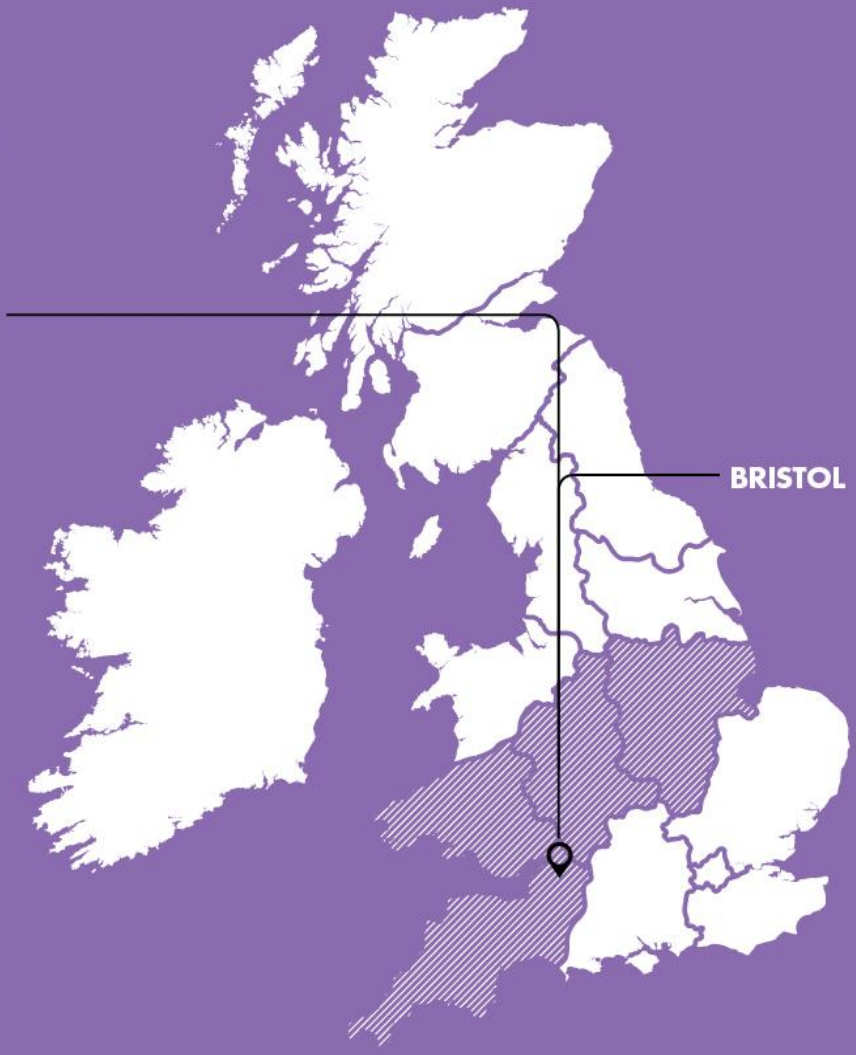
WESTERN POWER DISTRIBUTION

SOLA BRISTOL

PROJECT SOLA BRISTOL

Second Tier Reward Application



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LCN Fund Low Carbon Networks

BRISTOL CITY COUNCIL

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Executive Summary

Through this document, Western Power Distribution will demonstrate our commitment and approach to delivering innovation and embedding the learning into our business to the benefit of our customers. SoLa BRISTOL delivered significant insight about how behind the meter battery storage solutions can support the adoption of low carbon technologies into people's homes. The learning that was delivered has informed thinking about smart, flexible electricity systems and is shaping the development of combined solar PV and battery solutions to the benefit of consumers.

In order to ensure the successful delivery of the project and the core learning, an additional investment of £348k was made by Western Power Distribution to the project.

The project delivered noteworthy performance in a number of areas. In 2010 "behind the meter" combinations of low carbon technologies such as PV, battery storage and time of use tariffs were novel concepts that could facilitate uptake of solar PV and deliver savings for both customers and networks.

The project set new standards for engaging customers, retaining customers and ensuring a potentially disruptive project was delivered successfully. The project was included in Bristol City Council's winning bid to become 2015 European Green Capital, gaining wide exposure as a result. SoLa BRISTOL was also awarded the Best Residential Energy Storage Project at the first Solar Power Portal awards.

Through project partner Moixa, learning from SoLa BRISTOL was cited by BEIS and Ofgem in their join publication "Upgrading or Energy System", which is in turn referenced by the Clean Growth Strategy.

The basis for SoLa BRISTOL's application for consideration for a Second Tier Reward is:

- Excellent customer engagement, recruiting over 21% of customers from the 155 eligible and retaining the majority of customers for the entirety of the project.
- A ground-breaking study of the interaction of customer, network, commercial, social and economic facets in domestic level smart grids on the Low Voltage networks.
- A project that was ahead of its time in respect of the economics and maturity of domestic solar PV and storage technology.
- Providing valuable learning that has aided the development of behind the meter energy storage solutions, which are resulting in benefits for customers.

The project was ahead of its time focussing on understanding their network impacts and the viability of combining domestic PV and storage solutions on LV networks. Technological advances and significant cost reductions are improving the viability of these solutions today.

Given that those advances have evolved subsequent to the project, and that fully commercialised offerings are now available to customers, with substantial claimed energy savings, SoLa BRISTOL is now proving to be an exemplar of a project that is leading to real benefits for customers through the emergence of commercially viable solutions.

1. Project Description

BRISTOL (Buildings, Renewables and Integrated Storage, with Tariffs to Overcome network Limitations) received £2.2m of funding through Tier 2 of the LCN Fund in 2011. Throughout the project, it was widely referred to as SoLa BRISTOL (the name given to the project by the participants); this will continue for this report.

At the time of developing SoLa BRISTOL, reports[1] highlighted the greatest potential impact of smart appliances would be at HV/LV substations and on the LV feeder. With a forecast 50% penetration of electric vehicles and heat pumps by 2030, the predicted scale of the LV reinforcement required was £21.8bn, compared to a forecast £9.3bn using smart grid techniques[2]. This excludes the associated impacts on customers and the economy from the disruption due to the network reinforcement.

SoLa BRISTOL sought to find an alternative method to enable high density photovoltaic solar generation to connect to the Low Voltage network more efficiently by combining installed PV with in-home battery storage and time of use tariffs. The project aim was to address the technical constraints (reduce peak network demand, control voltage rise and reduce system harmonics) that DNOs expected to arise on Low Voltage networks as a result of the widespread adoption of solar PV and other Low Carbon Technologies.

The UK was seeing a significant and very rapid rise in the number of Solar PV systems connected to the LV networks and it was expected[3] that the same rapid rise in Heat Pumps and Electric Vehicles would follow. The costs associated with traditional network reinforcement can be significant. The typical unit cost of a feeder was £67,200/km and the unit cost of a transformer was £26,400[4]. This warranted the demonstration of alternative solutions that could have the potential to be more cost effective.

The output of PV panels is direct current (DC), which is then converted to AC through use of an inverter. This introduces losses, which are compounded if it is then reconverted for DC use. It has been recognised that direct connection of PV to batteries provides a range of benefits:

- avoidance of conversion losses in consumer products that ultimately require DC (computers, TVs, Lighting and portable electronics),
- energy storage that can be deployed to provide peak lopping, and
- provision of a level of uninterruptable power supply to home equipment such as lighting, or support to medical equipment used by disabled people.

