Ashton Hayes Smart Village

Close Down Report

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Executive Summary

British communities are moving towards playing a more active role with regard to the way in which they consume, and increasingly produce, electricity. Since this projects inception there has been a significant increase in the number of community energy pilot schemes across the country as well as the release of Britain's first 'Community Energy Strategy'[1] by the Department for Energy and Climate Change (DECC). The strategy outlines the role communities can play in Britain's low carbon transition and the potential benefits they can deliver.

With the greater empowerment, awareness and support from the strategy and other initiatives it is likely that there will be a substantial increase in the interactions between communities and the Distributed Network Operator (DNO) industry. As such this project provided a precursor to many of the current projects working in this area and provided a DNO with an early opportunity to explore this relationship and ultimately the role of DNOs within community energy schemes.

Scope

The scope of the Smart Village project was to work with an engaged community (Ashton Hayes, a village in Cheshire) to help a DNO (ScottishPower Energy Networks) to better understand how increased small scale generation would affect the network while also helping Ashton Hayes reduce its carbon footprint. In order to ensure this was done successfully, it was necessary to understand in more detail the varying loads and voltages being encountered on the Low Voltage (LV) network. This more detailed understanding was expected to help inform future Tier 2 LCNF projects and existing planning processes within a DNO as well as helping to maintain network safety.

Aims

The project aimed to support Ashton Hayes towards its goal of becoming a carbon neutral community through examining the feasibility of connecting a range of low carbon technologies to the network. It also aimed to explore the relationship between the DNO and the community, establishing a blueprint for community engagement that could be adopted for projects across the country and integrated into normal business practice where appropriate.

To achieve these goals, the project sought to engage directly with the community on methods for reducing and optimising total energy consumption, install additional metering to help improve the accuracy and granularity with which total energy consumption was measured, and introduce new techniques to support demand side reduction including behaviour change in residential homes and public properties. The project sought to ensure it worked in a way which would allow maximum adoption of low carbon technologies without compromising the network.

[1] https://www.gov.uk/government/publications/community-energy-strategy

Work Undertaken

The work undertaken was split into three areas: community engagement, network monitoring and data analysis.

The community engagement work was an overall success. SPEN invested significant effort in building their relationship with residents, through a series of meetings with key stakeholders from the community, and a dedicated communications campaign though a wide range of channels. This ensured information reached as many people as possible. The process was documented at all stages, to enable dissemination of key lessons and support replication by other like-minded communities and DNOs.

Significant work was also carried out to improve network monitoring. The project aimed to improve the accuracy and granularity with which total electricity consumption was measured, by installing additional metering on the network. To achieve this, a tendering exercise was undertaken and monitoring equipment was subsequently installed at all distribution substations, and two feeders as well as in some buildings.

The data collected from the network monitoring made it possible to perform detailed analysis of LV profiles. In turn, this permitted completion of a more rigorous assessment of potential connections of new technologies to the network as well as their implications for the design and operation of the network. This analysis included observing the effects of varying voltage and also analysing the variations in rating of a transformer at different times of day and year according to the temperature experienced.

The planned Demand Side Response (DSR) trial was not achieved due to a delay in the role out of Smart Meters and hence a lack of any means by which to accurately measure individual customer demand and observe the effects of demand shifting. The project was slightly ahead of the progress of the sector with regard to the deployment of Smart Meters and was therefore unable to reach agreement with any of the four energy suppliers approached. No method of interfacing directly between the DNO and the customer to engage in DSR could be established within the time and budget restrictions of the project.

Outcomes and Learning

Community Engagement

A well-managed process of engagement with the residents of Ashton Hayes provided SPEN with an understanding of what is required for successful community engagement. A generic flow diagram was developed to capture the good practices established.

The project highlighted that while a trusting relationship takes time and effort to establish, over the longer term it may save time and cost in other parts of the business. For example, helping to reduce the cost of reinforcement and time spent on network planning.

The information provided to the community increased the visibility of their demand on the network. It allowed residents to take more informed actions to reduce their energy consumption and also gain an understanding of the potential for Demand Side Response.

Network Monitoring

Greater insight has been gained into the LV demands within the village through the project. This information was essential for analysis and community engagement.

Network monitoring was not as reliable as would be required for business-as-usual implementation. However, on-going development of the equipment during the trial via upgrades and debugging did take place, helping to improve the performance monitoring, although it was still not completely error free. Information gathered during network monitoring was implemented into Flexible Networks Tier 2 LCN funded projects.

Data Analysis

The availability of network capacity to accommodate increased levels of distributed generation was found to be greater than that assumed by existing planning processes. This was important as it demonstrated that more renewable generation and low carbon technologies could be connected than conventional assessments would predict, thus facilitating a reduction in the carbon footprint of the village, while retaining confidence in the network's integrity.

Monitoring of one of the pole mounted transformers demonstrated that, although when compared to its nameplate rating the transformer appeared to be overloaded during peak times in winter, by applying a real time thermal ratings algorithm, it was found that the reduced temperature meant that the transformer was operating within its capability.

With respect to Demand Side Response, the actual load data demonstrated that non-time dependent models that simply allocate an after diversity demand to each connection could underestimate predictions of available capacity. Studies showed the scope for DSR within the village was some 7.5-10% of total load at peak time.

Conclusions and Further Work

The project achieved all of its success criteria. It supported Ashton Hayes in the introduction of low carbon technologies through the use of monitoring data to establish the voltage headroom, connected new technologies to the LV network (including photovoltaics, heat pumps, and an electric vehicle charging point) and ensured integration and optimal utilisation of these technologies to reduce the village's carbon footprint. Notable achievements included:

- The project developed a 'blueprint' for successful community engagement which is available for use by other projects. Building a trusting relationship between a DNO and a community takes time and effort and is aided by the use of a trusted 3rd party. Further consideration needs to be given to how this can form part of business as usual for a DNO at a much larger scale.

- LV data analysis showed that there was additional network capacity available, which was more than existing planning processes may assume, thus demonstrating that more renewable generation and low carbon technologies could be connected than conventional assessments would predict. Some findings regarding the increased capacity that can be realised through the use of dynamically rated assets (such as the pole mounted transformer in this project) also merit further consideration as an alternative to conventional reinforcement techniques.

- Lessons learned from monitoring the LV network were used in Flexible Networks Tiers 2 LCN funded project. However, LV monitoring was not error free and further work is required to make this monitoring more effective.

- The scope for voltage variation to allow the connection of increased levels of distributed generation needs to be carefully considered.

Future work includes:

1. The planned DSR trial was not achieved due to a delay in the role out of Smart Meters. The appetite for DSR trials amongst suppliers is now greater due to increased pressure on the energy market and Smart Meter role out becoming a reality. Further work is needed to establish how to balance DNO priorities around control of the local network to the priorities of suppliers seeking the best deal on the national electricity market.
2. Data analysis once verified will provide the information to more accurately assess the impact of new generation connections. This could be fed into network planning techniques and feed into awareness campaigns to reduce demand.
3. Whilst the monitoring has delivered some major benefits, within this trial the desired reliability was not achieved. LV monitoring reliability needs to be proven prior to installation en masse.
4. In future a more targeted approach to monitoring may be appropriate as knowledge of specific data requirements becomes clearer.

2 Project Background

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1.4 Initiation of the Smart Village Project 10

1 Project Background

Ashton Hayes, with the backing of the Parish Council, launched their Going Carbon Neutral[2] project approximately 7 years ago. This rural community of 1,000 inhabitants outside Chester declared an ambitious aim to become England's first carbon neutral village.

Since the project's inception, the village has reduced its carbon emissions by 22.8% through a raft of predominantly simple measures such as the use of low energy light bulbs, turning down heating thermostats, lagging lofts, recycling, composting, taking trains instead of driving and reducing travel by air. Growing concern over climate change and fluctuating energy prices also sparked interest in the possibility of Ashton Hayes taking control of its energy use and reducing its carbon footprint even further through new and innovative ways of managing locally owned renewable generation. This formed the basis for the Ashton Hayes Smart Village LCN Fund trial. It built on a Feasibility Study and IFI study completed previously, and was implemented in parallel to activities funded through a Low Carbon Communities Challenge award. Steps were taken to ensure cross-learning between the two.

1.1 2008 Feasibility Study

A 2008 study funded by Carbon Connections investigated different types of small-scale renewable energy, measured local load and renewable energy resources and investigated legal structures for community management of the generation[3]. This work was carried out by EA Technology and the University of Chester in active partnership with the community; consultation with villagers was of the utmost importance for the project.

1.2 IFI Initial Study

Using one feeder in Ashton Hayes as a case study, SPEN worked with EA Technology on IFI project 0706 'Ashton Hayes Microgrid'[4]. This identified the technical issues and benefits of small-scale generation including the thresholds of capacity after which innovative LV network design would be needed.

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[2] http://www.goingcarbonneutral.co.uk/ accessed August 2013

[3] More information at http://www.goingcarbonneutral.co.uk/microgrid-study-informaton/ accessed 15th October 2013

[4] More information at https://www.ofgem.gov.uk/ofgem-publications/52254/scottish-power-ifi-report-2008-09.pdf accessed 15th October 2013

1.3 Low Carbon Communities Challenge Award

As a result of the work above, the village was awarded around £400,000 to install low carbon technologies and develop organisational structures to own and manage community-owned low carbon technologies[5].

1.4 Initiation of the Smart Village Project

As a result of the previous work described, it was proposed that the LCN Fund Smart Village Project would be built up in a step-by-step manner in parallel with the work undertaken as part of the Low Carbon Communities Challenge (LCCC) Project[6]. This would facilitate the LCCC project but the LCCC project would also provide valuable information that would benefit the LCN Fund Smart Village project. Analysis which benefited both projects was carried out as information on load and power flows within the village was gathered and new technologies, such as community-scale generation and electric vehicles, were installed.

[5] Evaluation report available at: https://www.gov.uk/government/publications/low-carbon-communities-challenge-evaluation-report accessed 15th October 2013.

[6] More information at www.goingcarbonneutral.org.

2 Scope and Objectives

The objectives of the Smart Village Project were technical innovation and delivery of information to the community aimed at achieving a sustained reduction in carbon emissions. More specifically, project goals included:

- To facilitate the connection of various micro generation technologies (wind, PV and CHP) and potentially electric vehicle (EV) charging point(s) on the LV network and its 11 kV feeders.
- To engage with the village and community to assist in the reduction and optimisation of total energy consumption to reduce carbon footprint.
- To improve the accuracy and granularity of total electricity consumption measurement by installing additional metering on the network at secondary substation feeder level and at renewable energy source(s) providing measurement of the gross generation embedded within the community.
- To introduce innovative and new techniques to introduce DSM capabilities aimed at assisting change in energy use related behaviours within residential homes and public properties.

Ashton Hayes represented an engaged community interested in reducing their carbon footprint. In order to achieve this, there was a need to use a variety of low carbon technologies, but the issues that this may present to the local distribution network were unknown. There was therefore a need for the DNO (SPEN) to work closely with the community and to analyse the local network such that the various low carbon technologies could be connected. This is articulated in the first objective:

To facilitate the connection of various micro generation technologies (wind, PV and CHP) and potentially electric vehicle (EV) charging point(s) on the LV network and its 11 kV feeders.

The stated desire of the local community to achieve carbon neutral status clearly required engagement from a range of stakeholders, including the local DNO. As consumers in general become more active and want to understand their impact on carbon levels in more detail, there will be a growing need for DNOs to be able to engage and communicate effectively with these customers, whether individually or, perhaps more likely, in community groups. Given that the village was already aware of its desires with regard to installation of low carbon technologies and had already established local organisations that could act as a channel through which communications with the DNO could be established, it was an ideal base to trial the way in which a DNO can engage with a local community on such matters. As such, the village was well placed to provide a platform to achieve the second objective:

To engage with the village and community to assist in the reduction and optimisation of total energy consumption to reduce carbon footprint.

SPEN were aware that they had little visibility of the LV network and the impact on the network of increasing numbers of low carbon technologies. There was also little recent experience of monitoring LV networks with modern monitors. With this information, analysis could be used to develop new working and planning practices to ensure the network is as efficient as possible. As customers become more active, SPEN was also aware that it was important to better understand how to engage with customers. This led to the third objective:

To improve the accuracy and granularity of total electricity consumption measurement by installing additional metering on the network at secondary substation feeder level and at renewable energy source(s) providing measurement of the gross generation embedded within the community.

The village was an ideal base to understand power flows at LV and the impact of low carbon technologies and behaviour change because:

- It was of a manageable size to learn how to install and manage LV monitoring. Four different types of substation or transformer gave a range of experience whilst minimising the number of sites where maintenance or upgrades might be needed.
- The village was already aware and engaged and wanting to install low carbon technologies.
- Organisations already existed within the village which could facilitate effective engagement with SPEN.

This information could then be used to develop new planning techniques and understand how Demand Side Response (DSR) could be used. The project was always intended to be a starting point, the results of which could be fed into and extended in larger trials and then integrated into normal working practices. It would also help develop a framework for other field trials requiring customer engagement. Pulling these strands together was required to meet the first and fourth objectives.

To introduce innovative and new techniques to introduce DSM capabilities aimed at assisting change in energy use related behaviours within residential homes and public properties.

Minor alterations to the project were required and these are discussed in section 7 .

3 Success Criteria

The following success criteria were identified:

- Supporting Ashton Hayes in the introduction of low carbon technologies.
- Connection of the new technologies to the LV network.
- Integration and optimal utilisation of these technologies to reduce the carbon foot print of Ashton Hayes village.

And this was achieved through:

- Development of innovative connections,
- Monitoring and analysis of the power flow;
- Community engagement.

The success criteria were designed to encompass a three-pronged approach: the physical and design challenges of monitoring, together with the technical analysis of the data, but also the human input via community engagement.

As discussed in the proposal, options for innovative Distributed Generation (DG) connections at LV with a comparison of the costs and benefits including the impact on the rest of the network were considered. The lessons learned could help support the development of a more cost effective design and operation of the network as more technologies with new import or export profiles are connected.

The data collected gave SPEN visibility of load profiles on the network and enabled analysis of how they alter with the addition of more low carbon technologies and behavioural change and the resulting potential estimate carbon savings.

To achieve the success criteria, it was important to analyse the impact of new connection designs as well as investigating how behavioural change affected the success of a solution. Therefore, the project also reported on the potential interactions between licensed energy suppliers, community organisations and DNOs in future. These included new methods of operating that could be used in Ashton Hayes and elsewhere including possible changes in DG or other Use of System charges. For all of the above, learning how to engage effectively with customers could help reduce costs.

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Key Lessons:

1. Working with a village which already wants to go low carbon provides more likely conditions for success.
2. Working with a community which already has organisational structures for engagement provides more likely conditions for success. Where these don't exist time is required to develop suitable structures.
3. Working with a village of a manageable size and well defined geographic area provides more likely conditions of success.
4. Engagement with communities using a trusted third party as an inter-mediatory is a quick way to build a relationship and is considered best practice by SPEN.
5. Ashton Hayes already had the skills required for successful engagement with a DNO. These included organisational skills to run a project, an understanding of finance, active participation by trusted individuals within the village, and skills to communicate with the remainder of the village.
6. There are no financial inducements for DNOs to integrate these lessons into business as usual. While benefits do exist these are not widely recognised. Further work is required to encourage DNOs to take these approaches into business as usual.
7. Not everything will always be successful or achievable. It is important to accept and expect that some elements may fail. For example DSR and EV.
8. Be realistic about what can be achieved within the project and the timeframe.

