DNO business plans. The report will also contain an appendix with all the early learning reports from previous milestones and a feasibility study for installing a SoLa Bristol solution in an office using the learning generated from the trial. | the appendices from the key areas of learning highlighted in the other Successful Delivery Reward Criteria. The report containing the information above will be published by 15th January 2016.<br>The results from this milestone will determine if the solution can be adopted into mainstream. If limiting factors are present, preventing the inclusion into mainstream adoption at the end of the project, the report will recommend areas that need to be monitored (e.g. the future cost of energy storage, deployment of smart meters) which may facilitate the future inclusion as a network reinforcement technique. | The link is here:<br><br>http://www.westernpowerinnovation.co.uk/Document-library/2016/WPDT2003_SoLa-Bristol_SDRC9-8-resubmissionv2-0.aspx |

Table 2: All SDRCs and detailed criterion and status

# 7. Required modifications to the planned approach during the course of the Project

SoLa Bristol did not require any changes to its approach. It did however require two separate changes during its lifecycle to reflect the changing nature of the project. No change in Methodology (it remained a waterfall delivery) was required throughout the project but for the purposes of clarity we are detailing the two approved change requests and the rationale for them.

Links to the relevant changes are provided below for completeness.

## 7.1 Change Request CCR005

There was a need to reduce the anticipated domestic sample size from 30 to 26. This did not in any way undermine the results, but the change was necessary as it proved impractical to maintain a sample size of 30 despite the best efforts of the local team supporting the project.

There were a couple of key reasons for the need to reduce the sample size, the first being the need for a particular amount of roof space to support the batteries and PV and secondly, given this requirement it reduced the amount of available population and their subsequent interest in participating in the project. All of this could not have been foreseen at the time of the bid. What this does though provide is useful anecdotal evidence for future trials of this technology should someone wish to pursue such a trial. There is a vast amount of recorded knowledge pertaining to customer engagement contained within the Final Report (SDRC 9.8).

https://www.ofgem.gov.uk/sites/default/files/docs/2015/03/wpd_hh_change_request_0.pdf

https://www.ofgem.gov.uk/sites/default/files/docs/2015/03/ofgem_decision_solabristol_hh_cr_0.pdf

## 7.2 Change Request CCR004

This change dealt with the reduction in sample size for the commercial properties, and extended the timeline by twelve months. This was required due to a number of challenges faced by the project.

These included:

- The Project Direction specified that we should avoid recruiting project participants until issues with the first three homes were resolved and a report produced.

- delays putting in place an installation contract due to the technical specification being revised,
- Equipment design modifications and repeated CE marking tests caused by system changes following initial installations,
- delays with trial home installations due to enhanced training needs and
- Additional time taken to produce, and for the approval of, the customer engagement and Data Protection plans.

https://www.ofgem.gov.uk/sites/default/files/docs/2014/12/wpd_sola_change_request_publish_0.pdf

https://www.ofgem.gov.uk/sites/default/files/docs/2014/12/ofgem_sola_change_request_letter_publish.pdf

In its letter of 19th August 2015, Ofgem asked us to consider, as part of Project Closedown, further the causes of increased costs/budgeting. WPD remains of the view that increased costs are a fact of life when delivering change; It is even more acute when managing, delivering and testing innovation. It is not possible to know precisely costs associated with delivering the unknown. Whilst WPD is always looking to take learning from new things, we are confident that the relevant controls internally were in place.

The project suffered significant challenges and ones that WPD is absolutely keen to take forward, what we could not legislate for was customer behaviour, design changes and the unknowns that are ever apparent when trialling new things. Every effort has been made to ensure that all of our projects return value for money for customers and where they cannot we are more than happy to return funding. In this instance, the budgeting challenges were a mixture of unforeseen changes to the planned scope and necessary design changes; they were not due to poor estimating or accounting.

Further, in its letter of 13th March 2015, we were asked as part of Closedown to look at our installation and decommissioning costs, to see whether any costs could be returned to customers. First and foremost, whatever costs can be returned to customers are always returned to customers. We see no benefit in holding back money that is not required or is not spent. It is also not in the spirit of the LCNF/NIC.

The costs of the equipment were estimated at the start of the project, the costs of installing it were based on our best estimate at that time. As the project progressed it became clear that changes to budgets would be needed and therefore whilst less equipment was installed the overall total remained the same.

## 8. Significant variance in expected costs

Detailed below is the final Budget for SoLa Bristol. Whilst it is disappointing that the project could not be accomplished for the original cost, the reasons for the overspend we believe to be well documented.

The learning and benefits to the industry of the project are, we believe, there to see. It is clear from SoLa Bristol that this particular problem is not an easy one to solve and we believe that SoLa Bristol has proven that DNO's are not necessarily best placed to solve it.

In the Project Progress Report of June 2015 we highlighted that the equipment category was going to overspend. This was accepted by Ofgem in their letter of 19th August 2015. In that letter Ofgem sought assurances that we had considered any lessons that could be learnt as part of this project.

The reason for the overspend was not due to any lack of budgetary control on our part, it was the impact of a series of events that started with having to change designs, change the sample, a reduced budget because of a smaller commercial property trial size and then trying to ensure that the project could deliver against those changes.

We have throughout all of our projects maintained a dialogue with the relevant case officer at Ofgem to ensure an appropriate level of communication about our projects. We accept that SoLa Bristol did go over budget on the equipment side, but this overspend was not a consequence of oversight on our part. There are some inherent difficulties in these research projects and things will inevitably be subject to trial and error. We have a rigorous process for managing our projects financially and perhaps any delay of our part in managing the change process is out of a desire to get things right, rather than a lack of procedure internally.

We would like to have a more detailed discussion about how the change mechanism for these projects could be enhanced to make the process more efficient for all parties.