SoLa BRISTOL used in-home battery storage to provide benefits to customers and aid the DNO with network management. Twenty-six houses, five schools and an office were commissioned with solar PV and battery installation. Within the domestic properties, the solar PV was connected directly to the battery using a DC/DC converter. The project did not fund any of the solar PV installations.

The AC lighting circuits in all the premises were converted to DC and a set of DC outlets were installed to enable customers to run small USB connected appliances directly from the PV/battery. The battery was "shared" between the customer and the DNO. At the time, this was an innovative

[1] Energy Networks Association and Imperial College summary report "Benefits of Advanced Smart Metering for Demand Response based Control of Distribution Networks -version 2.0", April 2010
[2] Energy Networks Association and Imperial College summary report "Benefits of Advanced Smart Metering for Demand Response based Control of Distribution Networks -version 2.0", April 2010, Page 40, Table 6.1 and 6.2
[3] http://erpuk.org/wp-content/uploads/2014/10/52990-ERP-Energy-Storage-Report-v3.pdf
[4] Electricity Distribution Price Control Review Final Proposals - Allowed revenue - Cost assessment appendix " Office of Gas and Electricity Markets, ed., Office of Gas and Electricity Markets 2009.

concept; to evaluate how a battery could be used by multiple parties and understand the potential for conflicts between those parties. SoLa BRISTOL explored how a battery could be fully utilised by the customer when not needed by the DNO and utilised by the DNO when required to meet network needs. Today, this is referred to as 'Value Stacking'.

The customer was provided with a pseudo variable tariff that rewarded consumers for electricity use at times of high PV generation and incentivised use of electricity stored by the battery when the network was heavily loaded. The DNO was able to communicate with the battery to charge and discharge it to demonstrate how it could help with network management challenges created by both peak solar outputs and at peak demand periods.

The project aimed to:

- solve the network problems that arise when a number of customers in a local area connect PV solar panels to their house;
- investigate how a battery installed in a property can help customers to manage their energy usage and save money on their bills;
- understand how the characteristics of demand side electrical storage could benefit network operations;
- test how customers respond when offered different electricity tariffs during the day;
- explore the benefits of utilising direct current (DC) in the home, rather than the traditional alternating current (AC).

SoLa BRISTOL was conceived in 2010 by Western Power Distribution and key interested stakeholders. The purpose was to demonstrate a truly innovative project and deliver real learning about a "behind the meter" solution. At the time this could only be achieved through a Distribution Network Operator working collaboratively with others.

In 2011 behind the meter energy storage was still very much at an infancy stage, especially for domestic and small business locations. There were significant uptakes in integration of domestic and commercial solar PV, along with the predicted future potential uptakes of Heat Pumps and Electric Vehicles, which could all trigger the need for DNO network reinforcement. This led to the concern that, based on the system design practices at the time, significant amounts of the LV networks would need to be reinforced to accommodate the new connections and behind the meter demand growth. SoLa BRISTOL was designed to establish the contribution that demand side, shared energy storage and DC networks could make to avoiding this reinforcement.

The Second-Tier application for the SoLa BRISTOL project was a significant departure from the engineering practices current at the time. Traditionally, DNOs would install and integrate new substations within the network and overlay or install new low voltage cables and overhead lines to accommodate new demand or generation. Using batteries installed behind the meter, DC networks within properties and demonstrating a pseudo time of use tariff was considered to be a substantially greater risk than the traditional practice.

SoLa BRISTOL was designed to address these challenges and unlock significant learning about behind the meter applications. SoLa BRISTOL was designed to inform where behind the meter approaches could be used by the DNO and other parties to address the challenges and also to identify market changes required to enable further energy storage integration at Low Voltage. There was also significant effort and learning generated, far beyond what was expected at the Full Submission stage in 2011. Specifically, this related to how to successfully engage with customers, how to overcome the design requirements for behind the meter energy storage solutions and establish why the same equipment can produce radically different outcomes due to the way people use energy.

The key evidence submitted in the following criteria has been summarised as:

1.1 Criterion A: Exceptional Performance of the Project

SoLa BRISTOL delivered significant learning, especially about behind the meter energy storage. The project demonstrated that the stand alone benefits for the Distribution Network Operator were not sufficient based on the economics at the time. However, SoLa BRISTOL also identified that there were potential benefits accruing to other parties.

38 domestic energy storage systems have already been connected behind the meter within Western Power Distribution's licenced areas, largely funded by customers. Whilst it is looking increasingly unlikely that DNOs will be able to operate energy storage, the knowledge shared has helped others to develop and install the solution that can deliver the benefits identified in SoLa BRISTOL, irrespective of whether the learning is used by WPD or others.

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

To ensure successful learning could be generated, the Western Power Distribution contributed £348.2k additional funds to the project, ensuring the successful delivery of the project and that the key learning could be captured and shared with the industry.

1.3 Criterion C: Exceptional Efforts

Significant and sustained effort was required for SoLa BRISTOL to be delivered successfully. This was especially true in relation to customer acquisition for the project and the ongoing customer support. Over 21% of the eligible customers signed up to participate in the project from three adjacent distribution networks[5]. The SoLa BRISTOL approach to customer engagement highlighted the clear benefit of having an embedded trusted partner in the project. Their ability to provide advice to the project on customer engagement approaches, liaise with customers and provide engagement expertise enabled the project to run smoothly, especially when unforeseen challenges arose. This resulted in an exceptional conversion rate of 21% for participant recruitment. All but one of the recruited participants were retained throughout the duration of the project.

For such a domestic focused project it was essential that participants could be recruited from the applicable homes connected to the selected substations. This was only achieved by WPD establishing a close working relationship with the customer engagement specialists Knowle West Media Centre throughout the project.

[5] BRISTOL Project Progress Report June 2012 - Table 1, Page 8

Tier 2 Project Name	Licensee	Project summary	Tier 2 funding £k (nominal prices)	Licensee compulsory contribution £k (nominal prices)	Other contributions £k (nominal prices)	Link to Close-Down Report
BRISTOL (Buildings, Renewables and Integrated Storage, with Tariffs to Overcome network Limitations)	Western Power Distribution	Demonstrating an innovative combination of energy storage in customers' premises, coupled with new variable tariffs and integrated network control to overcome generation or load related constraints at key times of the day, testing the potential benefits for both DNO and customer. The range of premise types including homes, schools and a business. Through the use of direct current (DC) power in customer premises in conjunction with battery storage shared virtually between DNO and customers	2,196	229	348.17	https://www.ofgem.gov.uk/system/files/docs/2016/04/sola_BRISTOL_closedown_report_final.pdf

Table 1: Summary of Tier 2 BRISTOL (Buildings, Renewables and Integrated Storage, with Tariffs to Overcome network Limitations), widely known as SoLa BRISTOL.

2. Reward Criterion A: Exceptional Performance of the Project

SoLa BRISTOL demonstrated what was, at the time, a novel concept and provided valuable outputs that have supported the uptake of behind the meter energy storage by third parties. The project was developed at a time when the potential for the significant network disruption caused by the adoption of low carbon technologies was beginning to be recognised. However, there was little evidence to support decisions on how DNOs could most effectively support the adoption of these technologies in the best interests of the consumer. Through this section we will demonstrate how the learning delivered by SoLa BRISTOL was both ahead of its time and is providing exceptional insight into the role demand side storage can play in a smart, flexible electricity system.