9. Sometimes you just need to try something to learn how to do it best.
10. Using a wide range of communication channels ensures messaging reaches as wide an audience as possible and is central to effective engagement.
11. Investing time and effort into engaging effectively with the community helped build trust, which in turn meant that the community was willing to provide data out with the scope of the project (and its cost) which further aided analysis.
12. Keep it simple to maximise chances of success.
13. The whole industry benefits from the learning. For example, the deployment of the monitors and the recovery of real LV network data was invaluable to several academic institutions in need of real data for analysis.
14. These types of projects can generate recognition for DNOs with rewards in terms of their reputation and public image. (Less tangible than financial rewards but equally important.)

Details of the work carried out

The work undertaken fell into three areas:

I. Community Engagement
II. Network Monitoring
III. Data Analysis

The process for engagement flowed from the initial introduction of the community to SPEN by EA Technology. The project utilised a wide range of communication media to disseminate information to as many people as possible. The process and its impact were documented for future use elsewhere.

In order to conduct the required network monitoring, a tendering exercise was undertaken by SPEN and monitoring equipment subsequently installed at substations, on feeders and in buildings. Learning, and improvements in data handling, was carried out and the lessons were carried forward into Flexible Networks Tier 2 LCN funded projects.

Analysis of the LV profiles, connections and their implications for the design and operation of the network was undertaken by SPEN.

4.1 Overview of the General Approach

The LCN Fund was designed for investigating technologies, new ways of working and gathering information to reduce the carbon emissions of the network itself but also to facilitate low carbon technologies (LCTs).

This area requires a large amount of work and information that historically has not been collected. It is therefore necessary to begin at a manageable scale and use the approach of ‘start small, think big, and scale fast’ to build up information and learning. The village of Ashton Hayes was identified as a suitable location for a trial using this approach. It was not intended to provide definitive answers to all the challenges facing the LV network, but rather provide the first results that could be expanded upon and investigated further in larger, subsequent projects. Figure 1 shows the different activities within the village.

The project itself was a trial and was not expected to be replicated as a whole. The level of community organisation in Ashton Hayes is higher than average. Nevertheless, the techniques developed in the village can be used elsewhere and integrated into business as usual.

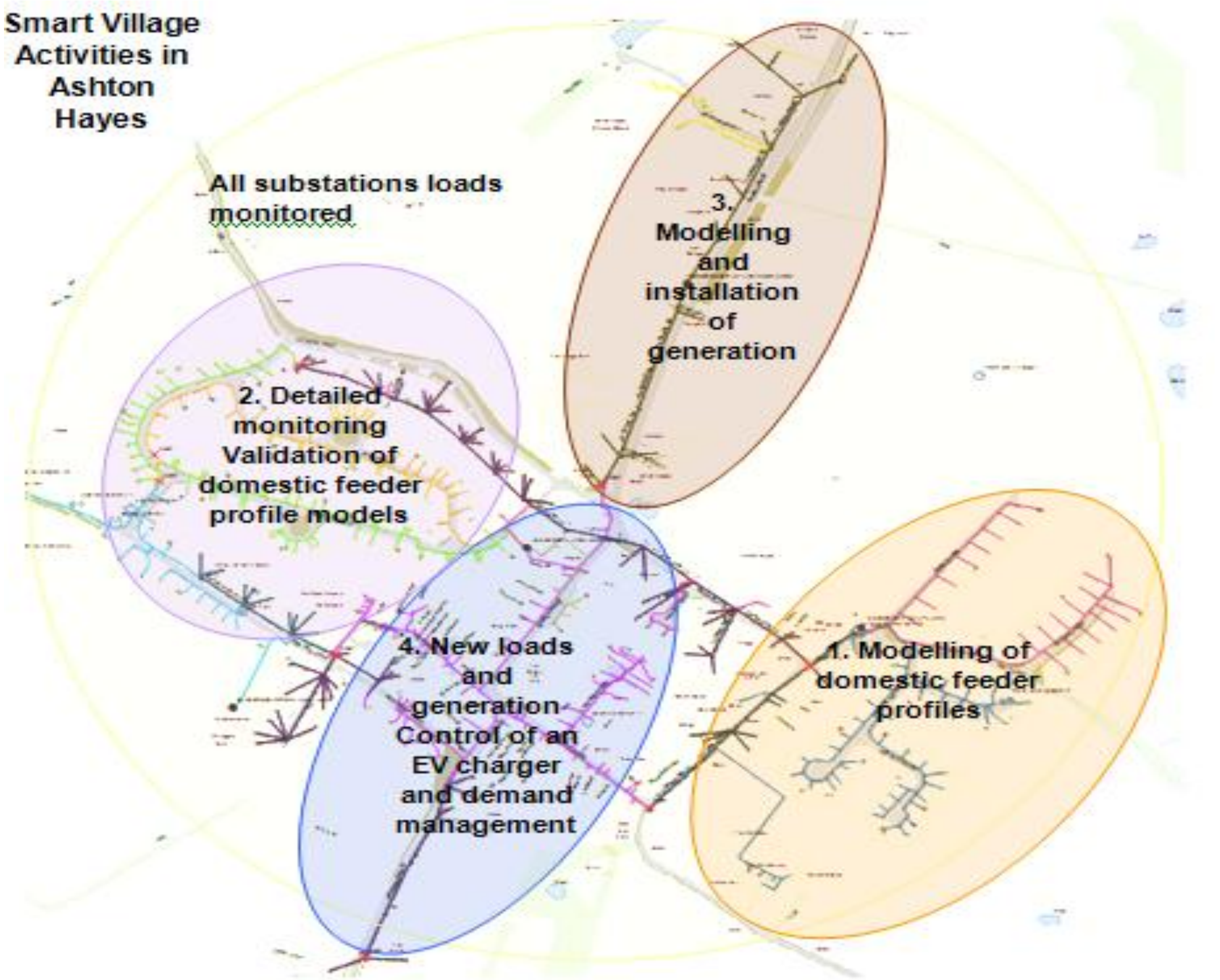


Figure 1 Overview of project activity in the village.

4.2 Justification of the Approach

4.2.1 Visibility of the Network at LV and Engagement with Communities

Historically there has been almost no monitoring of loads at LV, partly because data transfer and monitoring costs were too high for the quantities of feeders and partly because traditional power flows to properties at LV have been predictable. In addition, without the technology to control the LV network, the data could not be fully utilised.

With falling costs of monitoring and the need to control the LV network to incorporate low carbon technologies, understanding how to cost-effectively monitor the LV network and gather knowledge on power flows and demand curves at LV is essential. This will feed through to the development of new planning techniques and designs. Monitoring two ground mounted transformers (GMTs) and two pole mounted transformers (PMTs) supplying a defined area and two feeders was a good starting point for this learning process (Figure 2).

Ashton Hayes

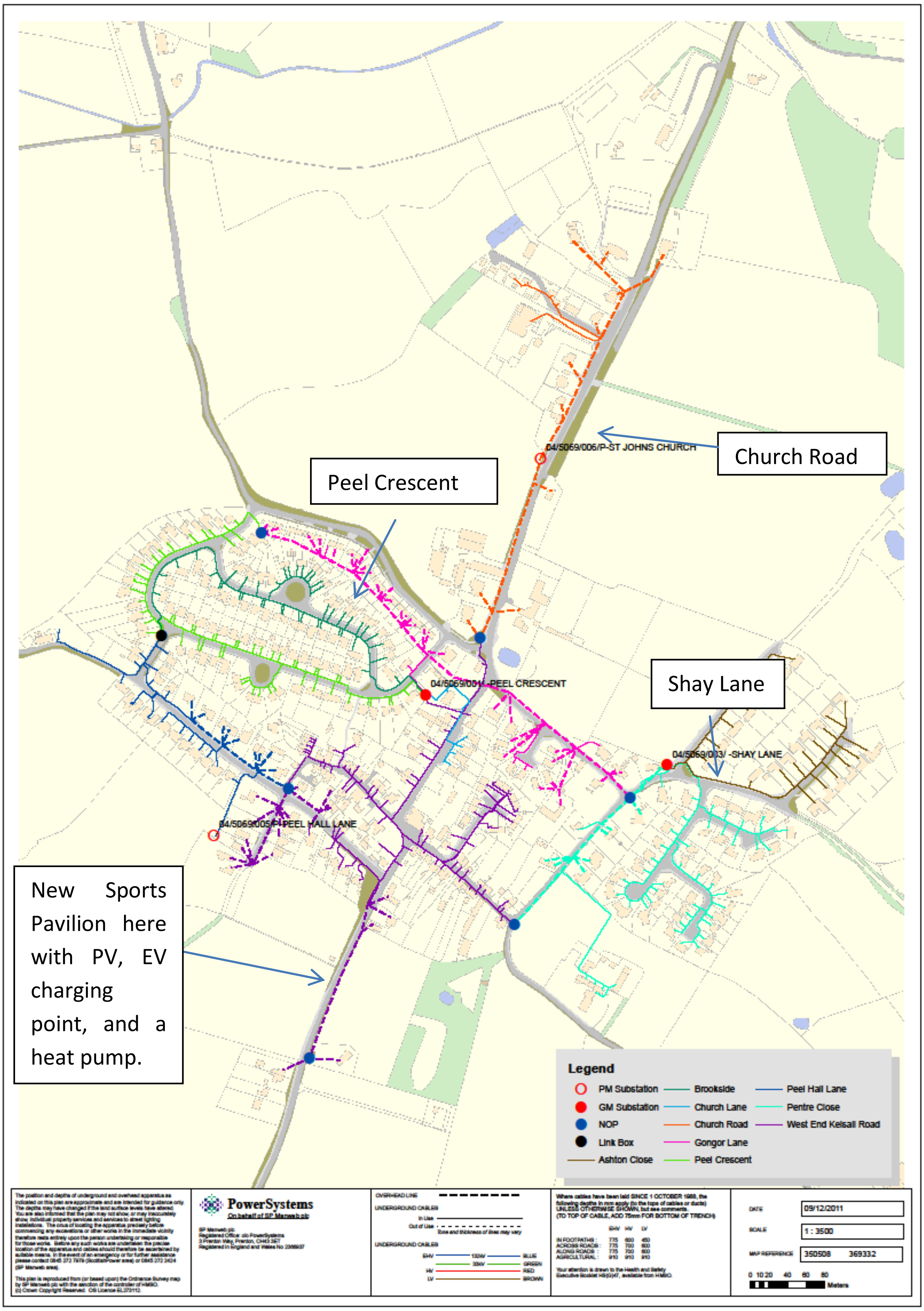


Figure 2 Diagram of the electrical network and the substations that were monitored

In the past, residents have been passive consumers but as customers wish to match their load to local generation and become more active in energy management, there will need to be a move to a smarter grid. Customers will need to understand the network and how their actions affect it. DNOs will need to have a relationship with customers and therefore their ability to engage with communities will take on greater importance. Ashton Hayes has a well-established community structures and is already involved in sustainability and was therefore an ideal group for this project to work with.

4.2.2 Why Ashton Hayes was an Ideal Location.

Ashton Hayes' past and on-going low carbon projects meant that SPEN could work alongside existing activity, feeding into and benefiting from it. It has a strong community with existing organisational structures making communication easier. Geographically and electrically it is obviously defined.

Further, while the village is ahead of most communities, others are following its example. It therefore provided an example of the types of activity that will become common place in the next few years. It was an ideal place for a DNO to learn how to work with a community in preparation for when such activities become more commonplace.

The network is rural, and fed by an overhead 11kV feeder which is reasonably robust and of a typical design. There is a mixture of overhead and cable LV feeders, pole mounted transformers (PMTs) and ground mounted transformers (GMTs). There is a range of feeder lengths and number of connections per feeder, making it electrically representative of villages across Great Britain.

4.2.3 SPEN Resourced Investigations

SPEN led the tendering and installation of the monitoring and the collection of the data. They established a known presence and relationship with the community.

An added benefit was the opportunity for Year In Industry students to supplement the day to day support. They worked with SPEN staff on presentation of the data for the community as well as for a technical audience. It gave the students a valuable opportunity to learn, and particular experience of where the future of the industry may be headed.

4.2.4 EA Technology's Role and Skills

EA Technology has developed a long standing relationship with the community having provided technical support for their activities over a number of years. At the same time, they have worked on new technologies and designs for the distribution network since the company was founded. They therefore have a good understanding of both the needs of the community, and those of the DNO. EA Technology provided the introductions necessary for SPEN, on-going engagement support and independent technical analysis.

4.2.5 Engagement with Energy Suppliers

Under the present regulatory framework, the Energy Supplier has the main relationship with the customer not the DNO. It was therefore felt that it was important to gain Energy Supplier involvement. This was particularly the case as it was expected that Energy Suppliers would oversee the roll out of smart meters within the lifetime of the trial and these could be used to facilitate demand side response. Unfortunately, despite engaging with a number of Energy Suppliers the development of a strategy for smart meters was too immature for Energy Suppliers to actively engage with the project.

4.3 Areas of Work

Throughout the project the work fell into three categories:

I. Community Engagement
II. Network Monitoring
III. Data Analysis

4.3.1 Engagement with the Community

This area of work developed learning on how best to engage with a community. The process demonstrated the benefits and cost savings to the DNO as a result of customers understanding the DNO's role and the challenges for the distribution network. At the same time it also demonstrated how the community could learn how working with the DNO and changing their behaviour could help them achieve their aspirations to develop the village in a sustainable manner.

Note that in this instance, there was a community 'pull' for the project, which was an important factor in its success. Residents understood that they needed to engage with technical aspects of the project in order to develop their Going Carbon Neutral project further, even though they were unsure of the solutions required.

4.3.2 Monitoring

This activity involved gathering data to enable analysis of the demand on the network, load profiles, voltage profiles and unbalance. It also provided the information to raise awareness and provide feedback to the community. As well as the data gathered, the activity was essential to learning how to install the equipment and its technology readiness. During the trial, experience in managing problems with the hardware and software was gained. Procedures for sending data to relevant parties who needed to store and manage it were also improved. This activity was essential for understanding demand curves voltage profiles at LV and for carrying out analysis on the impact of new low carbon technologies.