The final budget is detailed below with WPDs additional contribution added for clarity:

| Cost Category | New Budget | Actual LCNF Spend Nov 2015 | LCNF Variance to Budget Nov 2015 | Additional WPD Contribution | Total Project Spend Nov 2015 | Notes |
|---|---|---|---|---|---|---|
| **Labour** | **165.7** | **159.55** | **-4%** | **32.05** | **191.6** | |
| Overall Project Manager | 151.2 | 151.2 | 0% | 32.05 | 183.25 | |
| Substation installation (including any civil modifications) | 14.5 | 8.35 | -42% | | 8.35 | Note 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Equipment** | **486.73** | **479.58** | **-1%** | **124.95** | **604.54** | |
| Distribution Sensing Equipment | 11 | 11 | 0% | 0.44 | 11.44 | |
| Customer Sensing Equipment | 2 | 2 | 0% | 0.86 | 2.86 | |
| Substation installation (including any civil modifications) | 14.5 | 8.35 | -42% | | 8.35 | Note 1 |
| DC Meters | 5 | 4 | -20% | | 4 | Note 2 |
| Domestic premises equipment (supply) | 237 | 237 | 0% | 74.96 | 311.96 | |
| School equipment (supply) | 114.4 | 114.4 | 0% | 28.34 | 142.74 | |
| Office equipment (supply) | 22.43 | 22.43 | 0% | 5.54 | 27.97 | |
| Substation equipment (supply) | 50.4 | 50.4 | 0% | 12.81 | 63.21 | |
| Smart Appliances & ICT Equipment | 30 | 30 | 0% | 2 | 32 | |
| **Contractors** | **1329.46** | **1275.9** | **-4%** | **341.48** | **1617.38** | |
| BCC Project Management | 60 | 60 | 0% | 1.34 | 61.34 | |
| Detailed Installation Survey and Planning | 50 | 50 | 0% | 0.38 | 50.38 | |
| Training and Installations | 166 | 166 | 0% | 38.48 | 204.48 | |
| Trial Property Recruitment, Equipment Maintenance & Ongoing Support | 159.5 | 116.13 | -27% | | 116.13 | Note 3 |
| Equipment Decommissioning (including battery disposal) | 161 | 150.81 | -6% | | 150.81 | |
| System Design and Engineering | 101.76 | 101.76 | 0% | 24.84 | 126.6 | |
| Domestic premises equipment (supply) | 67.49 | 67.49 | 0% | 21.34 | 88.83 | |
| School and Office equipment (supply) | 12.5 | 12.5 | 0% | 3.1 | 15.6 | |
| Substation equipment (supply) | 70.98 | 70.98 | 0% | 18.04 | 89.02 | |
| Data archiving and access equipment (supply) | 62.92 | 62.92 | 0% | 38.14 | 101.06 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Installation, commissioning and operation support | 101.76 | 101.76 | 0% | 34.46 | 136.22 | |
| Input to smart tariffing | 104.41 | 104.41 | 0% | 60.69 | 165.1 | |
| Input to network design | 151.89 | 151.89 | 0% | 95 | 246.89 | |
| Dissemination planning | 59.25 | 59.25 | 0% | 5.67 | 64.92 | |
| **IT** | **43.7** | **43.53** | **0%** | **7.91** | **51.44** | |
| Data Communications (LV Connection Manager & LV Network Manager) | 20 | 19.83 | -1% | | 19.83 | |
| Domestic premises equipment (supply) | 8.4 | 8.4 | 0% | 2.66 | 11.06 | |
| School & Office equipment (supply) | 3.08 | 3.08 | 0% | 0.76 | 3.84 | |
| Substation equipment (supply) | 8.4 | 8.4 | 0% | 2.13 | 10.53 | |
| Data archiving and access equipment (supply) | 1.82 | 1.82 | 0% | 1.1 | 2.92 | |
| Input to smart tariffing | 1 | 1 | 0% | 0.63 | 1.63 | |
| Input to network design | 1 | 1 | 0% | 0.63 | 1.63 | |
| **Travel & Expenses** | **0** | **-** | **0%** | | **-** | |
| **IPR Costs** | **47.33** | **47.33** | **0%** | **14.88** | **62.21** | |
| System Design and Engineering | 12.83 | 12.83 | 0% | 3.14 | 15.97 | |
| Domestic premises equipment (supply) | 2.15 | 2.15 | 0% | 0.68 | 2.83 | |
| School equipment (supply) | 0.72 | 0.72 | 0% | 0.17 | 0.89 | |
| Substation equipment (supply) | 1.69 | 1.69 | 0% | 0.42 | 2.11 | |
| Data archiving and access equipment (supply) | 1.21 | 1.21 | 0% | 0.74 | 1.95 | |
| Installation, commissioning and operation support | 28.73 | 28.73 | 0% | 9.73 | 38.46 | |
| **Payments to users** | **18** | **2.43** | **-87%** | **0** | **2.43** | |
| Battery Charging Costs | 9 | 0 | -100% | | 0 | Note 4 |
| Variable Tariffs - Payments to users for changes in behaviour | 9 | 2.43 | -73% | | 2.43 | Note 4 |
| **Contingency** | **149.87** | **148.12** | **-1%** | **30.88** | **179** | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Scope change Contingency (Survey results) | 49 | 47.25 | -4% | | 47.25 | |
| System Design and Engineering | 13.8 | 13.8 | 0% | 3.37 | 17.17 | |
| Domestic premises equipment (supply) | 30.46 | 30.46 | 0% | 9.63 | 40.09 | |
| School equipment (supply) | 22.33 | 22.33 | 0% | 5.53 | 27.86 | |
| Office equipment (supply) | 2.59 | 2.59 | 0% | 0.64 | 3.23 | |
| Substation equipment (supply) | 12.82 | 12.82 | 0% | 3.26 | 16.08 | |
| Data archiving and access equipment (supply) | 7.72 | 7.72 | 0% | 4.68 | 12.4 | |
| Installation, commissioning and operation support | 11.15 | 11.15 | 0% | 3.77 | 14.92 | |
| **Decommissioning** | **0** | **-** | **-** | **-** | **-** | |
| **Other** | **40** | **40** | **0%** | **25.02** | **65.02** | |
| Input to smart tariffing | 2 | 2 | 0% | 1.25 | 3.25 | |
| Input to network design | 2 | 2 | 0% | 1.25 | 3.25 | |
| Workshops | 12 | 12 | 0% | 7.51 | 19.51 | |
| School engagement | 24 | 24 | 0% | 15.01 | 39.01 | |
| **TOTAL** | **2280.79** | **2196.44** | **-4%** | **577.17** | **2773.62** | |

| | |
|---|---|
| Note 1 | Civils in substation installations were less than expected |
| Note2 | DC Meters for commercial installations not required |
| Note 3 | Overall costs less than originally estimated. |
| Note 4 | Battery Charging & Tariff payment costs have been less than anticipated. |

# 9. Updated Business Case and lessons learnt for the Method

The original FSP detailed a series of perceived and potential benefits to customers and DNOs. These were as follows:

- Financial benefits
- Customer benefits
- DNO benefits
- Environmental benefits
- Other energy industry benefits
- Relevance to ED1

Below we detail the findings from the project in a summary format; more information can be found in the final report. It is important we feel to remember what whilst we have not been able to prove the method that this does not mean that the project has not been of value. We believe that the project has been extremely valuable in determining the viability of using LCTs to manage networks.