SoLa BRISTOL demonstrated that DNOs were not the right parties to roll out behind the meter solutions, and that others are better placed to realise the benefits from the solution. In selected locations, customers are using the solution to unlock network capacity, avoiding the need for the investment and disruption associated with significant network reinforcement.

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

One of SoLa BRISTOL's core aims was to inform the challenge facing the UK of incorporating Low Carbon Technologies (microgeneration, heat pumps and electric vehicles) into all types of existing housing stock and buildings, and aiming to incorporate LCTs into the existing distribution network in the most cost-effective manner[6]. In 2011 the scenario of future distribution networks with higher distribution peak demands and customers exporting generation into the network was seen as extremely likely. It was also seen that innovation (including energy storage) could offer a more efficient way to design and operate more complex networks.[7]

SoLa BRISTOL kick-started the practical understanding of this area through a concentrated demonstration of behind the meter energy storage coupled with Low Carbon Technologies. The project generated the knowledge and the learning required for further commercialisation in this area, addressing several aspects identified in both the Carbon Plan and subsequently in the Clean Growth Strategy, specifically:

- Development and deployment of technologies before they are considered a cost-effective solution, this includes energy storage. The rationale for this is that by doing so, the costs of the technology could be reduced in future periods through improved design based on the emerging learning, further design innovation to meet the better understood requirements, economies of scale being achieved as demand for the technologies grows, based on improved confidence accelerating adoption by consumers and attracting investment in the supply chain.[8]
- Demonstrating the use of storage, and identifying how it could help manage the strain placed on the electricity grid by the adoption of Low Carbon Technologies such as heat pumps.[9]
- Using innovative technologies such as electricity storage (after cost reductions) to support balancing of systems with high proportions of intermittent generation[10].

[6] LCNF Full Submission Proforma, Page 2, Paragraph 3.
[7] LCNF Full Submission Proforma, Page 11, Paragraph 2
[8] Carbon Plan Page 167 - B3.22
[9] Carbon Plan Page 42, 2.62 bullet point 4

- Supporting a diverse electricity system that supplies homes and businesses with secure, affordable and clean power. SoLa BRISTOL, once economies of scale are achieved and the economics improve, could, in certain areas, provide an alternative means of upgrading the electricity system, so it is smarter and more flexible[11].
- Demonstrating how behind the meter energy storage and solutions can help others to enable a smarter, more flexible system, identified in the Smart Systems and the Flexibility Plan. When applied, it is expected that consumers could use the solution alongside smart appliances and smart tariffs to help balance the grid in return for lower bills.[12]
- There is continued support for further renewable energy projects, such as solar panels or small wind turbines linked to battery storage, through SoLa BRISTOL's demonstration of what can be achieved and the business case for itself and the potential business case for others.[13]

  SoLa BRISTOL focused on the impact of battery storage on the distribution networks and intentionally did not explore innovative battery technologies themselves. Since the project completed, ongoing global development has significantly improved storage density (and thus size) and reduced the costs of battery storage. "The costs of average lithium-ion batteries has fallen by over 50% since 2012"[14] (consequently, the viability of the project solution continued to evolve after completion of the SoLa BRISTOL project). The learning from SoLa BRISTOL has been taken forward into the development and deployment of commercially viable solutions[15] that claim to save customers up to 60% of their energy bills[16].

The project was ahead of its time in respect of the economics of PV and storage technology then available. It acted as a beacon to the future viability of the technology as the costs of these have subsequently significantly reduced.

Moixa, the battery provider partner on SoLa BRISTOL, was identified as a case study in the Updating Our Energy System, Smart Systems and Flexibility Plan, July 2017[17]. Simon Daniel, CEO and founder noted that SoLa BRISTOL "*Helped validate Moixa's approach for Batteries, DC, and home management, and informed the benefit of delivering much more integrated smart battery solutions (rather than bespoke/multi-vendor on site installation at high cost and volume). The project also helped educate BEIS/OFGEM and informed the scopes of subsequent procurement and InnovateUK projects, as well as NIC. Subsequent to SoLa BRISTOL, Moixa won and delivered a 200 home battery demonstration for DECC – and the company has grown 4 to 5 fold since Sola-BRISTOL in headcount, scale and is now exporting internationally". The approach demonstrated in SoLa BRISTOL has now reached commercial deployment, with Moixa;"* the company states that, "*By 2020 Moixa expects to have installed 50,000 UK batteries and to be managing twice as many using its patented, cloud-based "GridShare" platform. This will create a Virtual Power Plant aggregating around 250MWh of capacity to deliver services to the National Grid and utilities that will help reduce the costs of running*

[10] Carbon Plan Page 124, A21
[11] The Clean Growth Strategy Page 95 – paragraph 1
[12] The Clean Growth Strategy Page 95 – paragraph 1
[13] The Clean Growth Strategy Page 95 – paragraph 1
[14] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/633442/upgrading-our-energy-system-july-2017.pdf - Upgrading our Energy System page 6
[15] https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-new-economics-of-energy-storage
[16] https://www.moixa.com/solar-battery/
[17] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/633442/upgrading-our-energy-system-july-2017.pdf - Page 5.

the electricity network and allow it to support increased levels of renewables. Moixa has been awarded UK and US patents on managing distributed batteries for grid services[18]."

As detailed in the project close down report[19], the SoLa BRISTOL project successfully designed, developed and demonstrated a battery storage solution working in parallel with PV solar generation. The project learnings[20] have been shared with the industry, supporting further developments core to the Carbon Plan and Clean Growth Strategy.

Through the demonstration of Low Carbon Technologies, such as solar PV integrated with energy storage, the close down report identified that significant progress was required in the energy storage market before there would be a benefit to the DNO that would justify a shift from traditional network reinforcement. Such technological progress has subsequently occurred, and the approaches explored in Sola BRISTOL are promoted by both the UK Government and Ofgem[21] and are now viable and sold commercially. This represents an exceptional example of a novel project that (although the case at the time was negative due the then existing costs and technology readiness level) acted as a lighthouse to demonstrate the future viability as technology advanced and costs reduced. This has now occurred.

Figure 1 shows an extract written by Bloomberg in August 2017 on Ofgem's vision for UK Energy, showing how energy storage is increasing and behind the meter PV and storage will be the fastest growing technology between 2020-2024 in terms of capacity installed.

There have been a number of additional research and development projects which started after SoLa BRISTOL that have benefited from the learning, including by project supporter Moixa. As a result, there have been substantial developments since the close down report was written in 2016. Commercially available behind the meter energy storage solutions are now commonly available and their costs continue to fall. Such behind the meter storage solutions can be installed across domestic, commercial and industrial properties[22]. With the continued reductions in costs of energy storage it is expected that the growth in behind the meter energy storage will continue to increase.