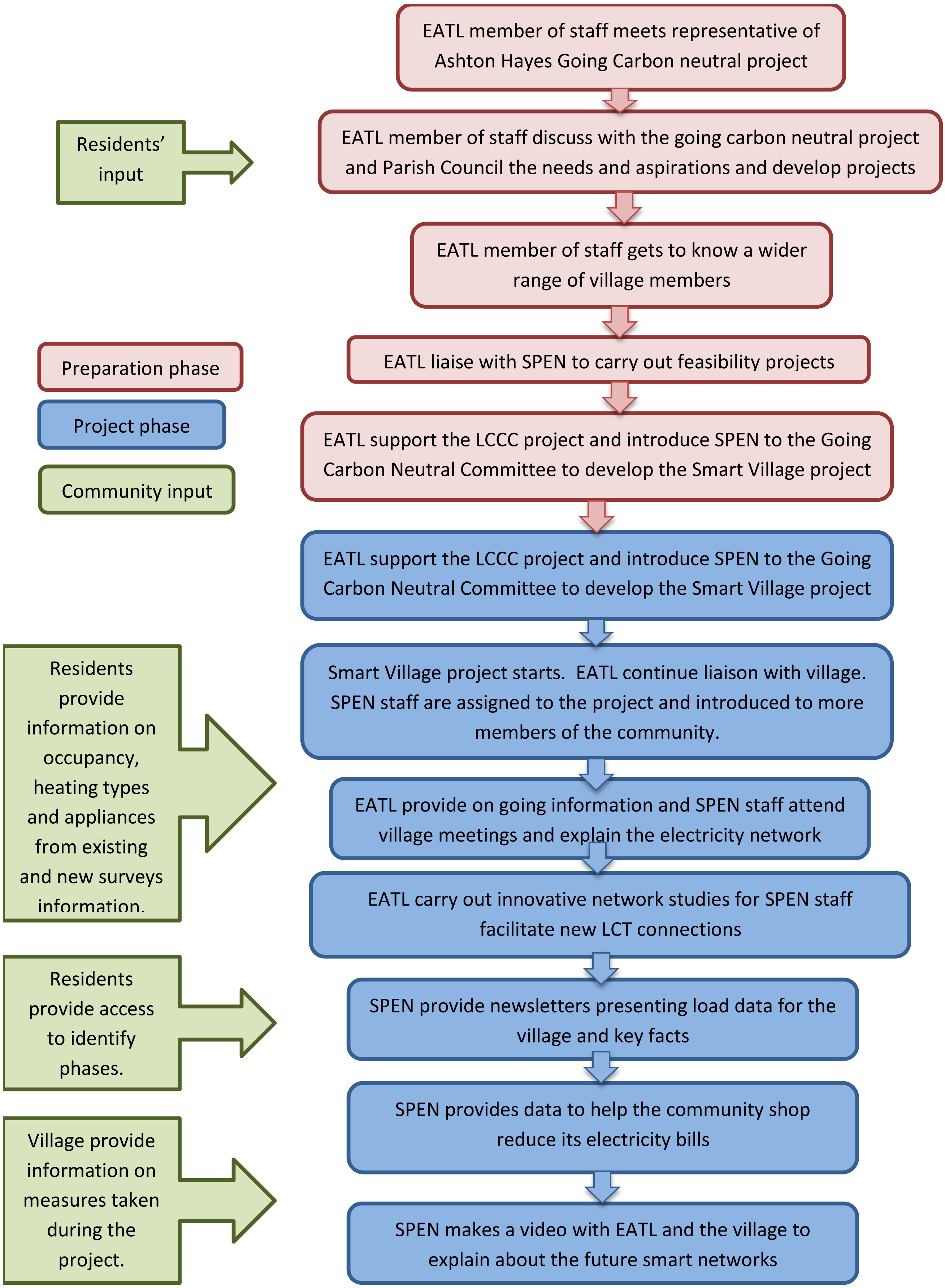
4.3.3 Analysis

The analysis was carried out by EA Technology and SPEN. The aim was to draw out results and recommendations that could be checked on a larger scale during Tier 2 LCN Fund trials, in particular 'Flexible Networks for a Low Carbon Future', for their validity and range of application. The analysis used the information from the monitoring and from the community.

4.4 Engagement Process

4.4.1 Flowchart of Process

The flow chart overleaf gives an overview of the engagement process through time before and during the project.


EATL member of staff meets representative of Ashton Hayes Going Carbon neutral project
Residents' input
EATL member of staff discuss with the going carbon neutral project and Parish Council the needs and aspirations and develop projects
EATL member of staff gets to know a wider range of village members
Preparation phase
Project phase
Community input
EATL liaise with SPEN to carry out feasibility projects
EATL support the LCCC project and introduce SPEN to the Going Carbon Neutral Committee to develop the Smart Village project
EATL support the LCCC project and introduce SPEN to the Going Carbon Neutral Committee to develop the Smart Village project
Residents provide information on occupancy, heating types and appliances from existing and new surveys information.
Smart Village project starts. EATL continue liaison with village. SPEN staff are assigned to the project and introduced to more members of the community.
EATL provide on going information and SPEN staff attend village meetings and explain the electricity network
EATL carry out innovative network studies for SPEN staff facilitate new LCT connections
Residents provide access to identify phases.
SPEN provide newsletters presenting load data for the village and key facts
SPEN provides data to help the community shop reduce its electricity bills
Village provide information on measures taken during the project.
SPEN makes a video with EATL and the village to explain about the future smart networks

Introduction to Community and Key Organisation

Engaging with a community is more effective if existing organisations are used rather than operating from a 'cold start'. Such organisation could be a Parish Council, Local Development Trust, Community Centre or similar.

Within the village, activities that have the goal to achieve carbon neutrality as a main driver were initially led by the Going Carbon Neutral Committee that was a sub-committee of the Parish Council. Once community-owned renewable generation was installed, Ashton Hayes Community Energy Community Interest Company was established to own and maintain the assets. A representative of the Parish Council sits on the board as does a Trustee of the Ashton Hayes Sports and Recreation Association (AHSRA) and representatives from the Community Shop, the primary school and church (

Figure 3). The strong level of accountability was important to ensure that the project had the full support of a community. These were key organisations because:

- The school is where community owned PV is installed
- Ashton Hayes Sports and Recreation Association own and manage the low carbon sports Pavilion where community owned PV is installed and the electric vehicle charging point is housed
- The Community Shop needed to reduce its demand
- The church was keen to reduce its demand

In addition the Women's Institute and Village Hall acted as nuclei for gatherings of the community and dissemination to those not actively involved in the project.

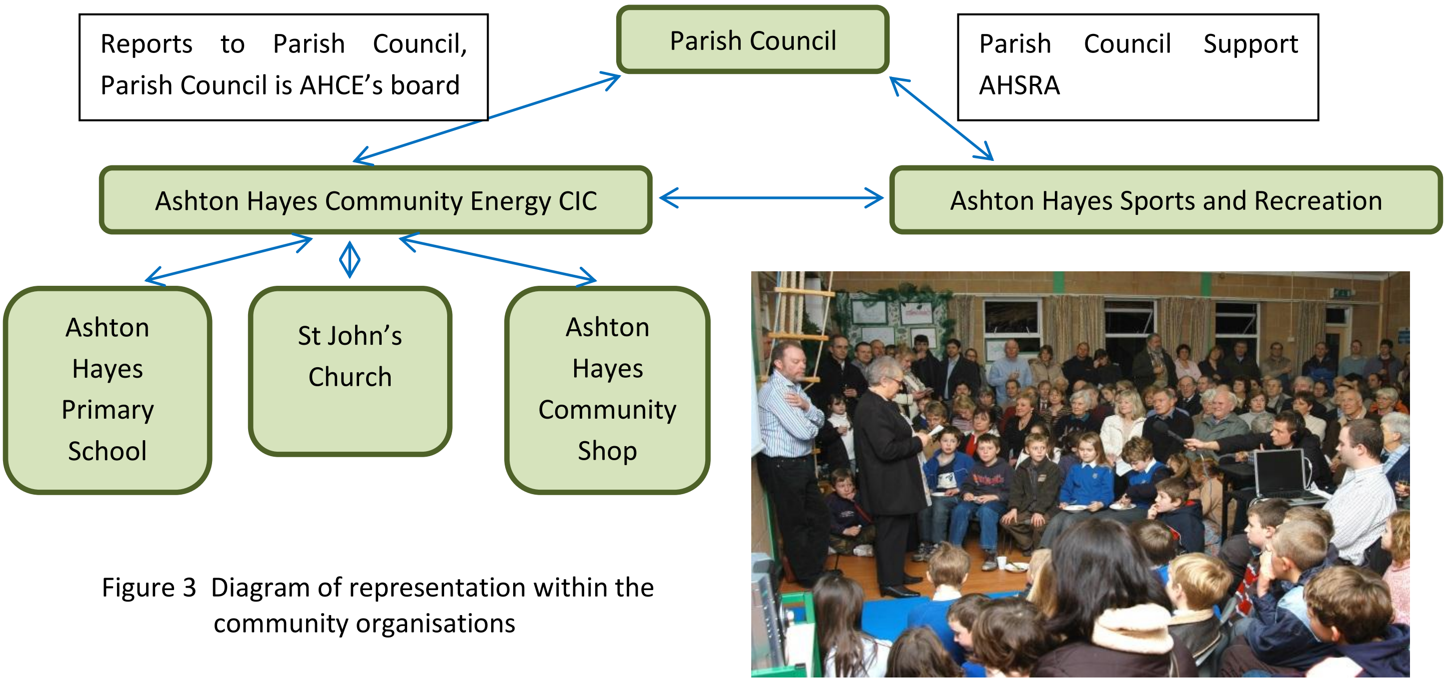


Figure 3 Diagram of representation within the community organisations

Representatives of AHSRA, the shop, church and school on AHCE's board

SPEN were first introduced to the Going Carbon Neutral Committee. As the project developed they met other members of the community both informally and at meetings, and presented on a number of occasions. . To gain as wide an audience as possible and to use the community's time efficiently, the project presented at meetings that incorporated other aspects of village life for example, the development of the Neighbourhood Plan or a meeting for the community shop.

Within these organisations, there were the following essential skills.

- Organisational skills to run a project,
- Individuals who were trusted within the village
- Understanding of finance
- Skills to communicate with wider members of the village community

4.4.2 Range of Communication Media Used

A range of communication media were used to provide information in an accessible format to as many people as possible. These included:

- **Newsletters** that interpreted the monitoring data and provided updates on the activities of the Smart Village project. These were posted on a website and copies were made available around the village, on notice boards and in the shop. See **Appendix A 'Community Reports' for the Ashton Hayes Quarterly reports and Community shop report.**
- **Presentations** at meetings for the Going Carbon Neutral project or for Parish Business incorporated presentations from SPEN or EA Technology. See **Appendix A 'Community Reports' for the Community presentations.**
- **Face-to-face dialogue** via Mary Gillie from EA Technology and Geoff Murphy from SPEN. These were the key contacts for the village so residents knew and recognised them. SPEN staff who carried out work on the network took the time to explain to passers-by what work they were doing.
- A **diagram of the network** showing how residents are connected to the network was circulated at meetings and in newsletters. This allowed residents to understand where their power was drawn from and how faults might be managed (Figure 2).
- A **poster** describing the project was printed and put up on a number of noticeboards around the village.
- **Case studies** were developed, e.g. the village shop highlighted that its electricity bill was high. SPEN installed a monitor and provided reports to help the shop make decisions on how to reduce its bills. See **Appendix A 'Community Reports' for the Ashton Hayes Quarterly reports and Community shop report.**
- **Leaflet drops** to homes.
- **Video footage** was taken by the village together with SPEN to document how they had worked together and how communities can help themselves by working with DNOs (description and link in section 5.1.1).

Whilst some techniques engaged with more residents than others, the range helped ensure the project reached as many people as possible.

4.4.3 Surveys and information Received from the Village

By engaging with the community, a level of trust was created that meant the community was willing to provide further data to the Smart Village project to aid the analysis. Some of this was obtained by additional survey work whilst other information had been gathered for previous activities. Information obtained included:

- **Appliances survey.** Residents were asked what appliances they had in their houses. This enabled ownership in Ashton Hayes to be compared to the national average. The ownership levels were used to adjust the parameters within a domestic load model to improve its accuracy (section 5.3.4.4). The importance of this information was not understood at the start of the project and could only be gathered with the collaboration of the village. It was used to develop more accurate models of the load profile and understand the potential for Demand Side Response at a domestic level.
- **Phase connections**. The phases of connections were not known. Residents gave access to their homes to check the connection phase and hence determine whether connections were balanced. Unfortunately not enough residents were at home for a significant sample. However, an understanding of the level of unbalance was useful.
- **Occupancy levels of homes.** The village had information on the occupancy levels of homes. This helped improve the accuracy of the domestic load model by using actual rather than estimated values for the village (section 5.3.4). It was used to develop more accurate models of the load profile.
- **Heating types**. The village had information on the heating types of homes. This helped improve the accuracy of the domestic load model by using actual rather than estimated numbers of electric heating installations for the village (section 5.3.4.4). It was used to develop more accurate models of the load profile and understand the potential for Demand Side Response at a domestic level.
- **Survey of actions taken.** During a village festival in July 2013, the Going Carbon Neutral Project surveyed what actions residents had been taken as a proxy for increased awareness (section 5.1.4).

4.5 Monitoring

Each of the four transformers was monitored. Information from the Sports Pavilion was also available. Table 1 shows the range of number of connections and the type of transformers. This provided the opportunity to investigate the impact of the number of customers and non-domestic connections on load profiles.

Table 1 Description of the substations monitored

Station name	Peel Crescent	Peel Hall Lane	Shay Lane	St John's Church
Capacity	500kVA	100kVA	200kVA	100kVA
Approximate number of connections	246	27	75	24
Type of connections	Domestic with some community facilities	Domestic	Domestic	Domestic with some community facilities
Type of TX	Ground mounted	Pole Mounted	Ground Mounted	Pole Mounted

The measurements taken per phase were:

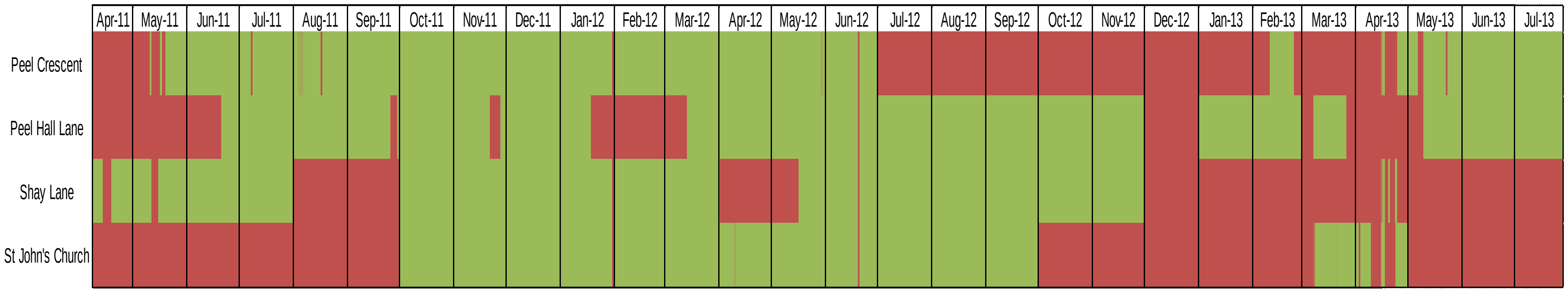
- Apparent, real and reactive power
- Voltage
- Power factor

Information from the Sports Pavilion gave the voltage at the end of the feeder as it is the last connection.

The community shop was monitored from July 2012 to October 2012 to provide information to help decide how to reduce its energy consumption.

The monitoring was not always successful and a number of failures or lost data were experienced over the monitoring period. Table 2 shows the times when monitors failed (red is a failure, green is operational). Note that whilst there were significant times when the monitors were not operational, each of these periods was the result of a single fault that took time to fix, including getting a team to the site. In some cases it was difficult to determine whether it was a hardware or software problem and therefore more than one visit to site was required, taking more time to schedule. Furthermore a move from daily to monthly data retrieval meant that some faults took time to detect. It is reasonable to assume that if the software and hardware bugs are all fixed and new bugs not introduced, the performance will be greatly improved. Note, the monitors were not failing intermittently, which operationally would have been harder to manage.

Table 2 Periods when monitoring was operational/unavailable at each location



4.5.1 Tender Process for the Monitors

SPEN decided early in the project to over specify the requirements for monitoring the LV network as prior to this activity being undertaken it was not known what level of performance would be sufficient to fully analyse the network. To this effect, a specification was produced that contained elements from a similar specification for 11/33kV power quality monitors; with the major changes being the requirements for the monitors' housing and physical connections to the network. It was also decided that for this project that it would be sufficient to monitor the entire load at each substation and not the load on individual feeders. This decision greatly simplified the installation process and kept the monitoring costs down significantly.

Upon the creation of the specification (**see Appendix B 'Monitoring Specification'**) SPEN circulated it to several manufacturers known to provide power quality instruments. The resulting bids/proposals received were then assessed on technical and commercial grounds and the preferred vendor was awarded the contract.

4.5.2 Specifications for Monitors

The company winning the tender for monitoring equipment, eMS originally supplied 4 sub.net systems for monitoring the four LV transformers that feed Ashton Hayes in January 2011. These used the IMVC-LV input modules and 3 phase Rogowski coils supplied by SPEN. Each sub.net emailed a daily power trend report to a number of users which included the source data files in CSV format. A GSM wireless modem was used to send the reports and to allow remote access to the sub.nets.