## 9.1 Financial benefits

In the original submission we stated that the network reinforcement costs for conventional reinforcement are well known. However we felt that the amount of network reinforcement needed for an installation of micro generation or other LCTs can vary substantially depending on the location. Networks have a finite capacity to connect LCTs. The learning from the Tier 2 project LV Network Templates provided a much clearer idea on the capacity of LV networks. We do have examples of micro generation triggering network reinforcement, however the number have been historically low. The increasing connection of microgeneration has the potential to increase the number of locations requiring network reinforcement. A recent example where network reinforcement was triggered by LCTs resulted in a quote of £67,000 for the connection of 27kW PV over three phases. The cost for a SoLa Bristol connection for this example, after the proof of concept, could be in the region of £18,100.

### 9.1.1 Outcome

We undertook extensive analysis of the data obtained from SoLa Bristol. Detailed conclusions and analysis are provided within the Final Report, however we have detailed below a summary of the main findings:

- There is little benefit for DNO's in using these technologies, the benefits are tiny where there is low penetration (as little as £300).
- Substantial reductions in cost would have to be realised as well as a significant take up per distribution substation in order for this to make economic sense to a DNO (reductions of several thousand pounds were our calculations).

- Because it was a trial, it was very hard to determine whether the technology was having an effect on demand. It is our view that you would need a much more densely populated trial in order to validate overall success but of course this would make the trial prohibitively expensive.
- In addition whilst it is entirely possible that connection costs could be reduced we remain concerned that any connection must be based on a valid business case. It is clear that potential savings must be taken into context, lifestyle changes can significantly impact customer savings from these technologies (e.g. retirement would mean that customers would use energy throughout the day rather than during normal working peak periods).

## 9.2 Customer benefits

In the original submission we identified 4 areas where customers could benefit from the proposed solution.

- **Keeping the lights on:** Through the installation of the SoLa Bristol system, the batteries could be used to provide enhanced resilience during power outages. Lighting, computing, telecommunications and potentially central heating pumps could be available from the battery storage even during network power outages.
- **Lower energy bills through a better control of energy:** a Variable Tariff rewarding customers for reducing their peak energy demand, passing on the cost savings. Clearer, more transparent energy bills through the LV connection manager using energy efficiency, better use of PV
- **Improved energy efficiency:** Supplying DC equipment using a high quality AC/DC converter and PV panels powering the DC network instead of a large number of inefficient AC/DC converters will reduce electricity losses.
- **Quicker and cheaper connections:** Conventional network reinforcement can not only be costly, but also require significant scheduling; the BRISTOL solution is one that could be implemented much faster and cost effectively.

### 9.2.1 Outcome

There were some benefits for customers from the trials. More information is provided within the Final Report, but in summary there were:

- Customers can make savings from the use of storage and solar panels. However, given the variability of savings it is difficult to say what the normal saving for a customer would be. This we believe is because customers use energy in different ways and have different attitudes to its use/conservation. From the data obtained, we think there is still some way to go before we can genuinely say that all customers are fully engaged and fully understand the energy challenge that the UK faces. WPD has a role to play in this of course, but from SoLa Bristol we think that there is a need to have a wider debate about exactly how this is taken forward.

- There is some evidence that Time of Use tariffs work in that there were some engaged customers who did modify behaviour to reduce their bills.
- We are actively involved in an IET Working Group looking at Energy Storage in Domestic properties.

### 9.3 Distribution Network Operator benefits

In the FSP we stated that we thought that there are nine areas where DNOs could benefit from learning as a result of the BRISTOL project.

- The project would develop a tool that could rapidly be deployed by DNOs to reduce network hotspots created by the connection LCTs.
- The project would test the benefits of storage located at customer premises, rather than at substations, providing the additional LV feeder load and voltage control support.
- By oversizing the battery in the customers' premises, the project would explore the business case for DNOs operating a virtual partition of distributed storage.
- BRISTOL would test how batteries can be used with demand response by customers to take advantages of variable retail tariffs. From this DNOs will gain an insight into the residual impact of LCTs on the distribution networks.
- The project would provide insight into how customers perceive innovative solutions such as the BRISTOL solution.
- BRISTOL would create an intelligent self-managing network linking together the substation with multiple properties with battery storage and demand response to reduce voltage rise and reduced peak demand.
- This project would use intermittent generation and battery storage when making network planning assumptions for the connection of other customers.
- BRISTOL would explore lower harmonic distortions on the network voltage by solving the problem, reducing power quality issues
- The Project would provide better use of the existing distribution assets.

#### 9.3.1 Outcome

As stated elsewhere within this report, we are firmly of the view that the benefits for DNO's to take SoLa Bristol forward do not currently exist. SoLa Bristol produced some interesting insights and some very good data that could be used more widely by the industry as it explores what a smart grid might mean for all industry participants, but as it currently stands the perceived benefits for DNOs that we envisaged could materialise, did not occur.

There is some interesting food for thought, but our view is clear, this project should be taken forward by parties much closer to the consumer or parties interested in batteries as a business proposition. We do not believe that there is benefit to be gained unless significant change occurs beforehand through policy changes.

In detail the following table demonstrates this:

| Benefit | Result |
|---|---|
| The project will develop a tool that could rapidly be deployed by DNOs to reduce network hotspots created by the connection of LCTs. | It was not feasible to produce a tool per se as the network hotspots did not occur. Our view is that it is only when there is a significant density of LCTs connected to a substation that we will be able to see what impact it is likely to have on our network. At that point it will then be more beneficial to look at the tools required to manage the network to take advantage of the connected technologies. Given the variability of customer savings (seen through the data), this says to us that some work is required to communicate the reasons for our energy issues and what we are trying to achieve. |
| The project will test the benefits of storage located at customer premises, rather than at substations, providing the additional LV feeder load and voltage control support. | This was thoroughly tested across 26 customers and it did provide us with feeder load and voltage control support, but when one considers the cost of the installations we feel that this is of questionable benefit. |
| By oversizing the battery in the customers' premises, the project will explore the business case for DNOs operating a virtual partition of distributed storage. | Whilst batteries do provide the potential for providing solutions to network constraints we do not think that SoLa Bristol provided us with enough evidence to support this perceived benefit. |
| SoLa Bristol will test how batteries can be used with demand response by customers to take advantages of variable retail tariffs. From this DNOs will gain an insight into the residual impact of LCTs on the distribution networks. | We did ascertain the viability of this test. It is entirely feasible that in the future this could be made to work, but we think that the results are clear, more work is required. As the sample was small it is impossible to gauge the full impact of LCTs, but SoLa Bristol did provide us with some useful information. Our final report details how we think some of the findings could be taken forward. However, we do think that further debate needs to take place to fully understand how best to make use of the findings. |
| The project will provide insight into how customers perceive innovative solutions such as the BRISTOL solution. | We excelled here, we obtained a significant amount of knowledge in this regard but perhaps not unsurprisingly it was inconclusive. |
| SoLa Bristol will create an intelligent self-managing network linking together the substation with multiple properties with battery storage and demand response to reduce voltage rise and reduced peak demand. | We achieved this objective. |