[18] http://www.moixa.com/press-release/moixa-expansion-continues-2-5-million-investment-plans-100000-battery-virtual-power-plant-balance-grid/
[19] SoLa BRISTOL Close Down Report
[20] Final report Page 26 and 27, Bullet Point 2 and 3.
[21] https://www.gov.uk/government/news/plan-launched-to-bring-smart-energy-technology-into-homes-and-businesses
[22] https://www.theecoexperts.co.uk/solar-panels/storage-batteries - Accessed 09/04/2018

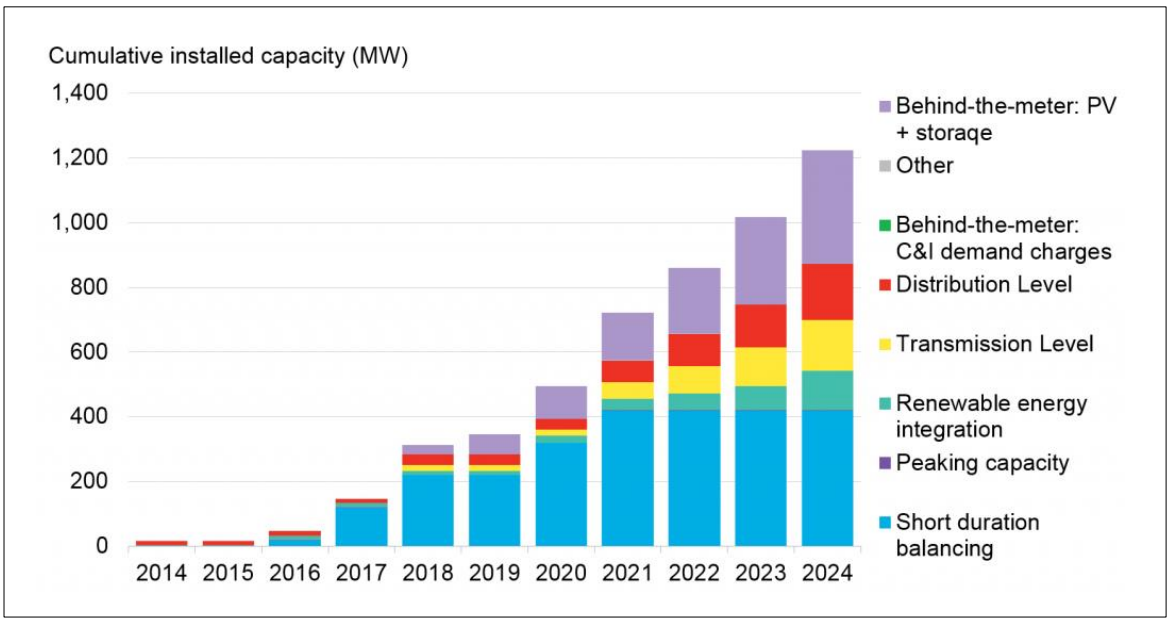

Figure 1 – Prediction of UK installed energy storage capacity up to 2024[23].

Moixa CEO stated that, "*SoLa BRISTOL was a pioneering UK project evaluation of residential energy storage deployment and DC (residential) micro-grids, with value demonstrations for households, communities (Schools) and network tests. Key outcomes included:*

- *Validation of technical approach and systems for installing remotely managed batteries in households (though at earlier / bespoke level of battery and control – several years ahead of later Moixa and e.g. TESLA systems)*
- *Data gathering of household solar, battery and usage across communities*
- *Need for wider business case where batteries are lower cost (now are) and can be deployed beyond just household level benefits, for wider local, network as well as Utility and grid benefits.*
- *Need for larger data set (100 households) due to sampling issues on small set (30) reflecting large energy variations on household use (kWh per day), Occupancy. Subsequent pilots at 100+ tend to migrate to national (e.g. ELEXON) average profiles, meaning groups of batteries perform in predictable load and shift."*

[23] https://about.bnef.com/blog/ofgems-vision-u-k-energy/

The following developments of behind the meter battery storage systems have occurred with over 50,000 batteries deployed in Germany, and over 5,000 deployed in UK[24]. It is forecast that there will be 50,000+ installations within the UK by 2020[25].

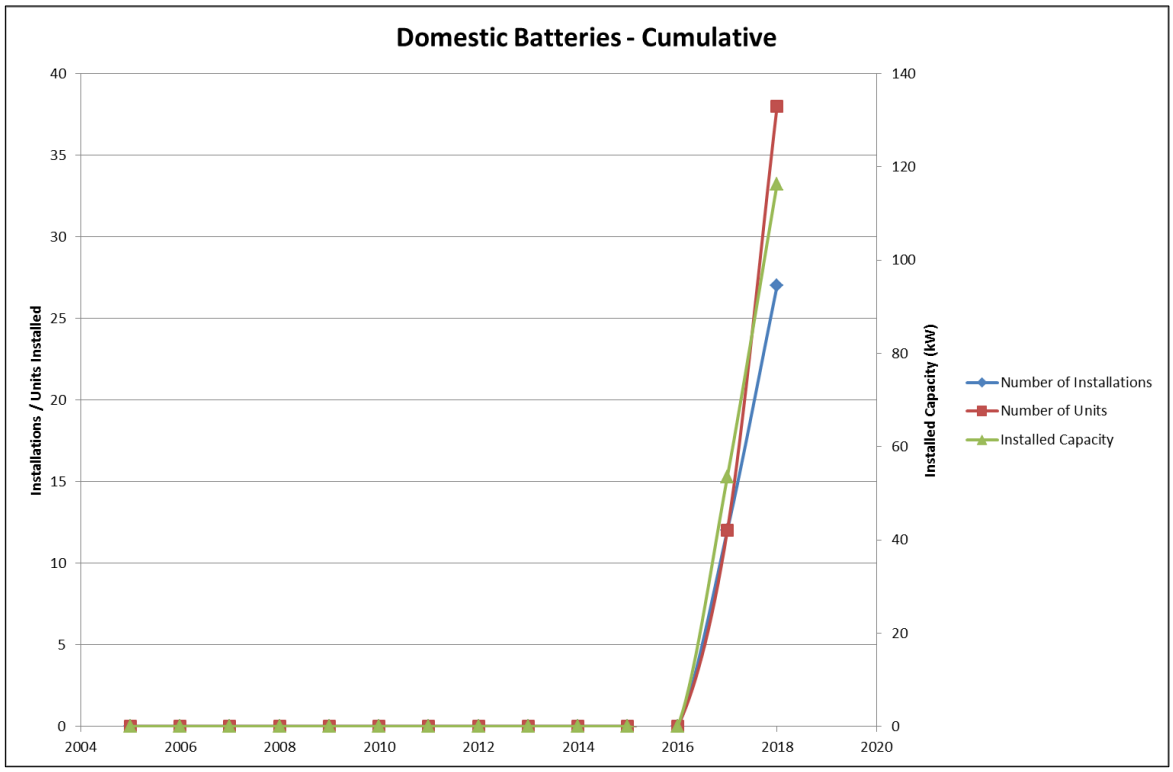

Figure 2 – Customer domestic battery installations behind the meter[26]

Figure 2 shows the recent acceleration in take up of behind the meter battery installations recorded in Western Power Distribution's Crown system. The number of units installed in the first quarter of 2018 is double the level recorded for 2017.

2.2 Releasing network capacity

At the time of the close down report, no DNO had proposed to use behind the meter storage to unlock low voltage network capacity. Since the SoLa BRISTOL close down report Ofgem has proposed the introduction of new conditions in the electricity distribution licence to ensure that distribution network operators cannot operate storage[27]. Whilst, as of the end of April 2018, a decision has not been made, it is increasingly unlikely any DNO will propose installing and operating energy storage on their network as a method to unlock network capacity. However, this doesn't not preclude DNOs unlocking network capacity by making use of services based on behind the meter storage owned and operated by others.