4.5.3 Data Flows

The large quantities of data involved and the number of discrete packages of data which it was necessary to keep organised called for standardisation and automation of the analysis processes. This initially involved the repeated use and adaptation of templates for each type of report, but was developed into a tool for use in further LV monitoring projects.

As the time periods being analysed and the data sources being compared grew larger over the course of the project, it became more efficient to write scripts to pull out the required subsets of data, to generate charts and to combine them into reports. This process was used and benefited the SPEN LCN Fund Tier 2 project 'Flexible Networks for a Low Carbon Future' where the amount of data was much larger and had to be handled automatically. Combining these scripts into a single application for data storage, extraction and analysis resulted in a system which permitted much quicker analysis of data and is currently being applied within the above mentioned project.

This system is based on Microsoft Access and Visual Basic for Applications. There is a front end Access application, of which each user has a copy. This accesses a central repository of information about all of the substations in which monitors have been installed, including the product used to monitor the substation, identifiers for the substation in other IT systems, the configuration of feeders being monitored at that substation and the format of the data files outputted at that substation.

Each substation has a file on the network which contains all the data recorded by that device which has been uploaded to the system. These files can be opened to view and export data directly, but generally would be viewed indirectly through the front end.

The front end itself pulls in all the data it needs to generate analyses from these two sources. The analyses are then carried out using Excel templates and transferred into a Word output file.

The knowledge gained through data processing during the Ashton Hayes project not only fed into this internal tool. By observing what types of analysis and what functionality SPEN has chosen to implement in its data processing and presentation tools, the IT systems partner in the Flexible Networks project, Nortech Management Ltd, was able to start developing new data management offerings for use by several UK DNOs. These developments will mean that in future, LV network monitor data will instantly be available in an analysed format, with no work required by the DNO.

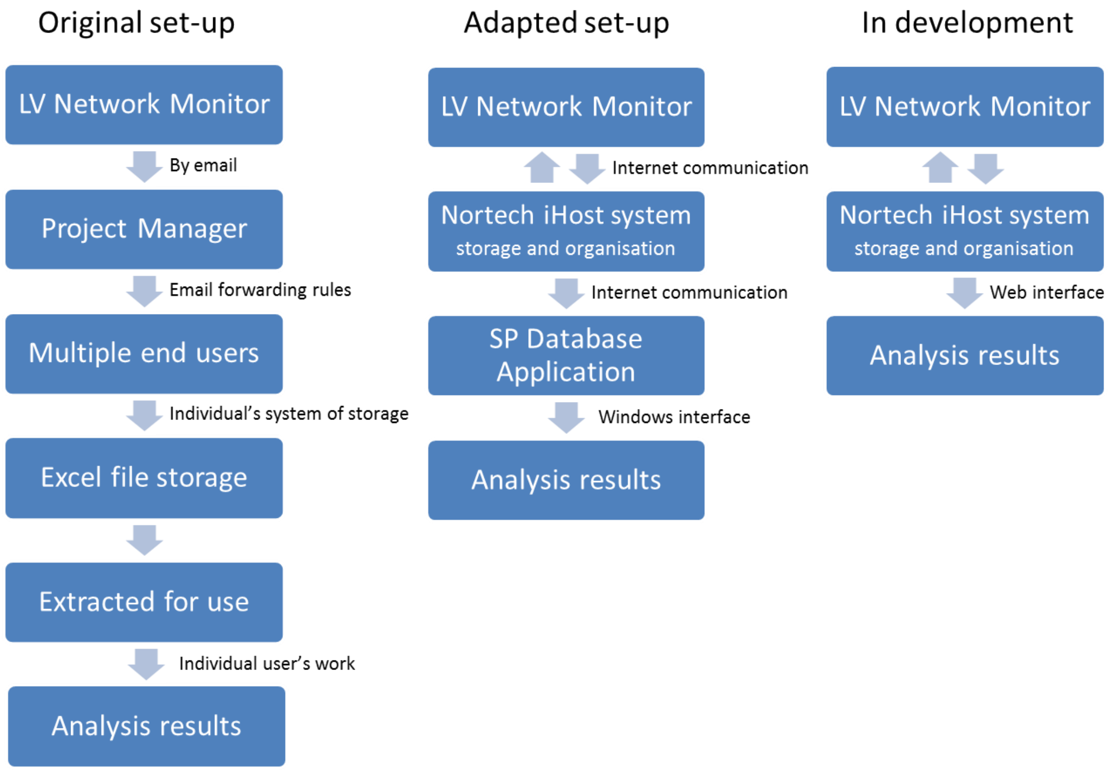


Figure 4 Diagram of the development of the data collection process

4.6 Analysis

SPEN developed a range of presentation formats for presenting the monitoring data to different audiences. This information was fed into an iHost data collection system developed outside the project. They extended a DIgSILENT PowerFactory model and carried out network studies that support work carried out by EA Technology on:

- The potential for Demand Side Response using domestic appliances to manage local network constraints and the incentives required.
- A new planning approach using the monitoring data
- The additional capacity available using real time thermal rating for transformers
- Model customer behaviour and energy profiles
- The impact of ownership and utilisation patterns of electrical appliances
- A probabilistic approach to estimating minimum and maximum after diversity loads and voltage

As Demand Side Response could only be investigated in a desk top exercise and not demonstrated on the ground, the potential for using Real Time Thermal Ratings for distribution transformers was investigated.

The data is now available on line. During the project, data was also sent to the following institutions for analysis:

- The project 'Investigation and monitoring of the estimation of after-diversity minimum demand on LV Feeders' carried out under the Strategic Technology Programme funded by all UK DNOs used the data in studying minimum demand.
- Andy Wright of De Montfort University used the data in an application for an EPSRC funded project to study at power factor at LV and possible ways of improving it.
- Peter Boait of Exergy Devices used the data in developing a system to detect small scale DG from network data.
- David Parra Mendoza, a PhD student at Nottingham University, used the data in studying applications for storage.
- Dr Gareth Harrison of the University of Edinburgh, used the data for research into load profiles for an EPSRC project called ARIES (Adaptation and Resilience in Energy Systems) that is looking climate change impacts and adaptation in the electricity and gas systems. This is being undertaken in collaboration with Heriot-Watt, National Grid, ETI, the Scottish Government and Scottish Power Renewables.
- The Sustainability First study on the potential for DSR to benefit the distribution network at LV.

4.7 Dissemination to Third Parties

A range of other dissemination processes were used to raise awareness and pass on the knowledge gained from the project. These included:

- A 2011 CIRED paper 'Community Energy from Policy to Practice'[7] helped raise awareness across the globe within the industry sector. The conference provided a useful venue to discuss the project and compare outcomes with similar work being carried out internationally. See **Appendix C 'Dissemination Material' for the CIRED Paper**.
- Data was used in the paper 'The Future for EVs: reducing network costs and hassle' for HCEV 2013. This was published November 2013.
- SPEN made a presentation to the Local Cheshire and Warrington IET branch.
- The project was a finalist in the IET Innovation Awards under the sustainability category. See **Appendix C 'Dissemination Material' for the IET Award**.
- Presentations were made at LCN Fund conferences and to Ofgem. – **Appendix C 'Dissemination Material' for the Ashton Hayes Smart Village Ofgem June 2013x.pdf**
- The project was referenced at The Women's Engineering Society Conference, Harnessing the Energy, 'Why We Need Community Energy' Friday 4th October 2013

[7] Community Energy from Policy to Practice', M Gillie, R Alexander, D Roberts, Proceedings of CIRED, Frankfurt June 2011

5 The Outcomes of the Project

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Key Lessons:

15. Learning how to engage effectively with customers may save time and costs in other parts of the business (such as the cost of reinforcement and time spent on network planning). Engaging successfully requires the DNO to adopt an approach unlike any other used in the business. It has to be more flexible and understand that the community is made up of volunteers whose level of engagement may fluctuate and that plans may be susceptible to change.

16. The community can benefit from working with the DNO. Better understanding the DNOs role and operating methods can help a community achieve its own goals. However, it is important to manage expectations of what a DNO can provide a community and be consistent in the messaging.

17. While proxy indicators such as anecdotal evidence suggested that the focus on engagement produced very positive results, it is difficult to measure the impact more rigorously and effected by factors outside the control of the project. If it is deemed important to capture

costs and benefits of engagements then the project needs to be designed with this in mind from the outset.

18. Actual load data demonstrated that non time dependant models that simply allocate an after diversity demand to each connection under estimate available capacity. Actual available headroom for renewable generation was found to be more than existing planning processes assume, thus facilitating a reduction in the carbon footprint of the community. Desk top analysis showed that the scope for DSR is significant (around 7.5 – 10% of the total during peak hours) and will increase as buildings become more energy efficient.

The outcomes of the project can be split into three areas:

I. Community Engagement
II. Network Monitoring
III. Data Analysis

5.1 Engagement

The community engagement aspects of the project provided SPEN with an understanding of what is required for successful engagement with a community. A generic flow diagram of the process was developed to capture the process adopted, enabling its duplication elsewhere.

The project demonstrated that while it takes time and effort to establish a trusting relationship, longer term it may save the DNO time and cost in other parts of the business (such as cost of reinforcement and time spent on network planning).

The community also benefited from the process; developing an understanding of the network and the role of the DNO, increased visibility of their load (enabling them to make better informed decisions about reducing consumption) and an understanding of the potential for Demand Side Response.

A video made with the village describes the role of the DNO and underscores the need for communities to work with DNOs to find solutions to their needs. The video was designed for dissemination to other communities.

The project also gave an opportunity to gauge the impact of engagement. Measuring the impact of engagement within Ashton Hayes however was proven to be very difficult because the outcomes can be intangible and there are a number of drivers from inside and outside the project that change people's behaviour and attitudes. In addition Ashton Hayes was already a very aware community and therefore most of the 'quick hits' in terms of efficiency and behaviour change had already occurred. The impact might therefore be less than in the average community.

Nevertheless there are proxies that can be used to evaluate the impact, albeit sometimes indirectly or qualitatively. These are:

- Anecdotal reporting from community members of their awareness.
- Awareness of the Parish Council.
- Actions taken by the shop
- Evidence from surveys of actions taken by individuals regarding energy use and generation.

These are discussed in more detail in the sections below.

5.1.1 Generic process

DNOs may wish to engage with a community:

- To facilitate alternatives to costly reinforcement and awareness raising activities
- When there is a community need that requires working with a DNO to deliver a solution.
- For field trials

From the engagement activities before and during the project, the following flow chart was developed showing a generic engagement process that could be used during business as usual or other trials. Note that where existing organisations are not present, time is required to develop suitable entities. There may be organisational, financial or communications skills lacking within a community in which case outside organisations may need to be involved to provide these.

Note, it is important to understand the lines of accountability for each organisation involved to ensure a project has the support of a broad range of people within a community. Further groups need to be contacted if accountability is not sufficiently broad.

It takes time and effort to establish a trusting relationship. Face to face meetings are essential, especially as the outset, to build up mutual understanding, and it is beneficial for the same staff to regularly attend community meetings. Other communications, such as, information from monitoring and posting on websites, can be streamlined. A broad range of communication media is required as otherwise sections of a community may be missed.

Whilst this exercise may be costly, it may save time and cost in other parts of the business (such as cost of reinforcement and time spent on network planning).

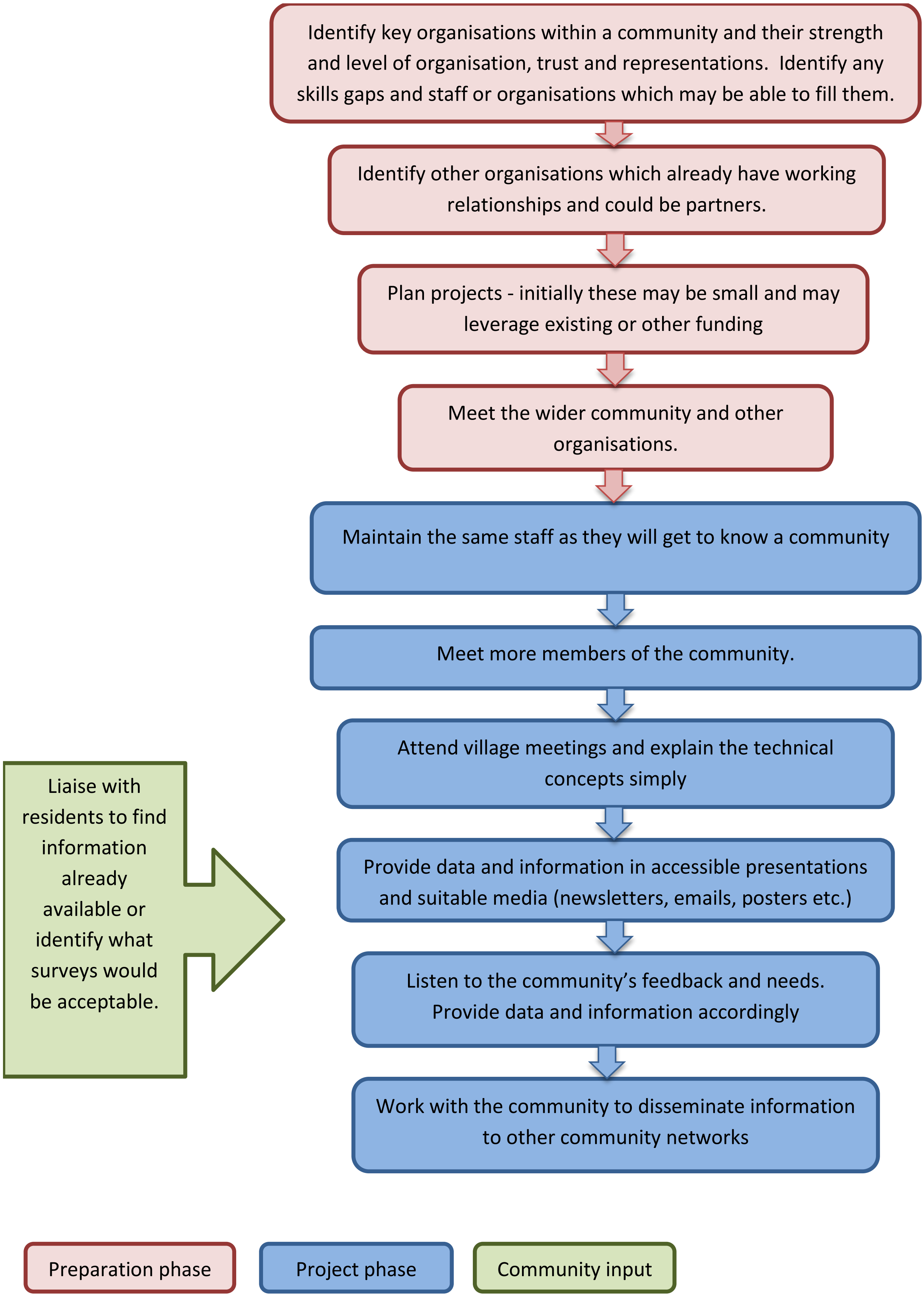
For further field trials, the engagement process can be included within NIA or NIC funding and may complement other funding available to a community itself. For business as usual processes, funding engagement or customer 'surgeries' may avoid reinforcement and be more cost effective.

5.1.1.1 Overview of the DNO's Role

A video made with the village could be used to help explain the role of the DNO to other communities. It is available at http://www.spenergynetworks.co.uk/innovation/ashton_hayes.asp?NavID=3&SubNavID=1

5.1.1.2 *Management of Expectations*

It is important to manage expectations of what a DNO can provide to a community and keep a consistent message. Providing new information and activities will help maintain momentum. However, due to the time required for fundraising, development for projects and limited time available to volunteers, there are peaks, troughs and changes in activities. DNOs have to anticipate and accommodate this in project planning and execution.