| | |
|---|---|
| This project will use intermittent generation and battery storage when making network planning assumptions for the connection of other customers. | We achieved this objective. |
| SoLa Bristol will explore lower harmonic distortions on the network voltage by solving the problem, reducing power quality issues | It was not feasible to develop this capability within the design due to the changes needed for each of the end user design requirements. In addition we believe that this functionality is not common and untried and therefore it was deemed to be too greater risk to develop based on the status of the project.<br><br>We are exploring ideas with other partners as to how this might be explored. |
| The Project will provide better use of the existing distribution assets. | Whilst the project allowed us to utilise assets in a way that was different to the norm, it did not provide us with a better way of using them. |

Table 3: Network Operator benefits

### 9.4 Environmental benefits

There are six environmental benefits through the integration of SoLa Bristol into properties as they install LCTs in areas with network constraints.

- SoLa Bristol will increase the ability of the existing distribution network, to accommodate LCTs that can be connected to the network without conventional reinforcement. Through the integration of LCTs the UK will be better set to meet its low carbon targets.
- This project will store renewable generation and off peak lower carbon grid electricity locally for use when customers' demands increase. This will reduce the reliance on the centralised national grid connected generation at peak times.
- Avoiding conventional network reinforcement will prevent the excavation of roads and footpaths, and the installation of additional cables, preventing additional carbon being released into the atmosphere.
- Reduce customers' energy losses, supplying DC equipment with DC power generated locally and efficiently converting from AC/DC with one converter instead of multiple inefficient converters.
- Reduce network losses at peak times, with customers having flatter ADMDs.
- Reduce waste heat from the losses associated with AC/DC converters on multiple IT devices, reducing the need for air conditioning particularly in offices.

#### 9.4.1 Outcome

As the general premise of the project could not be proven, it is clear that environmental benefits were not proven. A lot of the benefits from LCTs are clearly based on take up, and as such, until there is a density of these solutions it is unlikely that the environmental benefits will be of a level that their impact becomes significant. As mentioned elsewhere in

this report, we remain unsure that the benefits will accrue because we saw such a wide variance in measure benefit based on a varied level of energy usage. It is our considered view that significant engagement with customers is vital in order for the benefits to be realised.

The results from the trials around DC lighting were broadly positive, some customer views differed on their effectiveness but overall we do think that this merits further investigation.

## 9.5 Other energy industry benefits

Energy Suppliers can through this trial increase their knowledge of customers' behaviours and willingness to change energy patterns. It will also improve energy forecasting through the use of the in home intelligence, the LV connection manager. Great Britain System Operator (GBSO) could benefit through having more flexible demand responding to energy price signals. Customers will become more self-sufficient through the use of their battery storage and generation. Battery storage can be used to absorb excess intermittent renewable generation at periods of low demand.

### 9.5.1 Outcome

We see this as a particular strength of the project. We have an incredible amount of quality data pertaining to the adoption of these technologies, customer behaviour and the benefits that they could see. We also have a lot of factual evidence of customer opinion that we would urge all industry stakeholders to read.

We do believe that the results though need to be more widely discussed.

## 9.6 Relevance to ED1

SoLa Bristol has a significant amount of learning that will be collected and shared before the start of ED1 in 2015, where possible early learning will feed into plans and regulatory discussions. We expect SoLa Bristol to provide DNOs with a technical solution to increase the capacity of the distribution network when incorporating LCT without relying purely on conventional network reinforcement. This solution will provide an insight into the size of battery required in customers premises, and if a DNO can operate storage with a virtual partition. This project will provide an insight into how Customers perceive innovative solutions such as SoLa Bristol and their willingness to participate in smart grid initiatives. If positive, inclusion as an option in the business plan could reduce the funds required to reinforce the network and be used to respond to any quick uptakes in new Low Carbon Technologies. If successful DC networks with battery storage has the potential to become part of future UK building regulation requirements.

### 9.6.1 Outcome

We see SoLa Bristol as having some relevance to ED1, but not as much as we first thought.

From a technical perspective we have proven that the technology worked and to a certain extent we also showed that customers can gain some benefit through the use of innovative tariffs. However, we were not able to show that these technologies can work to provide alternatives to reinforcement and provide additional flexibility to DNOs through their use. This is disappointing, but of course provides additional learning and data for the industry to use and consider as it sees fit.

The most compelling thing to come from the project is the learning we gained about the effort required to engage initially with customers and maintain that engagement. We see this as being a good indicator of the sort of engagement that is going to be required for the national smart metering rollout.

There were also some positives around the use of DC and this could be subject to further projects/analysis.

## 9.7 Conclusions

As part of the ongoing work on SoLa Bristol we undertook some initial predictions. These were provided within the Final Report (reissued on 14th March 2016). The link to the final report is in Section 14.1.:

The predictions were an attempt to try and determine what might happen based on a picture of the project that was becoming clearer. We attempted to try and determine the level of benefit for customers and whilst we were able to predict some benefits they were not of the level that we initially thought. However the overall benefits to customers were, in the end, not material anyway.

Some initial findings from the analysis were that the early Battery Strategy is thought to be triggered by relationship between PV output and customer demand. We found that at that stage it was possible for PV to bring benefits to customers and networks and that the overall performance of the early Battery Strategy, did show that the battery does not bring benefits to tested customers and network.

When we ran the trials for real, we did find that the benefits to customers were low and that there were some benefits with both PV and storage, however the benefits to us do not make for a compelling business case unless adoption rates for these solutions are significant.

One key point is the relationship between the customers load profile and lifestyle, with the efficiency of such an installation. A ‘one size fits all’ approach is not the answer. For the maximum benefit to be realised, such a system needs to be ‘tuned’ to the customers’ profile. That is, their electrical and lifestyle profile. For a customer with a high daytime load the best use of the PV is direct support to the AC usage, however, if the householder works during the day, and the daytime load is low, the benefit of the excess PV is better served in charging the battery for peak demand support.