[24] Simon Daniel, Moixa CEO. Email 10/04/2018
[25] https://www.smartsolarukireland.com/article/101887/Moixa_expansion_continues_with_plans_for_100000_battery_Virtual_Power_Plant
[26] Based on data held in WPD's Crown system <15kW for battery installations
[27] https://www.ofgem.gov.uk/ofgem-publications/122285

At the time of writing this submission proforma, it is still considered that the deployment of behind the meter energy storage has not yet extended sufficiently for the DNO to use it as a method to release network capacity. Using behind the meter energy storage as an alternative to conventional network reinforcement was determined not to be cost effective[28] at the time SoLa BRISTOL, which completed in January 2016. This was largely because the SoLa BRISTOL project demonstrated that, for a DNO in isolation, there were insufficient benefits vs conventional network reinforcement.

The learning also demonstrated the complexity of energy storage ownership vs where the benefits from energy storage accrue. The need for further research[29] in this area was identified. It would require significant network penetration of storage for a DNO to have a sufficiently high level of confidence of network load reduction to adopt its use as a business as usual alternative technique to conventional network reinforcement. However, opportunities exist where there is sufficient density of these technologies through the widespread installation of batteries on new developments or some common rollout such as community led projects.

The project determined that, in order for the DNO to justify the use of batteries to release network capacity, many more batteries would need to be installed on the constrained network to achieve the necessary confidence levels. Given the cost of batteries at the time of SoLa BRISTOL, investment in batteries was not justified. Western Power Distribution therefore concluded that other reinforcement options are more viable.[30]

When both the penetration of batteries increases and the networks are capacity constrained, batteries can play a role in managing the constraint, leading to an increase in the number of years by which network investment can be deferred. The value of network deferral can increase to thousands of pounds. Sola BRISTOL recognised that additional research is required to validate the point at which the use of the trialled techniques become valuable, either through levels of penetration, storage cost reductions or increasing value of flexibility in a whole system context.

However, even though it looks increasingly likely that the DNO will not own or operate energy storage, customers are increasingly applying and installing energy storage in behind the meter applications, often to balance supply and demand, optimise distributed or embedded generation and unlocking capacity for new demand, including Low Carbon Technologies. A further example of this is within UK Power Networks' area where the level of behind the meter connection applications has resulted in them introducing a new fast track process,[31] making it easier for customers to connect behind the meter storage, like the SoLa BRISTOL method, to balance their energy requirements.

Whilst for some customers the installation of energy storage is for financial reasons, at the time of writing, it is estimated that a number of customers have installed behind the meter energy storage to prevent their LCT changing their power profiles, allowing them to avoid conventional network reinforcement, unlocking capacity for their additional Low Carbon Technologies.

Whilst there are commercially available solutions for low voltage, small domestic and commercial customers, their use is forecast to increase as there are further cost reductions expected. Forecasts

[28] SoLa BRISTOL SDRC 9.8 Section 7.1
[29] SoLa BRISTOL, Close down report, Page 29, Benefits table, fourth row.
[30] SoLa BRISTOL, Close down report, Page 43, Planned Implementation,
[31] https://www.energy-storage.news/news/uk-distribution-network-operator-unveils-fast-track-process-for-small-scale [Date accessed 15/03/2018]

predict energy storage costs falling to $100/kWh by 2025[32] and improvements in the value chain for energy storage can occur as they are installed, unlocking capacity for the uptake of LCT increase.

At the time of writing this report, battery installations are being led by customers. If, from the 5,000 installations in UK homes, there is an average of a 2kW inverter installed and 20% of the installations were on constrained networks, and therefore helped to unlock network capacity and avoid reinforcement, then 2MW of capacity will have been released.

2.3 Delivering Financial Benefits

The SoLa BRISTOL project has not been delivered as a business as usual solution by any UK DNO. This is because the SoLa BRISTOL project identified that the benefits to a DNO are not significant, and the method does not represent a more cost-effective method than conventional network reinforcement in the vast majority of cases where the sole value stream is the avoidance or deferral of network reinforcement. Based on the technology costs at the time of the project closedown, it was identified that cost reductions of several thousand pounds were required before the method could be seen as cost competitive in a high LCT uptake area[33]. There would also need to be a market mechanism to enable the DNO to make use of storage as a Business as Usual solution to overcome network constraints.

However, the method SoLa BRISTOL demonstrated is being used by customers across EHV, HV and LV networks as a cost effective method. Customers can stack value from numerous different sources, including integrating additional Low Carbon Technologies without upstream network reinforcement. Moixa CEO Simon Daniel states the "*project served to significantly educate the market and inform subsequent pilots, and contributed to growth in UK's leadership in smart battery and flexibility services, and potential future value for DNO constraint management.*" and "*The project was important as a pioneer on earlier TRL level, awareness level, and on initial assessment of battery value in reducing carbon (leveraging extra solar), DC in encouraging lower cost / carbon LED lighting, and on reducing peak (high carbon) grid.*"

As delivery of the solution is by customers rather than the DNOs, it is difficult to estimate the financial benefits being accrued compared to the traditional approach. Even at this early stage of battery storage adoption, benefits are conservatively estimated as £0.6m based on the evidence provided in 2.2 (Criterion A2) and the current UK installations, which is expected to grow considerably over the next 2 years.

2.4 Rollout across the DNO's system and across GB

The GB level impact is uncertain, as recognised in the 2017 report Upgrading our Energy System; "The Government and Ofgem cannot be certain how big a part flexibility provided by domestic consumers will play in our future energy system"[34]

However, as stated in sections 2.2 and 2.3, it is less likely that the project will be rolled out across the DNO's system by a DNO. However, the rollout across the DNO's system of behind the meter storage applications associated with Low Carbon Technologies will more likely be driven by customers, as is currently being seen. This will be accelerated as the uptake of LCTs increases, which will trigger the need for significant network reinforcement.

[32] https://www.bloomberg.com/news/articles/2017-12-05/latest-bull-case-for-electric-cars-the-cheapest-batteries-ever
[33] SoLa BRISTOL Close Down Report, Page 26, 9.1.1 Outcome. Bullet Point 2.
[34] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/633442/upgrading-our-energy-system-july-2017.pdf - Page 14

There are additional benefits to the customer (such as time shifting demand consumption) and potential for other revenue stacking services that improve the business case, as demonstrated by the current commercial offer from project partner Moixa, which claims up to 60% reduction in energy costs for customers. The rollout is likely to be with customers using energy storage to modify their consumption against time of use price signals and better utilise their existing connection capacity. With a high energy storage penetration, it could be possible for the DNO to contract customers or aggregators to access this flexibility and defer conventional network reinforcement, especially in high cost areas.

2.5 Value for money to customers

SoLa BRISTOL was a relatively small, but extremely complex programme of work. The project funding received from the Low Carbon Network Fund was £2,196k. The scale of the project was appropriate to produce meaningful learning, whilst representing value for money. SoLa BRISTOL delivered quantified data and experience of the actual benefits of storage in the context of network operation within a low carbon electricity system against the hypothetical use cases that were being discussed at the time, during 2010 and 2011.

Whilst statistical analysis showed that, in order to guarantee the network demand peak reduction, a much larger roll out would have been required to achieve a confidence level of 95% and 100%, with between 42 and 166 batteries needing to be installed on one feeder.

2.5.1 Effective use of funding

As detailed in the Full Submission Proforma[35], because a solution did not exist in 2011, the project designed a bespoke system. The aim was to utilise as many off the shelf products where available. The project recruited participants, successfully installed the bespoke system in 32 properties (homes, schools and an office) and installed monitoring equipment into 11 substations. Valuable insights were gained from all aspects of the project right up to decommissioning of the systems, all whilst ensuring all trial participants were satisfied and avoiding issues in customer properties.