Identify key organisations within a community and their strength and level of organisation, trust and representations. Identify any skills gaps and staff or organisations which may be able to fill them.
Identify other organisations which already have working relationships and could be partners.
Plan projects - initially these may be small and may leverage existing or other funding
Meet the wider community and other organisations.
Maintain the same staff as they will get to know a community
Meet more members of the community.
Attend village meetings and explain the technical concepts simply
Provide data and information in accessible presentations and suitable media (newsletters, emails, posters etc.)
Listen to the community's feedback and needs. Provide data and information accordingly
Work with the community to disseminate information to other community networks
Liaise with residents to find information already available or identify what surveys would be acceptable.
Preparation phase
Project phase
Community input

5.1.2 Awareness of the Distribution Network in the Community and by the Parish Council

It is difficult to measure the additional level of awareness of the distribution network that the project has brought about. However, individuals report that they now understand the role of the DNO much more clearly.

One proxy to indicate this increased level of awareness is the activities of the Parish Council. The Parish Councillors report that they are now aware of the potential implications for the electricity network of new developments in the village. They therefore take this into account when considering new developments. For example, at present the Parish Council is developing a Neighbourhood Plan and has asked for details of the local network and demand from the village to include within it.

Roy Alexander, Director of AHCE, lives in the village and has worked on surveying residents' activities and awareness from the outset of the Going Carbon Neutral Project. He commented on how useful the information from the monitoring is to the village.

I think the value of SPEN's monitoring to us has been considerable.

The first time we've had a real picture of total electricity use in the village;

very useful reports to the community that have helped keep things in people's minds and kept the behaviour change flag flying with lots of suggestions about what to do and what it would save - pity we can't do the same for Gas!;

……it gives us a realistic picture of what we've achieved so far and, more importantly perhaps, an idea of the scale of what we still need to do.

It would be excellent if there was some way to keep at least some of the monitoring going.

5.1.3 Reductions in Power Use at the Shop

The community shop was experiencing high energy bills. The awareness from the project highlighted to them that there may be ways that they could reduce their consumption. As a result they approached the project for assistance and the electricity profile of the shop was monitored to help identify what was causing the heavy demand by studying the usage by time of day.

This analysis identified that the shop had a very high standing load outside of its normal opening hours, and whilst there were significant peaks in the daily profile the shop would reap the biggest reduction in their consumption by tackling the appliances and lighting that were left on overnight. A site survey carried out by the project team, several residents and the shop manager identified the main issue as being the large number of chillers in the shop that as well as being high consumers of electricity were also raising the shops ambient temperature forcing the air conditioning unit to work much harder and consume even more electricity. The survey also identified a series of external halogen lights that were on 24 hours a day, through the identification of their power source and the introduction of a timer the shop was able to make an instant and significant reduction in their consumption. At the time of the projects close the community shop was looking into the rationalisation of the number of chillers it ran with as well as systems for extracting the heat they generated. **See Appendix A 'Community Reports' for the Ashton Hayes Quarterly reports and Community shop reports.**

5.1.4 Results of the Survey of Measures Taken

A survey of some of the residents was carried out during a village fete (Table 3). Whilst a small sample of 63, it was indicative of the types of measures undertaken during the project and demonstrated an awareness of the possibilities amongst residents. Other events and activities helped raise awareness alongside the Smart Village project. Whilst the data and interviewees are not the same, some comparisons can be made with a survey of 68 residents in 2010 and 52 residents in 2009. 2009 serves as a base line. The figures for 2010 are the increase in actions taken by residents after the Going Carbon Neutral project started. This shows the impact of the awareness campaign before the LCN Fund project started and the potential benefit to DNOs of such activity in lowering demand.

Table 3 Measures taken by individuals by 2009, 2010 and 2013 - % increase.

Item	2013 (% increase)	2010 (% increase)	2009 (% use)
Energy savings light bulbs	6.88%	14.06%	12.81%
Loft insulation	3.75%	n/a	11.25%
Cavity wall insulation	2.19%	n/a	9.38%
Solid wall insulation	0.63%	n/a	0.94%
Double glazing	4.06%	n/a	11.25%
Condensing boiler	3.44%	n/a	4.69%
Electric/hybrid vehicle	0.31%	n/a	n/a
Energy display monitor	0.63%	n/a	n/a
Purchased A+ appliances	3.13%	n/a	n/a
Green Tariff	1.25%	0.63%	n/a
Turn off lights	n/a	12.50%	n/a
Don't use stand-by	n/a	10.63%	n/a
Wash laundry at 30 degrees	n/a	10.00%	n/a
Dry laundry outside	n/a	9.06%	n/a

Other PV arrays have been installed but were not recorded in the survey. Given some of the arrays are at the backs of homes, it is difficult to identify all those installed. For others, estimating the capacity can be difficult.

5.1.5 Awareness of the Potential of DSR

Some residents now report increased awareness of the concepts of Demand Side Response and Smart Metering. Charging the electric vehicle at the Pavilion using power from the photovoltaics or using a cheap tariff at night highlighted the concept. Unfortunately without smart meters or an energy supplier involvement it was difficult to take this work further.

5.1.6 Technology Readiness Level

A TRL for community engagement is not appropriate as these activities involved human interaction and communication rather than a technology.

5.2 Monitoring

Key results from the monitoring were:

- Insight into the demand curves.
- Development of the equipment during the trial upgrades including debugging.
- Better understanding of the level of development and present reliability of the monitoring equipment and the ease of installing it.
- The Technology Readiness Level for monitoring was 8.

The improvements in the monitoring and understanding of installation have already been used in LCN Fund Tier 2 projects and could be adopted as part of normal working practices.

5.2.1 Insight into Demand Curve

The data provided valuable information on consumption and voltage levels. With the data from the community on occupancy, heating types etc., academic institutions (section 5.5) who used the data commented that it was some of the most detailed LV demand information available on this scale and measurement frequency to date. The awareness raised using the data is documented in section I and use of the data in the analysis is documented in section 5.3.

5.2.2 Development of the Monitoring Equipment

The systems were installed and commissioned from March to October 2011. During the period of the project some of the reporting parameters were changed to optimise the data volume. At this time eMS were also involved with a number of other LCN Fund LV monitoring projects. These led to a number of improvements in the sub.net platform:

- Creation of a new product specifically for LV monitoring
- External I/O; allowing a single sub.net to monitor up to 12 circuits
- Support for 1 minute trend measurements; the original was 10 minutes
- Support for snapshot mode in DNP3

These enhancements allowed a wider range of measurements at a greater 'granularity' for analysing the variations in load and the contribution of generation on different feeders or (when required) at a higher frequency of measurements.

Sub.net has a function to remotely upload firmware with the new functions. One of these versions had a fault which eventually caused the system to halt. The repair procedure was initially successful but a second site visit was required to finally resolve the problem. Time was needed to schedule qualified staff to visit the site especially as other emergency work had to take precedence. Together these issues caused a significant loss of available data from June 2012. The reduced system reliability is traceable back to the firmware problem. There were other short-term data losses due to configuration changes and issues with the communications.

5.2.3 Reliability

Section 4.5 shows that while reliability increased under the project, there remained room for improvement. Section 4.5.3 identifies the problems, many of which were resolved. However, compared to the quality of the readings provided during the IFI 706 project in 2008, the data is more readable and more easily retrievable, demonstrating an improvement.

There were a few readings that indicated problems with the network which on further investigation may not be 'real'.

5.2.4 TRL Level

The monitoring equipment utilised by this project was an established product used throughout the industry. However, until this and other LCNF projects it had not been utilised on LV networks to any great extent. With this project the monitoring systems performance was tested for this specific application. The TRL for the monitoring activities undertaken remained at 8 throughout this project.

5.3 Analysis

The key findings for each area of analysis are:

- The potential for DSR
- The implications of the load and voltage profiles and network models,
- The impact of customer behaviour
- The additional capacity available from dynamic ratings.

Each individual area of study is useful in itself. However, taking a holistic approach when studying the impact of behavioural change and weather provides even greater insights into the potential benefits for a DNO. Whilst more work is required through further projects, the outputs below can be incorporated into normal working practices.

5.3.1 Network Issues Investigated

The data processing completed by the project was the first work of this kind SPEN had undertaken. Data on both power and voltage in an LV network was not previously available, meaning that there were no established tools or methodology for interpreting the information.

Initial data processing was performed in the context of producing energy usage/carbon output/energy forecasting reports for the village and transformer usage reports for SPEN. Whilst the aims of the community reports were to represent their usage in understandable terms, and provide a platform for observing any reductions in consumption, the technical reports were intended to identify numerous different ways of graphically representing the data and identifying trends. As the project progressed, SPEN determined which charts and graphs were most effective at providing insight into the nature of the loads. Reports from the village calculated the carbon emission from their electricity use and the savings from renewables. Additional graphs and reports were provided to the Shop to help identify the pattern of its energy use.

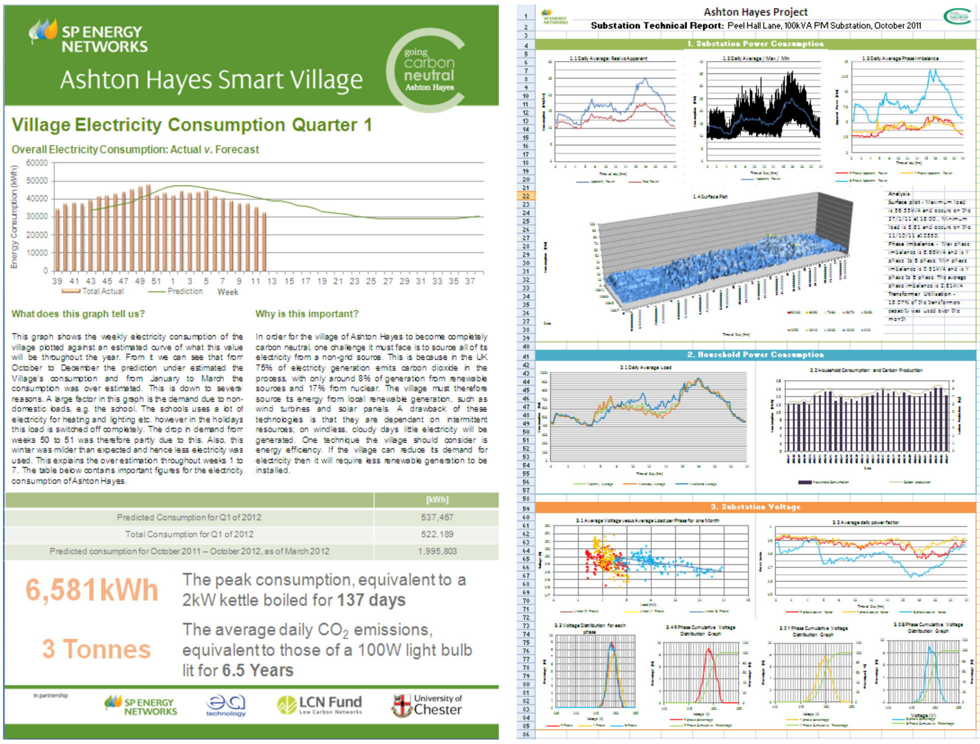


Figure 5 Examples of the graphical outputs for the village and for a technical audience.

5.3.2 Analysis of the Potential for Demand Side Response

With respect to Demand Side Response, the actual load data demonstrated that non-time dependent models that simply allocate an after diversity demand to each connection could underestimate available capacity. The extent of the underestimates depended on the location so further investigation is required.

- The scope for DSR is significant (around 7.5-10% of the total during peak hours) and will increase as buildings become more energy efficient.
- There is scope for DSR with new load such as heat pumps and EV chargers.
- Literature surveys highlighted that financial incentives from suppliers may encourage customers to shift load in a way that will benefit DNOs given that the highest prices on the wholesale market coincide with peak demand.
- Monitoring of new loads helped facilitate modelling of new LV load profiles.

The output demonstrated the potential savings from domestic DSR and how this could be harnessed if the regulatory regime was adapted to allow DNOs to harness DSR more effectively.

The drive to reduce carbon emissions from electricity use has led to a renewed interest in demand side response (DSR) measures particularly for domestic loads. Although in the UK DNOs do not have a direct relationship with domestic customers, there are potential benefits for network operators that were explored. Load reduction or shifting can:

- Reduce peak load to within the thermal rating of the network
- Reduce the minimum voltage that occurs
- Reduce network losses
- Match local generation and load

A literature survey of trials to date from other countries was carried out (mostly where companies are vertically integrated) and the trials were assessed for suitability to be carried out in Ashton Hayes. Unfortunately it was not possible to carry out any of these trials without an energy supplier engaged as recording in house use and incentivising customers is very difficult for DNOs under the Tier 1 framework. Within a Tier 1 project, customer engagement does not extend to installations within a domestic household. Without an energy supplier providing metering data, changes in behaviour within individual households could not be recorded or rewarded. Unfortunately delays in agreeing specifications of smart meters as part of the SMETS 1 / 2 standard meant energy suppliers were reluctant to engage. The size of the project and cost of installing smart meters when still under development also discouraged Energy Suppliers from engaging.

Despite these challenges, the way in which DSR could be used to manage the capacity on one feeder in Ashton Hayes was investigated. A study covering the management of an Air Source Heat pump in a highly energy efficient new sports pavilion and the control of an electric vehicle charger was undertaken to demonstrate how demand could be reduced during the evening peak demand period. This evidence could be used to propose changes to the regulatory framework to allow DSR to be implemented. See **Appendix D 'Technical Reports' for the 'DSM for DNOs' and 'DSM Pavilion final' reports.**

5.3.3 Network Model

A three phase time dependent network was developed for one feeder in Ashton Hayes using load, generation and network profiles. Modelling the village in DIgSILENT demonstrated how monitored data can be incorporated into such a model (**see Appendix D 'Technical Reports' for the Ashton Hayes LV Network Model**). The key learning points were:

- Knowledge of minimum and maximum load, and when it occurs, is required for LV planning in future in order to incorporate new loads and generation. For example, photovoltaics cause a change in profile during the day. Minimum load that occurs during the night is not affected.
- With large amounts of generation, reverse power flow can occur but will not necessarily affect the thermal or voltage constraints of a feeder.
- Models can be built up from domestic profile modelling tools.
- Non-domestic buildings have a significant impact on feeder profile if there are few domestic connections. These are harder to model.
- It may be possible to group loads to reduce model complexity.
- In the case of the photovoltaics at the school, it demonstrated that it is unlikely that there will ever be more than 11kW export as even at the weekend the base load of the school will be close to 4kW. Therefore an alternative to the present capacity limits could be an export limit.

Together these insights provide valuable information for more effective planning of new generation connections at LV and modeling techniques. The information requires validating on a larger scale to ensure it can be applied to a wide range of settings before use in network planning techniques.

5.3.4 Load and Voltage Analysis

Key points from the analysis of load and voltage are:

- A voltage reduction of one tap step could be made at all the substations in the village to allow more generation to connect whilst accommodating load and allowing feeders to be to back fed under fault conditions (able 5).
- Additional renewable generation can be connected when the voltage at the substation is reduced. The benefit of more generation connecting at LV is likely to offset any additional network losses or carbon emissions caused by a lower running voltage. If there is a significant amount of inductive load, the losses may reduce.
- The minimum demand per connection of a feeder is fairly constant, provided that there is more than around 50-70 domestic connections to the feeder, at about 240VA (Figure 6 and Table 4)
- The minimum load per connection at most of the substations is similar for the summer and winter.
- The After Diversity Maximum Demand varies more with the number of connections – between 1.05kVA and 1.65kVA/ per connection.
- The frequency distribution graphs per connection give a good visual means to understand the level of variation in power and by comparing the shape to the frequency voltage distribution, the level of voltage unbalance can be ascertained (Figure 7).
- The impact of reduction of significant loads such as schools at particular times of year on the capacity available for PV should be taken into account.
- The amount of capacity available for generation can be estimated by considering the minimum voltages recorded during 24 hours or during daylight hours. More PV can connect compared to generation in general as it is guaranteed to only operate during daylight hours when the load is higher.
- With the type of monitoring data available in Ashton Hayes greater insight into demand profiles can allow more efficient means to manage thermal overloads.
- DSR is theoretically possible given the numbers of cold appliances and schedulable loads. However, to control these devices automatically, control would need to be retro fitted given the slow change of appliances.
- Ownership of multiple appliances of the same sort (e.g. two freezers) is more common than the model indicated.
- Customers keep old inefficient cold appliances, this increases the base load.
- The model of the feeder load estimated the profile well but gives a lower minimum base load than reality.