We believe that the results of SoLa Bristol call for more discussion on how policy can be shaped to ensure that customers get real benefits from using their energy more intelligently and that that intelligence can then be used for benefits to users and DNO’s alike.

# 10. Lessons learnt for future innovation Projects

SoLa Bristol was a complex programme of work due to the extensive customer interaction requirement coupled with the trialling of new technologies. This of course meant that we obtained significant new learning and in particular with reference to customer engagement.

A lot of information on learning is provided within the final report however, we go into more depth here to build on what challenged the project and how this is now being used as a platform for more successful projects in the future.

Below we have taken the project management learning section of the final report, summarised it, removed the highlighted learning points and provided them as a table at the end with our commentary for the way forward as appropriate.

## 10.1 Multi-partner projects

An integral aspect of innovation projects is the inclusion of those outside of the typical business, to support the project and to introduce new methodologies and ideas to the project. However there are inherent risks in working with different industries and businesses that may approach the project in a different manner, and have different priorities or systems for tackling a large-scale project.

In particular during the SoLa project we learnt a lot about the importance of providing a clear specification at the start of the project and ensuring that each part of the project has a 'project owner'. This reduces the risk of project tasks being overlooked. Through encouraging ownership, tasks can be planned into the project time line better and have appropriate time and workload allocated.

However while it is important to be clear about job roles and tasks, in projects such as these it is likely that new, and unexpected, tasks will emerge during the project. It is important that all partners have a certain amount of flexibility in their contracts to respond to these new tasks and be open to working above and beyond their initial job description.

As in a number of industries it is often the case that learning reports are produced which provide final guidelines based on the final working technique and providing a clear "how to" guide for repeating the process. However, few reports include details of learning instances arising from experiments that failed. These types of learning are inherently important as while they may not help the reader to repeat the process, they may provide unexpected learning, or provide an insight into a new methodology. At the very least they will provide information that negates the need to repeat the experiment.

## 10.2 Project Partners

If partners are concerned about aspects of the project these should be raised as early as possible, and minimised to reduce the impact on other aspects of the project. Regulations

need to be defined at the start of the project that prevents a single partner from restricting key project activities due to internal change in their policies.

While LCNI projects are focusing heavily on the engineering solutions it is vitally important that other aspects of the project, such as participant engagement and knowledge management are not overlooked or stalled due to engineering issues. All project partners need to show respect for the expertise of others and be considerate about the implications of their own changes on others.

Similarly partners should feel confident to ask for explanations about unfamiliar aspects of the project. Partners should not presume understanding as often project partners are coming from substantially different backgrounds. This is of particular importance for project members who are public facing, as they need to have a level of project understanding that enables them to communicate not only with the other project partners, but also with the public partners such as the householders.

### 10.3 Personnel

Working on a large multi discipline project requires a large number of people with very different job roles. It is vitally important that these roles are clearly defined at the start of the project. While there are a variety of tasks being undertaken to complete the project, it is inherently useful if all project members are aware of the roles of others to minimise misunderstandings around tasks.

It was noted during project interviews that it can be useful to have a cross over in tasks as this not only provides support to project members it also reduces the chance of 'single failure points'. It is also important that sub-contractors do not rely on a single person as this can cause unexpected delays.

### 10.4 Bidding, Ofgem and Change requests

A key learning that has emerged in previous LCNI projects is the importance of building additional contingency time into the project. And in particular additional design phase time when a project will be using products that require additional certification or change of use.

It is important that those who write the bid are aware of the differences between obtaining an 'off the shelf' solution, and a bespoke design which will require more testing and time allocated to it in the project plan.

In order for LCNI projects to be innovative they need to have the freedom to move outside of the typical methodologies, however they are then at risk of failure due to time, cost and regulatory limitations. Despite these risks a large amount of learning can be obtained from trying something new. It is important that high level partners such as Ofgem are aware that innovation cannot be predicted or tied down to a timescale; therefore it is important that a certain amount of leeway is provided to allow the project to grow and evolve to suit, without fear of repercussions for delays or change of direction.

All partners need to be honest and upfront about their timescales and delays and be considerate of the, sometimes unexpected, impact this may have on other project partners. All partners need to be flexible and willing to change methods to respond to the evolving

project to ensure that useful learning can emerge, while minimising the risk to the public partners.

### 10.5 Customer Engagement

Working with KWMC has highlighted the clear benefit of having an embedded trusted partner in the project. Their ability to advise the project, liaise with customers and provide engagement expertise has enabled the project to run smoothly, even during times of disruption and delay.

It is suggested that future projects take this a step further with regular correspondence to the customers ensuring that they are aware of the wider project and of all the partners involved.

During SoLa Bristol, it was noted that entering a house alone was a potential safety risk, consequently a policy was introduced that ensure project members never visited a home alone, and all appointments were made through KWMC. Future projects need to consider the risks of working within homes and consider plans to minimise risk.

### 10.6 Innovation

Innovation is integral to the LCNI projects, however it is important that innovation is matched with tried and tested methods to ensure that the project can still function if the innovation fails, causes delays or responds unexpectedly. For example in SoLa Bristol the original bid suggested the use of a DCDC convertor; early communications suggested that regulations and supporting documentation would be easy to obtain. However, this was not the case resulting in changes to the technical design. Consequently the project was unforeseeably delayed, not due to technical problems but the bureaucratic regulations surrounding it.

Similarly the ability to connect the SoLa system to the school PV system was evaluated and deemed too time consuming and costly to be worthwhile to the project.

### 10.7 Unanticipated Issues

Changes in government policies surrounding education led to an unexpected impact on the project with a number of the city council primary schools choosing to become academies, as a consequence they severed their ties with the council resulting in a smaller pool of schools to engage with and take part in the project.

Internal restructuring of the Council also led to a reduction in available offices to use as part of the project. This period of uncertainty led to delays in recruiting the office for the project. Furthermore the office staff were relocated during the project which impacted the ability to monitor the behavioural impact of the project.

A number of tenants moved house during the project, while this is to be expected with a project of this length, this again changed the focus of the social learning.

As the area chosen was one of high poverty and unemployment, the majority of participants had a key budget meters. This resulted in, on occasions, the credit running out and the only lighting in the house coming from the DC of the battery. Inevitably after a time the battery would be fully discharged and the lights went out.