The learning from SoLa BRISTOL has delivered significant value to the industry, which has subsequently brought to market a full commercially available offer. Additionally, SoLa BRISTOL delivered learning that has informed the market and the emerging opportunity of batteries and behind the meter storage[36]. Simon Daniel, CEO of Moixa, estimates that between 5,000 - 10,000[37] behind the meter energy storage connections within the UK demonstrate the value that is accruing from the learning generated by SoLa BRISTOL.

Ultimately, SoLa BRISTOL was more powerful and delivered value for money because it established the challenges it was aiming to answer needed to be refined. SoLa BRISTOL identified (i) the value of the project to different customer groups who saved different amounts from the tariff and technology, (ii) the approach to excellent customer engagement and (iii) identified the further work required within this area. This learning has helped others to provide solutions, which is proving incredibly valuable for customers within Great Britain, providing them with new choices about how to meet their energy needs, and will become more valuable as the costs of the solutions fall.

[35] Full submission Proforma, Section 9.2.
[36] Simon Daniel, Moixa CEO. Email 10/04/2018
[37] Simon Daniel, Moixa CEO. Email 10/04/2018

2.5.2 Minimising the cost of resources

To minimise the costs for the project, a selection exercise was undertaken prior to the full submission to select partners who could provide solutions and services. The selection was based on the services they could provide, the knowledge and experience they had in these areas and the value for money of their offer.

Project Partners and supporters were involved in the development of the Full Submission Proposal and the costs were based on formal offers from partners.

In summary the project delivered value for money through the following areas of exceptional learning:

- The results created a strong foundation for the industry, especially for future customers whose systems will take into account the learning from SoLa BRISTOL. The solution has been further developed by behind the meter energy storage manufacturers, such as project partner Moixa, and is now being offered to customers for them to solve their own network restrictions and make better use of the energy they generate.
- Partnering with Bristol City Council providing synergy of thinking and access to common services necessary to work on their housing stock. This partnership also created project exposure at European level.
- A well-run project that, though the application of strong programme governance, was able to overcome challenges that could not have been reasonably predicted without the experience gained through SoLa BRISTOL. Significant insight has been delivered to the industry, including the necessary approach to customer engagement[38] and the potential benefits, or lack thereof, to the DNO of installing storage behind the meter[39].
- It has identified that more work needs to be done in order to make these solutions attractive for a DNO funded method. The IET working group looking at energy storage in domestic properties is helping to resolve some of the outstanding issues. WPD is actively involved by sharing the learning from SoLa BRISTOL[40] with the IET working group.
- The learning from the use of the DC circuits was shared with the IET and informed the 'IET Code of Practice for Low and Extra Low Voltage DC Power Distribution in Buildings[41]'. Mark Dale, WPD's lead for SoLa BRISTOL, joined the working group and his contribution is acknowledged in the Forward.
- SoLa BRISTOL provided evidence that this aspect of the transition to a low carbon economy will be better led by other market participants than DNOs for a number of reasons. Firstly, DNOs are not the primary relationship holder with consumers and, secondly, the benefits accruing solely to a DNO are insufficient to make the commercial case for DNOs in the medium term, possibly even longer. The SDRC 9.8[42] has identified potential ownership scenarios that could still deliver benefits to both the customer, DNO and potentially others, without ownership and operation by the DNO.

[38] SoLa BRISTOL SDRC 9.8 Page 139. Section 9.1.2.1
[39] Close Down Report, Page 32, section 9.7 Conclusions. Fourth Paragraph.
[40] SoLa BRISTOL SDRC 9.8 Page 210. Paragraph 1 and 2.
[41] IET Code of Practice for Low and Extra Low Voltage DC Power Distribution in Buildings, see forward.
[42] SoLa BRISTOL SDRC 9.8 Page 205. Section 11.3.1.2

By working with the University of Bath as the academic partner on a number of Low Carbon Network Fund projects, Western Power Distribution was able to leverage synergies between projects to create efficiencies in the use of resources, reducing the costs for customers. The University of Bath was originally selected based on value for money following dialogue with other universities.

2.6 Relevance and timing of project

During the development of the project, there was a significant number of applications for small scale domestic PV installations, especially on social housing, that could have resulted in the need for substantial network reinforcement. Due to changes in government policy there was a marked reduction in the conversion of these applications into additional roll outs of PV. This was reflected in adoption of solar PV in the SoLa BRISTOL area leading to the expected LCT hotspots not materialising.

The learning from the project was acquired at a stage that enabled it to be incorporated in approaches that support the future developments associated with customers installing energy storage behind the meter.

As detailed in preceding sections, behind the meter electrical storage is unlikely to be used solely by the DNO as a method to resolve issues. It is likely to be used by customers where the network reinforcement costs are prohibitive and energy storage offers them a lower cost alternative. More LV energy storage offers will be accepted by customers compared to standard connections.

SoLa BRISTOL required significant and sustained efforts to overcome the challenges faced and deliver the learning outcomes and associated value for the sector. The final report (SDRC 9.8) details the additional steps undertaken to overcome issues encountered; these included the extensive testing undertaken to ensure systems complied with regulations[43]; the dissemination of the additional learning generated by the project and the significant efforts undertaken by both WPD and all partners, especially in customer engagement[44].

An example of this was our work with the customer recruitment partners Knowle West Media Centre (KWMC). KWMC were involved in the project from the kick-off meeting. They managed the customer interface, overseen by WPD. Their role was to recruit and protect customers. The project was being operated in an area of high social deprivation, where many residents were fuel poor, did not speak English as their first language and a higher than average number of customers were on Western Power Distribution's Priority Services Register.

The learning from this experience has helped define WPD's approach to engaging with customers for innovation projects and has informed our approach to Business as Usual customer engagement. The success of taking the learning into Business as Usual is reflected in WPD being consistently ranked at the top of Ofgem's Stakeholder and Customer Vulnerability Incentive.

The project recruitment process was very thorough. Even with these constraints a very high number of customers were successfully recruited from a relatively low number of eligible customers. These customers were engaged throughout the project and elected to remain interested in the project, even during the system design and initial installation works. Customers were supported at all stages throughout the installation, operation and decommissioning stages. Due to the exceptional efforts by WPD, KWMC and the other project partners, the project saw only one participant leaving the trial process.

[43] SoLa BRISTOL SDRC 9.8 – Page 12 – 13, section 2.1.3 and 158, L28.
[44] SoLa BRISTOL Close Down report – Page 29, fourth box.

2.7 Methodology robustness and project readiness

SoLa BRISTOL was an incredibly challenging project to deliver, complicated by the inclusion of an initial project demonstration. This was introduced via the Project Direction, during which time the project could not fully engage with customers ahead of the demonstration of the solution, as detailed in Change Request 4[45] and Change Request 5[46]. Whilst in these change requests it was explained why there was a requirement to change the end date of the project, Ofgem accepted that some of the delay could not have been reasonably foreseen and reflected the innovative nature of the project[47].

The start of the project exceeded expectations with the kick off meeting occurring ahead of schedule and the contracts signed with project partners ahead of schedule. These were required for the design and installation processes. Where there were delays, the project teams worked collaboratively together to resolve the issues and ensure that learning could be captured in a timely fashion.