The key outputs above provide the information (once verified) to more accurately assess the impact of new generation connections and how to use monitoring data to assess load profiles and unbalance on the network. This can be fed into network planning techniques. Information on customer behaviour provides useful insight into how load profiles may change and how awareness campaigns could reduce demand.

The analysis of the load and voltage recorded during the winter and summer at Ashton Hayes drew key conclusions and learning from the data in the following areas:

- Minimum and Maximum Demand and Voltage
- Using Data in Decision Making Processes
- Implications of Customer Behaviour

For the full reports see **Appendix D 'Technical Reports' for the 'Summer Results 1.2' and 'LV Feeder Final4.0' reports.**

5.3.4.1 Minimum and Maximum Demand and Voltage

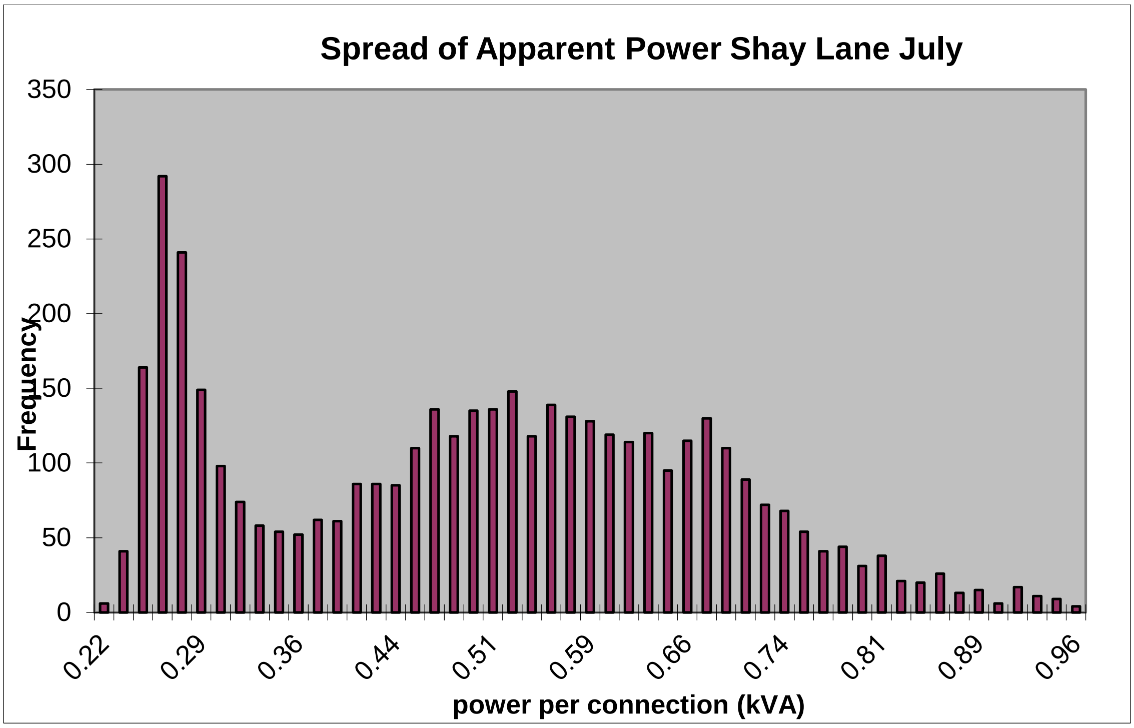


Figure 6 Example of the spread of power at the Shay Lane substation

Table 4 Example of the minimum demand estimations for the different substations

Substation	Month	Number of connections	Min load below which no more than 10, 10 minute intervals occur. (kVA) winter	Min load below which no more than 10, 10 minute intervals occur. (kVA) summer
Peel Crescent	February	230	0.24	**0.20**
Shay Lane	January	74	0.24	**0.23**
Peel Hall	**December**	**27**	**0.34**	**0.34**

able 5 Illustration of the calculations showing the impact of dropping the transformer voltage by one step. Note this assumes a maximum 6% rise above 240V.

Peel Hall	Summer	Volts reduced by 5%. Summer	Winter	Volts reduced by 5%. Winter
Voltage at busbar (V) Estimated via probabilistic approach.	252.8	240.9	243.1	231.1
Voltage rise headroom available (V)	1.6	13.5	11.3	23.3
Generation capacity 3 phase (kVA)	22.0	191.5	159.8	329.4
Voltage drop headroom available (V)	36.8	24.9	27.1	15.1
Load capacity 3 phase (kVA)	442.1	298.2	325.2	181.2

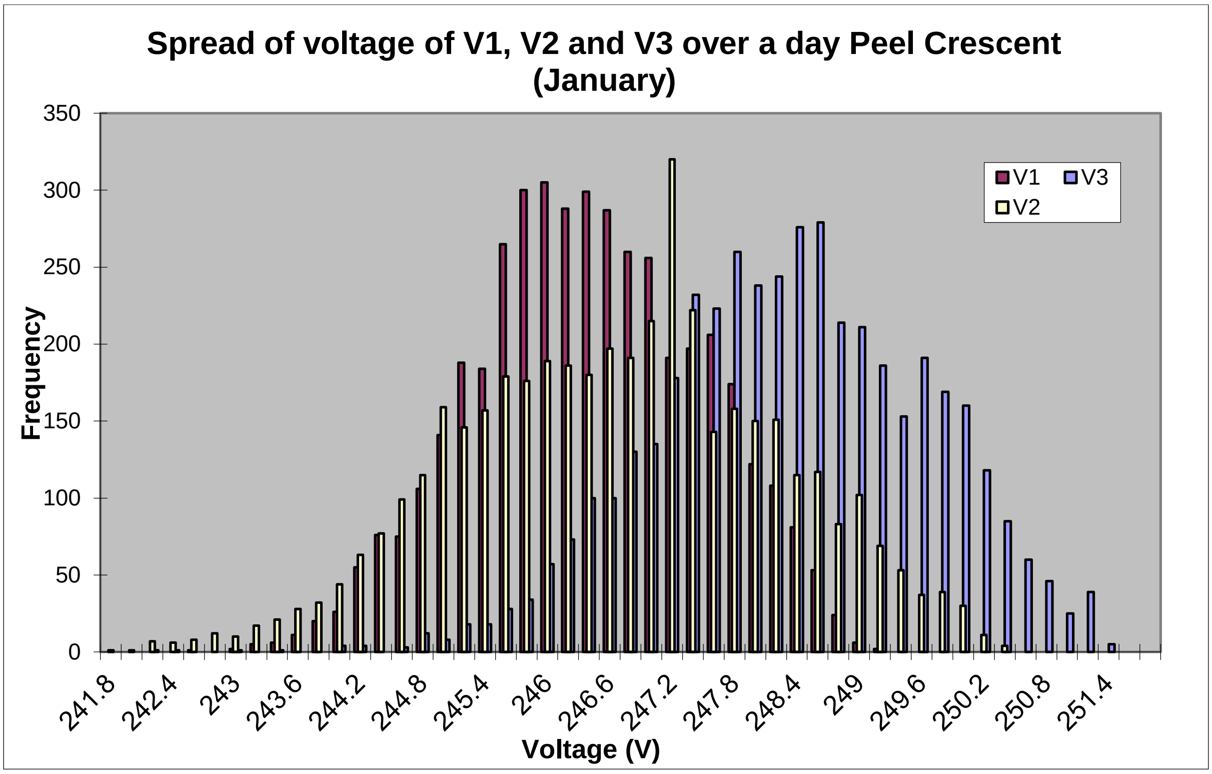


Figure 7 Example of a graph comparing the distribution of voltage on each phase on the Peel Crescent feeder.

- The minimum demand per connection of a feeder is fairly constant, provided that there is more than around 50-70 domestic connections to the feeder, at about 240VA (Figure 6 and Table 4).
- Below around 50-60 connections, the characteristics of the homes has an impact on the patterns of demand.
- The minimum load per connection at most of the substations is similar for the summer and winter. With more connections, due to diversity, the minimum load may be lower in summer than in winter (Table 4)
- Smaller houses seem to have a lower minimum demand but this is yet to be verified.
- The After Diversity Maximum Demand varies more with the number of connections – between 1.05kVA and 1.65kVA per connection.
- Voltage unbalance between phases appears to stay constant from month to month in winter.
- The voltage unbalance on Peel Crescent is consistent between summer and winter and different times of the day.
- The number of connections does not appear to be an indicator of the likelihood of voltage unbalance.
- The frequency distribution graphs per connection give a good visual means to understand the level of variation in power and by comparing the shape to the frequency voltage distribution, the level of voltage unbalance can be ascertained (Figure 7).
- Numerically, from data or from models, load profiles can be represented via the number of connections and the minimum and maximum demand over 10 minutes that is unlikely to

occur more than 10 times in a month. This can be for the whole day or for a period of the day. A similar approach can be used for voltage distributions.

- Larger loads such as a pumping station, pub, shop and school have a material effect on the load profile of the feeder to which they are connected. It is recommended that further investigations are made into the demand from sewage pumps.
- The impact of reduction of significant loads such as schools at particular times of year on the capacity available for PV should be taken into account.
- A voltage reduction of one tap step could be made at all the substations in the village to allow more generation to connect whilst accommodating load and allowing feeders to be to back fed under fault conditions (able 5).
- The amount of capacity available for generation in general and PV can be estimated by considering the minimum voltages recorded during 24 hours or during daylight hours. More PV can connect compared to generation in general as it is guaranteed to only operate during daylight hours when the load is higher.
- The generation connected at LV supplies homes directly with low carbon power. Additional renewable generation can be connected when the voltage at the substation is reduced. The benefit of more generation connecting at LV is likely to offset any additional network losses or carbon emissions caused by a lower running voltage. If there is a significant amount of inductive load, the losses may reduce.

5.3.4.2 Using Data in Decision Making Processes

With the type of monitoring data available in Ashton Hayes greater insight into demand profiles can allow more efficient means to manage thermal overloads. The following decision making process for troubleshooting a thermal overload was developed:

- Gather the load profiles for the months with the highest loading for the problem feeder/transformer and for adjacent feeders/transformers to which load could be shifted.
- Estimate the overload and time of day when it occurs. If possible identify if there are particular problem connections or spurs.
- Estimate the amount of spare capacity on alternative feeders/transformers.
- Estimate the costs of possible network reconfigurations.
- Check that the reconfigurations will not cause voltage drop problems or cause other assets to be close to their rated capacity.
- Estimate the cost of alternative reinforcements.
- Make a decision based on cost and benefits of the viable options.
- The presentation of the data to aid planners is an area that needs further investigation.

5.3.4.3 Implications of Customer Behaviour

In order to assess the impact of the changes in customer behaviour and the type of appliances owned, surveys were carried out. The key points were:

- DSR is theoretically possible given the numbers of cold appliances and schedulable loads. However, to control these devices automatically, control would need to be retro fitted given the slow change of appliances.
- Ownership of multiple appliances of the same type is more common than the model indicated; this could affect profiles especially in future if this practice increases. However, how often a number of the same devices will be used in one household simultaneously is unclear.
- Customers keep old inefficient cold appliances, this increases the base load.
- Appliances such as freezers and fridges are on average increasing in size.
- Comparing 2008 and 2011 data indicates that the range of values of demand has decreased and the base load has reduced slightly but overall the average profile is similar.

5.3.4.4 Load Model

The University of Loughborough have developed a high resolution domestic demand model[8]. It is probabilistic and a well validated model for a house demand that takes into account the appliances, occupancy and time of year. It was extended within the project to estimate the load on a feeder. That is, the model of a single household was replicated with the information on heating and occupancy for the homes on a feeder. The results were compared to reality using information on the occupancy level and the appliance ownership. It estimates the profile well but gives a lower minimum base load than reality. An example of the output compared to actually readings is given in Figure 8.

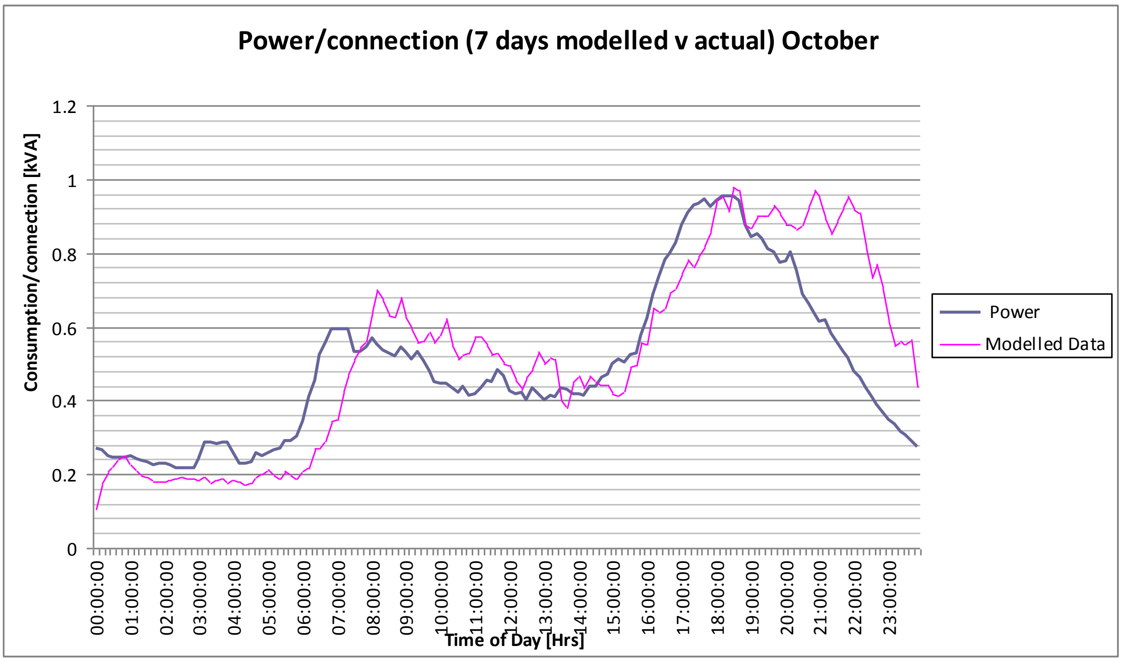


Figure 8 The output from the domestic load model compared to actual data.

[8] Model available at https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/3112 accessed September 2013

5.3.5 Real Time Thermal Ratings for a Pole Mounted Transformer

Key points from the real time thermal ratings studies are:

- The pole mounted transformer (PMT) is probably not overloaded in winter even though the static rating indicates that it is
- In summer, despite the load being lower and the transformer rating being higher than that indicated by the static rating, the transformer was overloaded.
- If the highest loading is during the coldest times of the year, upgrading a transformer that appears to be overloaded may not be required. This could save around £8,000 per site.
- If rapid changes in load or prolonged loading significantly affect the rating of a transformer, DSR could be used to avoid such loading. This could delay upgrading.
- Understanding how often transformer oil temperature actually rises above 98 ° C will enable better understanding of the lifetime of a transformer and better more cost effective asset replacement plans.
- If the saving in prolonged lifetime for an average reduction in temperature of X degrees can be estimated, this would give the cost that could be justified for designing improved passive cooling for PMTs.