While all of these issues were unexpected and impacted the project, they are perfect examples of why it is important that projects such as these are conducted in the real world with real people, rather than testing technology in labs.

| Learning Point | How it is being taken forward |
|---|---|
| L1 - A clear specification, which identifies a lead for each aspect, will encourage ownership and allow for appropriate time and workload to be managed. | In all subsequent mobilisation phases there has been a much stronger drive to ensure that all contracts are supported by clear statements of work. |
| L2- Project contracts need to include an amount of flexibility for unexpected tasks that emerge during the project lifespan. | We are exploring with our Purchasing department innovative ways of catering for flexibility. Moreover we are making it crystal clear to partners moving forward that they have to include things like Final Report effort, SDRC effort etc. |
| L3- Understanding the type of relationship between partners is vital for project success. | All projects now include time spent during partner days where partners explain to one another what their roles and interests are. |
| L4- Trust between partners is vital to allow the sharing of information and knowledge. | Partner days on projects have proven to be a useful tool in encouraging communication and increasing trust. |
| L5- Clear decisions need to be made with regard to knowledge sharing and the stage at which findings can be publically shared. | This is now part of the governance arrangements for all innovation projects. The project manager and the board will agree the dissemination plan at the commencement of the project. |
| L6- Project regulations need to be clearly defined to prevent disruption to the project should a partner's focus or internal policies change. | This is a procedure within our project governance for all projects now. |
| L7- It is important that all project members can explain the project and that understanding is not presumed. | At Project Kick off time is now spent explaining the project to all team members and forms part of project handbooks. |
| L8- Project partners will have different backgrounds so time needs to be allocated for learning new areas to enable effective communication. | At Project Kick off time is now spent explaining the project to all team members and forms part of project handbooks. |
| L9- If the team is geographically dispersed it is important that members can be easily contacted via phone and email. | Contact lists are now part of the mobilisation phase. PMO will ensure that they are maintained. |
| L10- Projects benefit from clearly defined roles. | All Projects now have mandated Terms of Reference for all participants. |
| L11- Sharing tasks and expertise can reduce the risk of single failure points. | We look to identify single point of failures as part of the planning process, this is maintained throughout the project lifecycle. |
| L12- Where possible a cross over period should be | We are currently working on how we integrate this |

| | |
|---|---|
| included to allow for job shadowing. | into projects. |
| L13- Introduce new members to the team via email, with details of their job role. | This is now the Project Managers role within the team. |
| L14- Ensure each member keeps clear documentation around decisions so new staff can understand the logic and continue to work in line with the project aims. | This is a procedure within our project governance for all projects now. |
| L15- Project partners need to be responsible for knowledge sharing within their own company. | This is now part of partner agreements moving forward. |
| L16- Key personnel need to be identified at the start of the project to ensure informed decisions can be made. | This is a procedure within our project governance for all projects now. |
| L17- The inclusion of the knowledge managers in correspondence and project meetings can help document the project and support the sharing of knowledge internally. | This is a procedure within our Innovation Project governance now. |
| L18- Bid writers need to factor in additional time if a product is not 'off the shelf' or is being used in an atypical manner. | We now explore all options before submission to ensure that COTS products are used over purpose built and where purpose built is crucial time is allowed for shaping of the solution. |
| L19- Innovation is at the core of LCNI; an appropriate amount of time and space needs to be provided for a project to evolve. | We have consistently reviewed all bids prior to submission to make sure that there is enough time at the outset to shape the project properly (it is normally included now as part of mobilisation). |
| L20- Project members are often working on other projects simultaneously, honesty about timescales and availability can ensure a project is planned effectively to suit all partners. | As part of Partner engagement we encourage partners to be honest about their work commitments in all projects. |
| L21- When applying for a change request it is important to evaluate the whole project and ensure other aspects continue while awaiting feedback. | This is a procedure within our project governance for all projects now. |
| L22- Ensuring that house visits always occur in pairs minimizes risk to project members. | This is to be implemented as a policy within WPD. |
| L23- Seek guidance from local community groups on how to present yourself when meeting new people and visiting their homes. | When engaged with local communities, this forms part of our engagement process now. |
| L24- Project members should be trained, not only on the technology that is being installed in the homes, but also how to talk to and engage with the homeowners. Sharing expertise can benefit the whole project. | This is now part of the ongoing project management process. |
| L25-It is important that there is a balance between innovations and existing methods, projects should be careful that they do not become overly complex. | When reviewing bids now we undertake a challenge exercise to check whether is it too complex/too simple. |
| L26-Extra time needs to be included where regulations may need to be amended or guidance sought for the use of existing technology but in new | Part of the project manager's responsibilities. |

| | |
|---|---|
| ways. | |
| L27- Outside factors may have an impact on the design of the project; where possible explore how this can provide additional learning and opportunity. | Forms part of the RAID process. |

Table 4: New internal learning and status

As can be seen from the table, we take the learning process of these projects very seriously. We are keen to ensure that we learn from mistakes and take them forward with a positive action. We readily accept that these projects are about positive and negative learning and that they are just as important. Wherever a genuine learning point can be of benefit to existing projects we are keen to ensure that it is disseminated quickly and if appropriate is embedded into business as usual.

## 11. Project Replication

More information on the design of the SoLa Bristol system can be found in Section 2 of the projects final report , this can be found here :

http://www.westernpowerinnovation.co.uk/Document-library/2016/WPDT2003_SoLa-Bristol_SDRC9-8-resubmissionv2-0.aspx

We detailed the overall design within this report:

http://www.westernpowerinnovation.co.uk/Document-library/2012/Confirmation-of-the-SoLa-BRISTOL-design-v1-0.aspx

A high level diagram of the system built under SoLa Bristol is provided earlier within the report in Section 4.

Within each premise there were a number of individual pieces of equipment. The individual components, for each type of install were:

| Equipment Description | Function |
|---|---|
| LV Connection Manager- based on Siemens SICAM TM e-mic | Allowed the solution to control/influence various elements of energy usage within the premises. |
| Feed In Tariff Meter | This was installed near the existing meter for measuring export/import as appropriate. |
| Sub Metering | For the use of measuring controllable loads. |
| Battery Bank | 4 x 130Ah 12V DC batteries installed at customer premises, 2 connected in series and then the pairs connected in parallel to create nominal 24V DC system |
| LV Network Manager - based on Siemens SICAM TM | This was installed at Substations to monitor and report on the AC network. |
| Data Concentrator | Used to log metering and operational data and allow access to the data for trial evaluation purposes. |
| Four Quadrant Inverters | Converted the AC power to DC- for domestic installs they were rated at 2kW, for commercial 3kW. |
| Load/Battery Management- based on Moixa Smarthub | This was required to control, monitor and report on the internal DC voltage system and battery storage.<br>Communicated with the LV Connection Manager. |
| GPRS Router | Connected the LV Connection Manager to |

| | |
|---|---|
| | the LV Network Manager. |
| Charge Controller | Used to protect batteries from overcharging. |

Table 4- Equipment list

Each installation was coordinated by WPD and undertaken with the Council. Overall this joint working worked well, but as mentioned within the Final Report retaining the same staff throughout installation and decommissioning was a key finding.