2.8 Other Benefits

As detailed in the previous sub criteria, the project has developed a considerable amount of learning across many areas, both for DNOs and also for customers and third parties. The learning ranges from government[48], academia[49], to other customer organisations.

The key learning includes:

- Smart tariffs: SoLa BRISTOL identified that there can be positive and negative outcomes for consumers from smart tariffs. There are some customers for whom it is very clearly a benefit, whilst we found for other customers that more active forms of engagement would be required to influence behavioural change.
- DC Network: For the domestic homes this consisted of all fixed lighting points being converted to LEDs and several USB device charging points being installed. Views on the lighting varied considerably, but most homes were positive about the USB points. For commercial properties this consisted of a DC solution for IT equipment and the conversion of the lighting system to LEDs in the IT suite. There were no significant issues found from these changes.
- Storage: whilst the devices worked broadly in line with expectation, SoLa BRISTOL identified that there is additional work required to make this kind of mode of market operation successful and attractive to DNOs.
- Customer feedback: whilst customer feedback was generally positive, SoLa BRISTOL identified that there are some significant lessons that the industry as a whole can learn from engaging with the local community around energy matters. SoLa BRISTOL demonstrated that the investment of time and effort in customer engagement is essential if the desired outcomes are to be achieved. Moreover, SoLa BRISTOL identified some invaluable insights into how to communicate the messages succinctly. Maintaining customer engagement throughout proved to be absolutely vital.

[45] https://www.ofgem.gov.uk/sites/default/files/docs/2014/12/wpd_sola_change_request_publish_0.pdf
[46] https://www.ofgem.gov.uk/sites/default/files/docs/2015/03/wpd_hh_change_request_0.pdf
[47] https://www.ofgem.gov.uk/sites/default/files/docs/2014/12/ofgem_sola_change_request_letter_publish.pdf
[48] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/554467/Energy_Storage_Use_Cases.pdf
[49] https://www.birmingham.ac.uk/Documents/college-social-sciences/business/research/smart-cities-project.pdf

- Network Benefits: SoLa BRISTOL provided a platform that enabled network benefits to be observed. The project determined that additional work would be required in this area before it could be confirmed as an alternative to conventional network reinforcement. SoLa BRISTOL indicated 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 corresponding network investment deferral was small.

When both the penetration of batteries increases and the networks are capacity constrained, batteries can play a role in managing the constraint. In this scenario, the number of years by which network investment can be deferred increases and the value of network deferral can increase to thousands of pounds. Sola BRISTOL recognised that additional research is required to validate the point at which the use of the trialled techniques become valuable, either through levels of penetration, storage cost reductions or increasing value of flexibility in a whole system context.

As a result of the SoLa BRISTOL behind the meter storage project, there has been a major uptake in behind the meter solutions. It was the SoLa BRISTOL project that helped to kick start these developments and bring commercial offers to market.

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

Western Power Distribution made an additional investment of £348k to ensure the project could successfully deliver vital industry learning. Further details have been included below.

3.1 Details and significance of DNOs additional contribution

As detailed in the close down report, there was a requirement for change within Sola BRISTOL. This was as a result of changes to the planned scope that could not have been reasonably foreseen without the experience of mobilising the programme and the associated learning that emerged. The necessary design change resulted in increased costs[50]. The objectives of SoLa BRISTOL were to generate valuable industry knowledge and deliver quantitative data about the potential for the use of LCTs in combination with storage to manage networks[51] and inform the industry use cases that prevailed in 2010 and 2011.

As a result, Western Power Distribution contributed an additional £348k to the project costs on top of the £229k compulsory contribution. This was to ensure the project could be finished successfully and the full knowledge captured. The additional funds allowed the project to operate for an extended period of time, delivering the learning generated from the project, specifically the operational learning from the project[52].

Given the subsequent uptake of the concept into the mainstream Government and regulatory narrative, coupled with the emergence of a fully commercialised solution that offers substantial energy and cost savings to customers, Western Power Distribution believes the additional contribution delivered excellent value for consumers. This is based on the use of the SoLa BRISTOL knowledge and these subsequent developments in behind the meter energy storage.

3.2 Issues that justified the additional contribution

In the Project Progress Report of June 2015[53] WPD 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 programme governance and financial controls in place on SoLa BRISTOL enabled early identification of the need for additional investment if the project was to deliver the learning outcomes. These programme controls enabled proactive discussions to be had and decisions to be taken. The controls identified 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 increasing the development costs on a per installation basis (the development costs being largely fixed and apportioned across a smaller number of installations) and then trying to ensure that the project could deliver against those changes. The project ran for an additional year to increase the potential for data acquisition and improve the learning generated. The additional contributions allowed the learning to be fully captured and shared across the industry.

[50] Close Down report, Page 21 – Paragraph 2
[51] Close Down report, Page 21 – Paragraph 1
[52] SoLa Bristol, SDRC report 9.8 – Sections 4, 5, 7, 8, 9 and 10.
[53] https://www.westernpower.co.uk/docs/Innovation/Closed-projects/SoLa-Bristol/SOLA-BRISTOL-Progress-Report-May-2015.aspx Page 16, Explanatory note.

Western Power Distribution has 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. Whilst additional investment was required to deliver the learning outcomes, this was a consequence of the emerging learning from the mobilisation of the project.

The only alternative option would have been to halt the project. This option was rejected as not being in the best interest of the sector as it would have eliminated the opportunity for learning in this vital area. Understanding the network impacts of low carbon technologies and the contribution that behind the meter storage can make to design and operation of networks that economically support delivery of the Carbon Plan and the Clean Growth Strategy is today proving its value.

3.3 Demonstrable benefits to customers

Increased effort, and as a result funding, was spent within the sections of the project listed below. One of the most significant aspects of the project was ensuring customers' safety and establishing a robust system that did not cause unnecessary disruption to customers. The extended time period allowed for Western Power Distribution and its partners to ensure the solution was ready for installation[54], had sufficient systems in place to account for how it was to be used by customers and was installed and operated in accordance to both Western Power Distribution's standards and Ofgem's requirements[55].

During the additional 12 months period the project operated for, additional funding was spent on project management and collecting and disseminating the additional learning. These were key to the delivery of the project and allowed significant extra learning to be captured by the project and shared with the industry.

- Ensuring that the systems being demonstrated were safe and reliable[56].
- Identification of the characteristics of suitable properties to ensure that systems are only installed where appropriate and minimising disruption to the consumer whilst maximising the benefits in terms of system design and operation[57].
- Ensuring that the key learning points captured within the additional 12 month period of the project could be fully captured and disseminated.
- The 12 month extension included the educational programme and development of the 'Schools Pack' with partner Gallomanor[58].

[54] SoLa Bristol SDRC9.8 Page 12, Section 2.1.3 System Testing,
[55] SDRC Page 5, Criterion 9.1
[56] SDRC9.8 Page 158 – L28, Page 13, section 2.1.3
[57] https://www.ofgem.gov.uk/sites/default/files/docs/2014/12/ofgem_sola_change_request_letter_publish.pdf, Page 2, Change 2.
[58] http://gallomanor.com/about-gallomanor/

4. Reward Criterion C: Exceptional Efforts

The project team undertook exceptional effort to generate valuable learning from all aspects of the project[59], which was significantly more than expected at the FSP stage. This learning has been systematically captured[60] and disseminated for the good of all DNO customers as described over the next three sections.