By understanding the impact of ambient temperature on distribution transformers, use cases for the information could be developed. For example to better plan replacement programmes or understand if the connections of technologies such as heat pumps that operate in winter are likely to overload a transformer.

As DSR could not be demonstrated, the potential for dynamic ratings for distribution transformers was investigated. A dynamic thermal ratings model showed that the pole mounted transformer is probably not overloaded in winter, even though it is found to exceed its static rating (Figure 9).

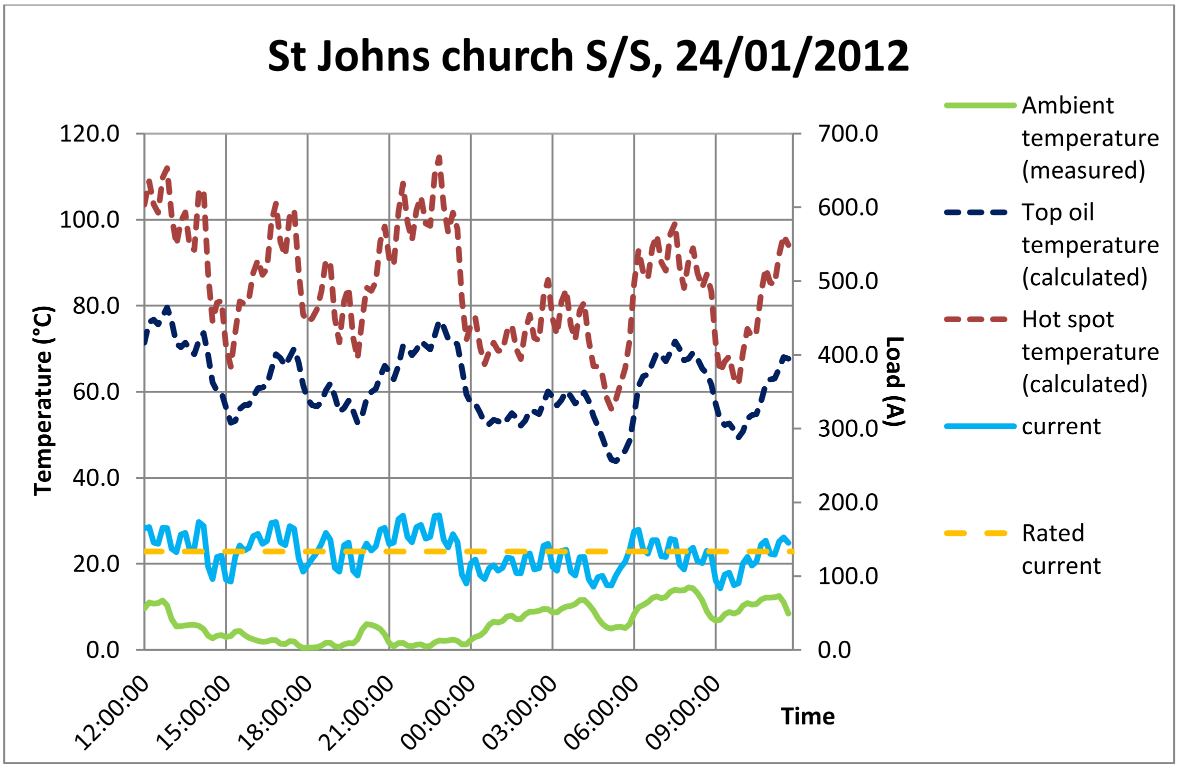


Figure 9 Example of the output from the dynamic ratings model (developed by EA Technology) using Ashton Hayes data.

The data from the pole mounted transformer (PMT) on Church Road with ambient temperature measurement was used to further assess the results and implications of the model.

There is insufficient data to validate the model; however, the work shows that temperature and changes in loading of the transformer have a significant impact on its rating. In general, the dynamic rating of the transformer is higher than the static rating.

In summer, despite the load being lower and the transformer rating being higher than that indicated by the static rating, the transformer was overloaded. However, the temperature at the PMT may have been lower than the ambient readings taken at the weather station which would have increased the rating further.

In its present form, the model is not able to take into account changes in behaviour due to ageing of the transformer but this is an area for further work. Once the behaviour and dynamic ratings are clearly understood, the loading of a transformer can be better managed:

- If the highest loading is during the coldest times of the year, upgrading a transformer that appears to be overloaded may not be required. This could save around £8,000 per transformer that is not replaced.
- If rapid changes in load or prolonged loading significantly affect the rating of a transformer, demand side management (DSM) could be used to avoid such loading. This could delay upgrading.
- Understanding how often transformer oil temperature actually rises above 98 ° C (above which degradation significantly increases) will enable better understanding of the lifetime of a transformer and better more cost effective asset replacement plans.
- If the saving in prolonged lifetime for an average reduction in temperature of X degrees can be estimated, this would give the cost that could be justified for designing improved passive cooling for PMTs.

Unusually, the two PMTs in Ashton Hayes have oil pockets so that the oil temperature can be measured. It is therefore recommended to install further monitoring on the Ashton Hayes transformers and elsewhere if possible to gather a year’s worth of data.

A real time thermal rating model developed by EA Technology in parallel with this project (funded solely by EA Technology) is at TRL 4.

5.3.6 Electricity Use and Impact of Generation

Key points from the development of a network model are:

- The installed generation does not cause voltage problems.
- The voltage variation at present is smaller than initially predicted.
- There is ample capacity for more generation on a monitored feeder.
- Where one load may have a significant impact on the feeder and there is little data, a statistical approach to voltage profile analysis that takes into account the fact that there is, for example, only one year’s worth of data available, and may be more appropriate. In this way, the likely voltage effects may be more easily identified.
- The reactive power drawn by the inverter is high and should be investigated further.

The experience in Ashton Hayes demonstrates that more generation can be connected than might be expected from traditional planning techniques. With further trials, this information can be used to adapt current planning approaches.

The south facing roof of the new Low Carbon Sports Pavilion has 9.8kWp of photovoltaics and the heating is supplied by an air source heat pump. The feeder to which it is connected was monitored, so the impact on its profile could be assessed.

The Pavilion is a new building and is at the furthest end of the feeder. As it has photovoltaics and a heat pump, it could cause significant voltage rise in summer and voltage drop in winter. This was a concern expressed when the new connection was assessed.

Some of the key conclusions from this investigation are:

- The installed generation does not cause voltage problems.
- The voltage variation at present is smaller than initially predicted.
- There is ample capacity for more generation on the Kelsall Road feeder.
- Where one load may have a significant impact on the feeder and there is little data, a statistical approach to voltage profile analysis that takes into account the fact that there is, for example, only one year's worth of data available, and may be more appropriate. In this way, the likely voltage effects may be more easily identified.

The feeder profile is similar to an all domestic profile despite the presence of a shop, pub and pavilion. The most significant differences are a higher base load and greater load at lunchtime. The lunchtime load recorded at the substation is less marked in summer and this could be due to the export from the pavilion. As highlighted by the other analysis, better understanding of LV voltage profiles is required and, as highlighted here, further work to understand in particular how non-domestic connections will affect the overall load.

Information from the manufacturer confirmed that the inverter for the photovoltaics draws a significant amount of reactive power even during the night. A number of inverters on one feeder could be a significant reactive power load. Further investigation of the reactive power demand of inverters and other loads is required.

The voltage unbalance is consistent during the year indicating it is not due to seasonal loads or the inverter only operating on one phase at low output.

5.4 Other Activities

Other activities carried out under the project were:

- The London School of Economics carried out interviews and workshops involving SPEN and EA Technology. These were to develop accounting methods to capture the value of the community projects.
- DECC Call for Evidence on Community Energy submission see **Appendix C 'Dissemination Material' for the 'DSM for DNOs and 'DSM Pavilion final' reports.**

5.5 Results and Feedback from Third Party Use of the Data

As yet there have been few published outcomes from third party use. However, Peter Boait who used data from Ashton Hayes to develop DG detection algorithms commented that:

> *'It was useful to have real load data from an actual village to test whether the algorithms could detect combined heat and power. The data of output from the photovoltaics also helped improve the algorithms.'*

This work was reported in a paper at a CIRED workshop in 2012 'Measurement and Prediction of Demand in the Presence of Renewable Distributed Generation.'[9]

Outputs from the ARIES project are at http://www.see.ed.ac.uk/drupal/research/ies/aries/

[9] Available at http://www.cired.net/publications/workshop2012/pdfs/CIREDWS2012_0042_final.pdf accessed September 2013

6 Performance Compared to Original Project Aims, Objectives and Success Criteria

6.1 Performance against Scope 51
6.2 Performance against the Success Criteria 53
6.3 Trial of DSR 53

Future Work:

19. The planned DSR trial was not achieved due to a delay in the role out of Smart Meters. The appetite for DSR trials amongst suppliers is now greater due to increased pressure on the energy market and Smart Meter role out becoming a reality. Further work is needed to establish how to balance DNO priorities around control of the local network to the priorities of suppliers seeking the best deal on the national electricity market.

6 Performance Compared to Original Project Aims, Objectives and Success Criteria

The scope of the project was:

- To facilitate the connection of various micro generation technologies (wind, PV and CHP) and potentially electric vehicle (EV) charging point(s) on the LV network and its 11kV feeders.
- Engagement with the village and community to assist in the reduction and optimisation of total energy consumption to reduce carbon footprint.
- To improve the accuracy and granularity of total electricity consumption measurement by installing additional metering on the network at secondary substation feeder level and at renewable energy source(s) providing measurement of the gross generation embedded within the community.
- To introduce innovative and new techniques to introduce DSR capabilities aimed at assisting change in energy use related behaviours within residential homes and public properties.

The success criteria was:

- Supporting Ashton Hayes in the introduction of low carbon technologies.
- Connection of the new technologies to the LV network.
- Integration and optimal utilisation of these technologies to reduce the carbon foot print of Ashton Hayes village.

6.1 Performance against Scope

The scope of the Smart Village Project was:

To facilitate the connection of various micro generation technologies (wind, PV and CHP) and potentially electric vehicle (EV) charging point(s) on the LV network and its 11 kV feeders.

- This was fulfilled by considering the network monitoring data and the export from the proposed photovoltaics installed at the school. This allowed more generation to be connected under Engineering Recommendation G83[10] criteria than initially thought possible.
- Monitoring data on the feeder where the Pavilion is connected showed that the photovoltaics and heat pumps could be connected without causing voltage excursions. The probability of different voltages from the monitoring data at different times of day showed the amount of additional generation that could be installed of different types.
- The research undertaken by EA Technology identified the importance of understanding the maximum and minimum network loads when planning the connection of low carbon technology.

[10] Engineering Recommendation G83/2: Recommendations for the Connection of Type Tested Small-scale Embedded Generators (Up to 16A per Phase) in Parallel with Low-Voltage Distribution Systems (August 2012)

- The network model established under the project now enables multiple low carbon technology adoption scenarios to be simulated for Ashton Hayes. In doing so future network excursions can be identified and corrective actions trialled, thus enabling the SPEN to maximise the capacity of the existing network for low carbon technology. These solutions include a network voltage reduction and the rebalance of the load on the phases of each circuit and substation.
- Over the course of the project the installed capacity of photovoltaic generation increased from 0kW to >30kW at the time of writing. Should the community wish to further invest in distributed generation (very likely), SPEN will be in a position to carry out thorough analysis on its impact over the course of 12 months relatively quickly.

Engagement with the village and community to assist in the reduction and optimisation of total energy consumption to reduce carbon footprint.

As described earlier, via village meetings, posters and representation of the monitoring data, the awareness of the role of the DNO and how a village can manage their energy use and reduce their carbon footprint was increased. The flow chart of the engagement process is in section 4.4.1. Figure 5 shows an example of a community newsletter and section 12 shows an example report. Anecdotal evidence shows the village became more aware of the role of a DNO (section 5.1.2) and the potential for DSR (section 5.1.5). Surveys showed they adopted more energy efficiency measures (section 5.1.4 and 5.1.3) and low carbon technologies during the project.

One of the key successes of the project has been the quantification of the village's total annual consumption as well as the contribution made by village's photovoltaic generation. This data has provided the village with a benchmark to assess its journey to carbon neutrality against. **See Appendix A 'Community Reports' for the Ashton Hayes Quarterly reports and Community shop reports.**

To improve the accuracy and granularity of total electricity consumption measurement by installing additional metering on the network at secondary substation feeder level and at renewable energy source(s) providing measurement of the gross generation embedded within the community.

This was achieved by monitoring all the distribution substations and 2 feeders. Data was also collected from the generation. The list of the data collected is given in section 4.3.2. Examples of the output were used in section 5.3.

To introduce innovative and new techniques to introduce DSR capabilities aimed at assisting change in energy use related behaviours within residential homes and public properties.

Desktop analysis of the potential for DSR showed that around 7.5-10% of the peak load could be shifted. The details are discussed in section 5.3.2. A trial could not be conducted for the reasons outlined in section 0

6.2 Performance against the Success Criteria

The following success criteria were identified and recorded in the registration pro-forma. They were all achieved.

Supporting Ashton Hayes in the introduction of low carbon technologies.

This was achieved by providing the village with connections for generation and low carbon heating, which was facilitated through the use of the monitoring data to establish the voltage headroom. This also demonstrated the level of additional generation that could be connected before network upgrades would be required. New representations of the data were developed to help planners ascertain the amount of headroom available. Examples are given in section 5.3.4.1.

Connection of the new technologies to the LV network.

Within the village, photovoltaics, heat pumps and an electric vehicle charging point were connected. The monitoring data was used to assess new planning approaches and potential benefits of generation to boost voltage (section 5.3.4). The proposal was very similar to the revised Engineering Recommendation G59/2 arrangements that in the event superseded the project due to delays in the installation (see section 5.3.4.2).

Integration and optimal utilisation of these technologies to reduce Ashton Hayes village carbon foot print.

The potential additional capacity available through the use of dynamic ratings for distribution transformers (section 5.3.5), use of network data to rearrange the network to maximise capacity (section 5.3.4.2) and adjusting transformer tap settings (section 5.3.4) were assessed. Actual available headroom for generation was investigated and this was found to be more than existing planning approaches may assume (section 5.3.4).

This demonstrated that more renewable generation and low carbon technologies could be connected than conventional assessments would predict. This facilitates Ashton Hayes reducing their carbon footprint by allowing cost effective connection of low carbon technologies.

6.3 Trial of DSR

It was planned to trial DSR to establish the potential scope. Unfortunately this was not achieved due to a number of reasons. Discussions were held with a number of energy suppliers (three of the major suppliers and one smaller supplier) to attempt to ascertain a way in which consumption patterns could be measured through the use of smart meters.

However, the delay in the roll-out of smart meters and the requirement to comply with the restrictions set out in Version 3 of the Guidance document (issued 22nd July 2010) for LCN Fund Tier 1 regarding engagement with customers meant this could not be achieved. No method of interfacing directly between the DNO and the customer to engage in DSR could be established within the time and budget restrictions of the project.

It is acknowledged that the appetite for DSR trials amongst suppliers is now greater due to increased pressure on the energy market and the smart meter roll out becoming a reality. However, there was insufficient time during the last year of the project to engage a supplier and to organise a trial within the village. Furthermore it is noted that most of the DSR trials currently in train are either larger scale or with commercial customers. .

At the start of the project it was thought that the most effective means to introduce a trial of DSR under a Tier 1 LCN Fund project was to work with a supplier. It was therefore proposed to engage with a supplier to measure consumption patterns and incentivise customers using smart meters. No funding for incentives was therefore included in the proposal. Unfortunately the delays in the roll out of smart meters meant that during the trial, suppliers were not sufficiently ready to participate in the project and provide the services required. Discussions were held with 3 major suppliers and one smaller supplier but participation was not possible. As well as the fact that suppliers were not ready for such a trial, the discussions also demonstrated that the priorities for a DNO in terms of control of the local network can be different to a supplier seeking the best deal on the national electricity market. Further work is needed to establish how these priorities can be balanced but was outside the scope of the project.