### 11.1 Domestic Installation

The domestic customers were required to be monitored on three levels, in-system, in-house and at the data repository. This required that each house had the following amendments to the usual in-house installation:

1. On the network side of the import/export meter, sensing equipment was connected and this provided voltage measurements and power to the LV Connection Manager.

2. An inverter connected the battery bank to the premises AC distribution.

3. The battery bank also fed a DC distribution system which in turn supplied DC loads such as lighting

4. The PV generation delivered its power to the battery bank and DC distribution system through a charge controller.

5. The LV connection manager was connected to control/influence the operating mode of the battery inverter and any loads (e.g. smart appliances, controllable AC loads such as immersion heaters and DC lighting).

6. The LV connection manager communicated with the LV Network Manager in the substation.

### 11.2 Commercial Installation

The commercial systems covered both the schools and offices, with the necessary additions to the system. The Commercial sites did have an onsite PV system but unlike the Domestic systems, these PV installations though linked through monitoring, were standalone systems.

At the project concept stage it was expected that all schools would use the DC PCs but during schools engagement visits it became apparent that a common DC platform would not be suitable for all participating schools.

The schools also did not participate in the battery storage trials.

## 11.3 Substation

Sensing equipment at the distribution transformer/substation was connected which provided measurements of voltage and power to the LV Network Manager.

The LV Network Manager monitored the local measurements it received, and those received from LV Connection Managers at premises on the LV network. This was to identify when the LV network reached constraint points. These were voltage and/or thermal constraints and may have been caused by an excess of load or an excess of generation. Requests were then made from the substation to associated properties which were electrically connected to request an intervention, either a load increase or decrease.

## 11.4 Testing

As this was a customer facing project, it was important to ensure that the system underwent extensive testing. The full Factory Acceptance Testing process is described in detail within the Final Report. There was also a fully programmable domestic test system set up at UoB that enabled a degree of testing before trialling updates in customer homes.

The project chose the facilities at the National Renewable Energy Centre. This was because we needed somewhere certified that could test the export of energy to the grid.

A two stage test was developed by the team and these tests took place over two visits. All of the relevant information pertaining to the tests is contained within the Final Report.

## 12. Planned Implementation

We do not see that SoLa Bristol affords DNOs with an immediate or medium term opportunity to modify their distribution systems.

The findings from SoLa Bristol are clear; there is no future implementation potential for the method under trial as it currently stands. The benefits are so small for the investment required that it does not make economic sense for a DNO to utilise these solutions. That is not to say however that housebuilders, Energy Suppliers or Building Management companies could not make a business case. We would be happy to provide information to other parties to help them develop a business case to take this method forward.

As detailed within the benefits section of the final report(SDRC 9.8), as the penetration of battery and PV was relatively low in the trial network and there was a degree of demand uncertainty, the network demand change could not be reflected in the measured data and the corresponding network investment deferral was relatively minor, at less than £300. This means that for a DNO it would not be in the interests of customers for us to invest in these solutions. We would have to see significant take up of LCTs of this ilk in order for there to be any expected return on investment/savings to customers.

In order to see significant changes to these numbers, many more batteries would need to be installed and given the current cost of batteries, it is our view that reinforcement is more viable. The cost of the solution would have to be drastically reduced coupled with significant numbers of installations per substation for any DNO to be able to justify the investment.

It is our perception that the market for storage is still evolving though and this can be revisited at a point where the market has achieved a level of maturity.

We believe that given that we could not prove that integrating PV and Batteries into the network could accrue significant benefit to customers and DNO's alike that it is extremely difficult to say whether or not the SoLa Bristol solution could then be adopted as a template for future LCT's. This is naturally disappointing but we believe there it does offer an opportunity for discussion.

As part of the SDRC 9.8 we had intended to undertake a commercial feasibility study based on the results, but given the findings we did not believe that this would be a good use of customer or WPD money. Much more work on the use of LCTs and the potential for them to be integrated into a functioning "smart network" needs to be done to establish the true value of the components to the relevant participants.

Given all of the above, it is our view that, in order for the findings of SoLa Bristol to be taken forward, a number of important things need to happen:

1. There needs to be a dialogue across the industry about who is best placed to take this forward. WPD is not convinced that DNOs are best placed for this.
2. There needs to be some discuss about energy policy (including the creation and use of domestic time of use tariffs) and how it might help to influence the costs of these technologies so that more research can be done to fully test whether LCTs are indeed going to make such an impact on DNOs. We are still exploring the use of ToU

tariffs with WREN in Wadebridge, but we do believe that there is more work that needs to be done across the value chain.

3. The industry needs to discuss, perhaps consult, on the customer relationship and engagement to ensure that the most is made of the smart meter rollout. It is clear to us from SoLa Bristol that more needs to be done to fully engage with customers and even more done to sustain that engagement to get the outcomes that the industry needs.

In conclusion we feel that there is some way to go before any of the learning from SoLa Bristol can be fully exploited for the benefit of customers and DNO's.

## 13. Learning Dissemination

We provided considerable information about the approach taken and learning gained during the project within the Final Report , a link to which is provided in Section 14.1.

In the final report we detailed the significant amount of external dissemination that we had to undertake to achieve what we did. It is absolutely clear that when the public is involved in these large innovation projects that the amount of work required to engage with the public throughout is substantial and whilst the results, it could be argued, justify the investment we do not see that there are real tangible benefits to DNOs and customers alike in order to justify that investment as it currently stands. Much more work is required to be done but the industry can take much from our experience.

Throughout SoLa Bristol the following engagement/dissemination mechanisms were used:

- Presentations & events
- Workshops
- Website's and Press Announcements
- Knowledge Sharing Events
- Reports

During the course of the project, some 385 different events occurred. These are all detailed within Section 3.3 of the Final Report. Because of the nature of the project, feedback has been a continual theme throughout. We have sought feedback throughout and that feedback has then informed subsequent activities. We have had to develop our approach, communications and working to fit with the customers- whether domestic or commercial. All of the mechanisms were undoubtedly of benefit, but for the customer elements the face to face interactions via events or meetings at the home were of considerable benefit, indeed we would argue, vital. The effort required to get the results that we did was immense and whilst the results did not validate the overall hypothesis we think that they do offer considerable food for thought.