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

There are many examples of where the project has delivered substantially more learning that was expected at the outset, largely due to the fact the project proved to be even more challenging than originally envisaged.

The final report[61] details the key learning. The areas where SoLa BRISTOL delivered significant additional and exceptional learning for all with regard to the development and use of behind the meter solutions were:

- how to successfully engage with customers for complex in-home projects[62];
- the complex design decisions and learning for a behind the meter solution and how to obtain the required approvals[63];
- how the same solution can provide very different benefits for different customers, and
- a strong design and testing assessment to ensure solutions work safely and as expected.

The combination of the significant and sustained effort and learning generated to successfully deliver the project exceeded the original learning expectations within the LCNF Submission document. As a result of the learning developed through the SoLa BRISTOL project, it was awarded the Best Residential Energy Storage Project[64] at the first Solar Power Portal awards ceremony. It was also referenced in the Bristol City Council submission that saw Bristol become 2015 European Green Capital.

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

Whilst there was additional learning across the project as a result of WPD's exceptional efforts, the three stand out areas are Customer Engagement, the performance of the solution for the different individuals and the detailed design and assessment process the project went through to develop a robust working system.

4.2.1 Customer engagement

The project delivered a new standard of customer engagement and support and the successful learning that came as a result of this. This learning was only possible form the close working relationship between the DNO, Bristol City Council and our recruitment partner, Knowle West Media Centre. This approach is now followed on all customer projects, as further demonstrated on the Tier 1 Community Energy Action project.[65]

[59] SDRC 9.8 Section 10, Project Learning
[60] SDRC 9.8 Section 10.2, Project Management Learning
[61] SDRC 9.8
[62] SDRC 9.8 Section 10.4.2.6 - Customer Engagement.
[63] SDRC 9.8 Section 2.1 – System Design and Approvals, Pages 11 - 29
[64] https://www.cleanenergynews.co.uk/news/storage/solar-power-portal-awards-2017-spotlight-energy-storage
[65] https://www.westernpower.co.uk/docs/Innovation/Closed-projects/Community-Energy-Action/Community-Energy-Action-Close-Down-Report-FINAL.aspx

The close working relationship and additional time spent at the very start of SoLa BRISTOL meant the project was presented to customers in the best way. The project was able to ensure the language being used was appropriate to the customers and that the KWMC staff had all the information required to fully understand the project and were able to share it with customers and participants in a way that was most comprehensible to the project participants[66].

WPD has embedded these lessons in the way we engage with our customers throughout our business. This is reflected in WPD being consistently ranked at the top of Ofgem's Stakeholder Engagement and Customer Vulnerability Incentive. Indeed, members of the WPD Innovation team regularly support the communication team in articulating the importance of stakeholder engagement based on the lessons from SoLa BRISTOL.

4.2.2 The performance of the solution for the different individuals.

One of the most significant areas of learning was the variation in the savings that customers could achieve. The amount of money saved by customers varied significantly throughout the project even though all customers had identical equipment installed[67]. Learning showed that higher use customers showed the least savings and that the different battery strategies impacted the savings of the three types of customers who had the solution installed.[68]

4.2.3 Detailed design and assessment.

The project produced considerably more learning on the design, testing and certification requirements than initially expected. This was as a result of WPD's high standards in safety, ensuring that the solution being provided was safe for the installers and the customers into whose homes it was installed. The knowledge gained within the design activities was particularly relevant to the IET's working groups, where the learning from SoLa BRISTOL is helping inform their activity and helping others to benefit from the good practice carried out and ensure future energy storage solutions and DC networks are designed and tested appropriately.[69]

As a result of this exceptional effort, new levels of learning were captured and disseminated, which have helped future parties to achieve similar levels of safety in these areas.

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

The learning from the project has been far and wide, including informing governmental updates on Energy Storage[70], influencing how smart city projects can be initiated[71] and engaging primary school children through the production of the 'Schools Pack' and creating an educational programme. Considering the project received a comparatively small amount of funding, the knowledge generated and disseminated has been exceptional and beyond that outlined in the original FSP.

The project undertook 72 external dissemination events and activities, with additional internal dissemination events. Section 2.4 of the SDRC9.8 details the range and breadth of the dissemination, ensuring that the learning was accessible to the widest audience. This included press

[66] SoLa Bristol SDRC9.8 Page 113-114, 9.1.1.1 Recruitment
[67] SoLa Bristol SDRC9.8 Page 122, Section 8.3 Customer Benefits.
[68] SoLa Bristol SDRC9.8 Page 122, Section 8.3.1 Customer Benefits.
[69] SoLa Bristol SDRC9.8 Page 207
[70] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/554467/Energy_Storage_Use_Cases.pdf
[71] https://www.birmingham.ac.uk/Documents/college-social-sciences/business/research/smart-cities-project.pdf

releases, industry and academic publications, as well as dissemination events, one to one meetings, including site visits for the DNO community.

The project was included in Bristol City Council's winning bid to become 2015 European Green Capital, gaining wide exposure and additional dissemination opportunities at both a national and international level[72].

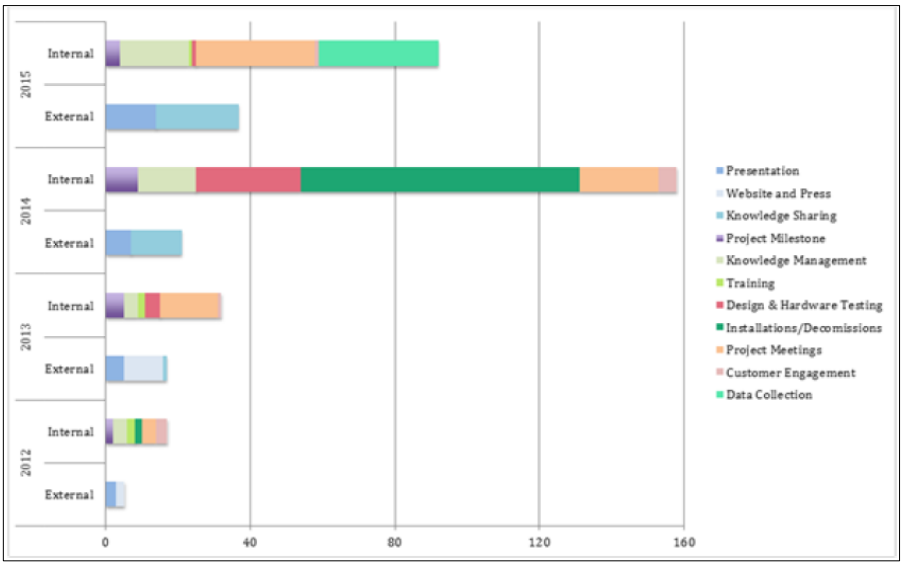

Figure 3 - Internal and External dissemination events by year[73]

One of the more passionate project customer participants shared his knowledge directly with a large audience at the 2013 LCNI conference where he was interviewed by Roger Hey, Future Networks Manager. This level of first-hand knowledge dissemination was incredibly valuable for utilities to understand the customers' perspective of the project.

Figure 4 – Roger Hey discussing the participation in the SoLa Bristol with one of the project Customer participants.[74]

[72] http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2013/06/Indicator-12-Energy-Performance_BRISTOL.pdf (Section 12 A3b and B2b)
[73] SoLa Bristol SDRC9.8 Page 41
[74] https://www.flickr.com/photos/enaevents/13246264134/in/album-72157642548318054/