Recent events since publication of the Final Report have been :

London Grid +Storage Event on 15th March

Energy UK storage summit at Twickenham on 28th April

Both events have or will enable us to share with stakeholders the final findings of SoLa Bristol.

Feedback from customers and other stakeholders throughout the project lifecycle has been consistently used by us to help inform future events and presentations. This has been an absolute necessity in maintaining the right momentum with customers and keeping them engaged and involved with the project.

We have engaged proactively throughout with other DNOs and held a workshop with them in September 2015 to share results and thinking. This was positively received and we feel gives us a good platform to start detailed discussions with all parties about the findings of SoLa Bristol.

In developing this Closedown Report we have also shared it with SP Energy Networks for peer review and have taken on board their feedback to further enhance it. Specifically additional clarity was provided within the Executive Summary around the context of the SoLa Bristol trials, and the outcomes were changed to further clarify the context of the technologies within the trials and their cost effectiveness. In addition it was deemed better for the flow of the report if one of the diagrams was moved. No further clarifications and questions were received.

We do not believe currently that the results of the SoLa Bristol trials have any impact on the TRANSFORM model, but are in dialogue with EA Technology to go through this.

# 14. Key Project learning documents

SoLa Bristol has generated a lot of learning during its lifecycle. Detailed below are the main reports, but also in the Appendices are some of the other documents, presentations and press releases pertaining to its activities.

## 14.1 Published Learning Documents

Confirmation of Bristol design- this document, published in December 2014, provides the reader with a detailed description of the overall SoLa Bristol System Design.

http://www.westernpowerinnovation.co.uk/Document-library/2012/Confirmation-of-the-SoLa-BRISTOL-design-v1-0.aspx

Domestic properties installation report – this document, published in December 2014, gives an understanding of the process and impact of the proposed domestic installations in properties.

http://www.westernpowerinnovation.co.uk/Document-library/2013/Sola-Bristol-Installation-report.aspx

Early Learning Report 2014

http://www.westernpowerinnovation.co.uk/Document-library/2014/Sola-Bristol-Operational-early-learning-report-fin.aspx

Measure Impact on the LV Network December 2014

http://www.westernpowerinnovation.co.uk/Document-library/2015/SDRC-9-5-REPORT-Final.aspx

Final Report (SDRC9.8)

http://www.westernpowerinnovation.co.uk/Document-library/2016/WPDT2003_SoLa-Bristol_SDRC9-8-resubmissionv2-0.aspx

## 14.2 Project Progress Reports

Below are all of the Project Progress Reports for the project:

June 2012 Project Progress Report

https://www.ofgem.gov.uk/publications-and-updates/bristol-six-monthly-report-june-2012

December 2012 Project Progress Report

http://www.westernpowerinnovation.co.uk/Document-library/2013/WPD-PPR-SoLa-BRISTOL-December-2012.aspx

June 2013 Project Progress Report

http://www.westernpowerinnovation.co.uk/Document-library/2013/PPR_WPD_SOLA_BRISTOL_MAY2013_PUBLIC.aspx

December 2013 Project Progress Report

http://www.westernpowerinnovation.co.uk/Document-library/2014/So-La-Bristol-Project-Progress-Report-Dec-2013.aspx

June 2014 Project Progress Report

http://www.westernpowerinnovation.co.uk/Document-library/2014/WPDT2003_May14PPR_Sola-Bristol_Issue1.aspx

December 2014 Project Progress Report

http://www.westernpowerinnovation.co.uk/Document-library/2014/Sola-Bristol-Nov-14-PPR-V1-0.aspx

June 2015 Project Progress Report

http://www.westernpowerinnovation.co.uk/Document-library/2015/SOLA-BRISTOL-Progress-Report-May-2015.aspx

## 15. Contact Details

Mark Dale

Innovation and Low Carbon Networks Engineer

Western Power Distribution

Feeder Road

Avonbank

Bristol

BS2 0TB

Tel: 01179 332236

Email: mdale@westernpower.co.uk

# 16. Appendices

## 16.1 Newsletters & leaflets

http://www.westernpowerinnovation.co.uk/Document-library/2012/WPD-leaflet-So-La-Bristol.aspx

http://www.westernpowerinnovation.co.uk/Document-library/2012/Bristol-How-does-it-work-leaflet.aspx

http://www.westernpowerinnovation.co.uk/Document-library/2014/Sola-Newsletter-Oct-2014.aspx

## 16.2 Press Releases

- http://www.electricaltimes.co.uk/features/article.asp?articleid=6887
- http://www.danewatkins.com/2013/06/knowle-west-media-survey.html
- www.bristolpost.co.uk/Council-houses-Knowle-West-solar-power/story-19917878-detail/story.html
- http://www.bristol247.com/2013/10/11/south-bristol-solar-power-scheme-goes-live-12561/
- http://www.bristol-business.net/solar-project-powers-mayors-ambition-to-make-bristol-green-laboratory-for-change/
- www.bristol.gov.uk/press/%C2%A328-million-solar-project-transforms-council-homes-and-buildings-knowle-west
- http://www.bristol.gov.uk/press/%C2%A328-million-solar-project-transforms-council-homes-and-buildings-knowle-west
- http://www.connectingbristol.org/2013/10/24/mayor-of-bristol-promotes-new-sola-bristol-energy-project-in-knowle-west/

- http://www.connectingbristol.org/2013/10/24/mayor-of-bristol-promotes-new-sola-bristol-energy-project-in-knowle-west/

- en.escn.com.cn/article/show/10442.aspx

- http://www.evepia.co.uk/how-should-the-uk-support-the-uptake-of-domestic-solar-pv-storage/

- http://www.myelifenow.com/2013/08/how-should-uk-support-uptake-of.html

- www.bristolpost.co.uk/Solar-goodRoof-panels-power-local-community/story-23036959-detail/story.html

### 16.3 Video

Below is a link to a video produced by Knowle West Media Centre as part of their role on the project and in particular focussing on customer benefit and engagement.

http://www.westernpowerinnovation.co.uk/Projects/SoLa-Bristol.aspx

It can also be found on our You Tube channel:

https://www.youtube.com/watch?v=7ukUnKDowvY