Although this could not be trialled, potential approaches and benefits of DSR and how energy suppliers, DNOs and communities could work together were investigated (section 5.3). Unfortunately the community electric vehicle was not a success and therefore very little charging occurred. Shifting this load could therefore not be demonstrated. The reason for the lack of uptake of the community electric vehicle was a matter of timing. It was adopted a little too early and the technology was not developed sufficiently to be practical for the village. ‘Range anxiety’ and lack of public charging points at the time were a problem. Elderly residents for whom transport is a problem were nervous about using a new technology, further reducing uptake.

The potential for DSR to manage loads was still investigated from the load curves data. A literature survey of the types of incentives required was also carried out to ascertain the value of DSR. As a transformer was found to be overloaded, the potential for network rearrangement was investigated using the load data (section 5.3). Initial investigations into the actual overload when using real time thermal rating were carried out (section 5.3.4.1).

7 Required Modifications to the Planned Approach during the Course of the Project

7.1 Demand Side Response Trial 56
7.2 G83/G59 56
7.3 Alternative Work Carried Out 56

7 Required Modifications to the Planned Approach during the Course of the Project

The key modification was that work on DSR was not carried out due to the lack of a supplier and smart meters. Engineering Recommendation G59 was updated such that it aligned with the recommendations of the project. Further work was carried out into real time thermal ratings for distribution transformers instead.

7.1 Demand Side Response Trial

As discussed previously in section 6.3, DSR could not be implemented due to the lack of smart meters and hence a method to accurately measure individual customer demand and observe the effects of demand shifting. The project was slightly ahead of the progress of the sector with regard to the deployment of smart meters. Also the electric vehicle was sold (again the project was ahead of the technology development curve) so DSR could not be implemented using this particular LCT. The potential for load shifting, in terms of the likely availability of demand that could be moved, was studied however.

7.2 G83/G59

During the trial, G83/G59 was altered so the proposed innovative connection was not so innovative. The project had demonstrated that the use at the school was such that although above the G83 limit, the PV would rarely export and not more than 4kW. Therefore, it was proposed that it should be connected under G83 connection requirements (normally for under 4kW per phase) rather than the previously onerous G59 (for larger generators). During the course of the project, G59 was modified to allow a connection process very similar to G83 albeit not on a fit and inform basis.

7.3 Alternative Work Carried Out

As the areas above could not be studied, further work on real time ratings for distribution transformers was carried out (section 5.3.5).

8 Significant Variance in Expected Costs and Benefits

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8 Significant Variance in Expected Costs and Benefits

Variance in Costs

The original project cost was £200,000, whereas, the actual project expenditure was £141,436 (-30%). This under spend was a result of the project's scope being limited by the adoption of low carbon technology within the village and the envisaged DSR trial being scrapped due to lack of smart meters and a retail partner.

Variance in Benefits

(i) Community Engagement

- The project has delivered many of the expected benefits and has started to influence SPEN's business as usual practices for engagement
- No particular carbon reduction within the village can be attributed to the engagement exercise at present

(ii) Monitoring

- The Flexible Networks project has been a major beneficiary of the learning that has come from this project's exercise of specifying, installing, configuring and maintaining monitors.

(iii) Analysis

- As with above the analysis of the data provided by the monitoring has influenced the analysis being undertaken in the Flexible Networks project
- Analysis of the village's network has highlighted key indications of the present network's performance, including its present and potential capacity, the stability of the network and the village's total consumption
- The data provided has fed into research at several academic institutes providing additional benefits

8.1 Variance in Costs

Table 8-1 highlights SPENs expenditure on the project

Table 8-1 Variance in Project Costs

Element	Forecasted Expenditure	Actual Expenditure	Variance
Contracts	£130,000	£117,453.53	£12,546.47
IT	£20,000	£-	£20,000
Labour	£30,000	£23,856.85	£6,143.15
Materials	£10,000	£126.00	£9,874
Legal	£10,000	£-	£10,000
TOTAL	**£200,000**	**£141,436.38**	**£58,563.62**

8.1.1 Contracts

The £12,546.47 variance in the forecasted and actual expenditure under Contracts was a result of the following elements:

- The contracts placed for monitoring equipment came in significantly under budget. This was due to the unit cost for the monitors being lower than expected and the number of low carbon technologies being monitored in isolation being lower than envisaged.
- The budget provision for equipment associated with a DSR trial was not required.
- Whilst the equipment contracts placed varied significantly from the initial budget, the contracts placed with the project's engineering consultants came in almost exactly as planned with only a minor over expenditure for additional dissemination activities.

8.1.2 IT

The expected developments within SPEN's data acquisition systems associated with the monitors were superseded by those being undertaken in the Flexible Networks Tier 2 project, as such all of the IT development costs were outside of this project's £20,000 IT budget provision.

8.1.3 Labour

SPEN did not require its full budget allocation for labour and as a result there was an under spend of £6,143.15. This was largely down to the level of monitoring being less than envisaged and the lack of a DSR trial. Whilst the overall cost was lower than forecasted, the labour costs associated with each monitor were almost double that which was expected and this was due to the requirement of repeat visits to rectify issues.

8.1.4 Materials

There was little requirement for additional materials outside of the equipment supplied under the contracts; hence this provision was hardly touched.

8.1.5 Legal

Without a DSR trial there was no requirement for any legal assistance.

8.2 Variance in Benefits

As detailed throughout this report, it was never envisaged that this project would provide all of the answers associated to each area of research, but it would provide key learning and experience that would benefit larger projects aimed at providing comprehensive answers. To this extent, the project has provided the expected benefits but it is fair to say it has done this more in some areas than others.

8.2.1 Community Engagement

The learning from the community engagement exercise has been invaluable, the process for engaging with a community has been documented and the experiences disseminated within SPEN to the benefit of the wider business. However it is fair to say that at the project's inception it was envisaged that the activities undertaken under the project would directly deliver a reduction in the village's carbon contribution and this has not happened. A significant portion of the expected carbon reduction would have been delivered by the DSR trial and changes in the community's behaviour as a result of SPEN's engagement. Without retail partner participation and a system to allow consumers to benchmark their consumption against others, this was a difficult task. Despite this, there is anecdotal evidence that the information provided by SPEN has been taken on board by many of the residents and that awareness of the network and electrical consumption has increased significantly thanks to the engagement activities.

8.2.2 Monitoring

The monitoring undertaken in this project has delivered all of the learning benefits expected, but not the performance levels hoped for. The exercise of specifying, installing, configuring and maintaining the monitors has been a major influence on the larger monitoring scheme undertaken in the Flexible Networks project.

8.2.3 Analysis

Similarly to above, the learning from the analysis of the data provided by the monitoring has influenced the analysis being undertaken in the Flexible Networks project. Within the village's network, the analysis has identified:

- The capacity of each substation and circuit
- The stability of the network's voltage
- The additional capacity for distributed generation that could be introduced by a voltage reduction
- The potential benefits from the real time thermal rating of a pole mounted transformer
- The village's annual consumption
- The percentage of the village's consumption met by existing and future PV schemes

Further to this, there has been additional analysis at academic institutes utilising the data provided by the project. Given the project's relatively small size, it has more than exceeded the expected benefits.

9 Lessons Learnt for Future Projects

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Future Work:

20. Data analysis once verified will provide the information to more accurately assess the impact of new generation connections. This could be fed into network planning techniques and feed into awareness campaigns to reduce demand.

21. Whilst the monitoring has delivered some major benefits, within this trial the desired reliability was not achieved. LV monitoring reliability needs to be proven prior to installation en masse.

9 Lessons Learnt for Future Projects

The documented engagement processes will be used in projects and under business as usual. Projects have to be adaptable to changes within communities. Monitoring and data handling was improved that also facilitated these larger projects. Lessons were fed into LCN Fund Tier 2 projects on a larger scale. Analysis provided better understanding of load profiles, the potential role of DSR and voltage distributions. Even those areas of the project that had to be changed provided useful learning.

9.1 Learning Carried on in other LCN Fund Project

The monitoring techniques have been used within Flexible Networks LCN Fund Project and the findings of the analysis can be further investigated as part of SPEN's proposed LCN Fund Tier 2 proposal ACE project[11].

9.2 Engagement Process

The generic engagement process developed from experience in the village is in section 5.1.1.

The project had to be adaptable to changes in circumstance such as delays in installing photovoltaics, the building of the pavilion, selling of the electric vehicle and delays in the smart meter role out. This is partly because a project such as this is experimental and is at the forefront of development and partly due to changes in customers' lives. The community electric vehicle was a little too ahead of its time. The number of charging posts was insufficient for long journeys and elderly members of the community who suffer from a lack of transport were slow adopters of the new technology. These parts of the trial should not be seen as a failure as much was learnt from the exercise.

Working with communities requires the DNO to adopt an approach unlike any other used within the business. It has to be more flexible and understand that the community is made up of volunteers and funding arrangements / plans can be susceptible to change.

Community structures can be quite fluid and hard to put down on paper, but there are several key components that a DNO should look for in a community group prior to engagement (section 5.1.1).

3 years was not sufficient to identify if SPEN's engagement in Ashton Hayes will have any lasting effect on the carbon neutrality of the village, although there is evidence that attitudes and knowledge have changed within the village linked to increased knowledge and awareness of the role of a DNO.

If the benefits of engagement are proven in subsequent trials across the UK, the same approach could be replicated at a significantly reduced cost via the development of automated community reports and lower cost monitors. If operated as an initiative outside of a field trial, in a number of locations, the provision of a full time community liaison expert covering a number of sites could potentially be justified. With the generic tools developed in this project, other DNOs can adopt a similar approach.

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[11] See https://www.ofgem.gov.uk/ofgem-publications/75318/spen-ace-isp.pdf accessed October 2013.

9.3 Monitoring

The project has enabled SPEN to start learning about LV monitoring techniques. The production of the specification, installations, fault finding etc. has underpinned SPEN's LV monitoring programme in the Flexible Networks Tier 2 project where the monitoring has increased from five units to several hundred.

Whilst the monitoring has delivered some major benefits, within this trial the desired reliability was not achieved. As a result several repeat visits to each unit for repairs/reconfigurations were required. LV monitoring reliability needs to be proven prior to installation en masse. This fits the approach of *THINK BIG, START SMALL, SCALE FAST.*

GPRS communication worked reasonably well when sending daily reports, very few issues occurred once antennae were located in the optimum positions.

The analysis / modelling provided increased understanding of the implications of the monitored data. Even alone, the daily reports from each unit gave a quick and insightful overview of the network, quickly highlighting overloads, phase imbalance or power quality problems.

The deployment of the monitors and recovery of real LV network data was invaluable to several academic institutions in need of real data for analysis.

9.3.1 Development of Data Collection

The knowledge gained through data processing during the Ashton Hayes project has not only fed into this SPEN internal tools but the IT systems partner in the Flexible Networks project, Nortech Management Ltd, is developing their data management services used by several UK DNOs. These developments will mean that LV network monitor data will instantly be available in an analysed format, with no work required by the DNO.

9.3.2 Improvements of Monitors

The project has provided the experience for eMS to improve their product (section 5.2).

Developing a design that positioned data cards lower down a pole would provide for easier access.

9.4 Analysis

Below is a summary of the results as described in detail in section 5.3. The summary below focuses particularly on the findings that can be used to develop new planning or operational techniques.

- There are potential savings from domestic DSR and how this could be harnessed if the regulatory regime was adapted to allow DNOs to harness DSR more effectively. Around 7.5-10% of the total during peak hours could be managed.
- A voltage reduction of one tap step could be made at all the substations in the village to allow more generation to connect whilst accommodating load and allowing substations to back feed.
- Knowledge of minimum and maximum load and new load and generation profiles is required for LV planning in future in order to incorporate new loads and generation. This project provided valuable information for more effective planning of new generation connections at LV and modelling techniques. The information requires validating on a larger scale to ensure it can be applied to a wide range of settings before use in network planning techniques.

- Additional renewable generation can be connected when the voltage at the substation is reduced.
- Modelling and monitoring together can identify alternative LV network configurations to relieve overload and increase the capacity for generation at LV voltage.
- The minimum demand per connection of a feeder is fairly constant at about 240VA, provided that there are more than 50-70 domestic connections to the feeder.
- The After Diversity Maximum Demand varies more with the number of connections – between 1.05kVA and 1.65kVA/ per connection.
- The frequency distribution graphs per connection give a good visual means to understand the level of variation in power and by comparing the shape to the frequency voltage distribution, the level of voltage unbalance can be ascertained
- The impact of reduction of significant loads such as schools at particular times of year on the capacity available for PV should be taken into account.
- The amount of capacity available for generation can be estimated by considering the minimum voltages recorded during 24 hours or during daylight hours. More PV can connect compared to generation in general as it is guaranteed to only operate during daylight hours when the load is higher.
- With the monitoring data available in Ashton Hayes, greater insight into demand profiles can allow more efficient means to manage thermal overloads.

The key outputs above provide the information (once verified) to more accurately assess the impact of new generation connections and how to use monitoring data to assess load profiles and unbalance on the network. This can be fed into network planning techniques. Information on customer behaviour provides useful insight into how load profiles may change and how awareness campaigns could reduce demand.

By understanding the impact of ambient temperature on distribution transformers, use cases for the information could be developed. For example, to better plan replacements programmes or understand if the connections of technologies such as heat pumps that operate in winter are likely to overload a transformer.

10 Planned Implementation

10.1 LCN Fund Projects 67
10.2 Engagement 67
10.3 New Ways of Working 67

10 Planned Implementation

Implementation will be via wider trials and integrating the findings into normal working practices via improved customer engagement and use of data.

Improved and new modelling and planning techniques may enhance network design and operation.

10.1 LCN Fund Projects

Section 9.1 outlines how the learning from this project is being implemented within further Tier 2 LCN Fund projects. This has helped them run more efficiently and also provide a basis for further analysis. This has been most significant within the Flexible Networks Tier 2 project.

10.2 Engagement

- SPEN have looked to recreate the positive response and trust achieved in Ashton Hayes through the 'community pull' approach in our RIIO ED1 stakeholder engagement events.
- SPEN is trialling the same level of transparency / disclosure in community engagement ahead of major network reinforcement programmes at Wigtown. This is not part of a trial but rather part of business as usual operation.

10.3 New Ways of Working

Whilst not yet fully developed, the project has opened up new possibilities for new ways of working to be developed into a strategy with input from Tier 2 projects so that they can become Business As Usual. In particular:

- Engaging with communities when:
  - A community has a need that requires close working with a DNO or large scale works are required.
  - A DNO may wish to explore different options with a community to avoid reinforcement or ensure efficient design for connections.
  - A DNO would like to work with a community for a field trial.
- Incorporating knowledge of minimum load, load profiles and dynamic ratings into planning processes.
- Investigating the potential for adjusting policy such as tap settings for distribution transformers.

For further field trials, the engagement process can be included within NIA or NIC funding and may complement other funding available to a community. For business as usual processes, funding engagement or customer surgeries may avoid reinforcement and be more cost effective.

11 Facilitate Replication

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11.3 Analysis 69
11.4 IPR 69

Future work:

22. In future a more targeted approach to monitoring may be appropriate as knowledge of specific data requirements becomes clearer.

11 Facilitate Replication

Implementation will be via wider trials and integrating the findings into normal working practices via improved customer engagement and use of data. Sufficient monitoring is required for replication. However, in future a more targeted approach may be more appropriate as knowledge of what data is required becomes clearer with experience.

To replicate and use the learning the project, the following issues are very important.

11.1 Process for Engaging with a Local Community

Referring to the generic flowchart (section 5.1.1) for community engagement, it is necessary to find suitable community organisations and champions with which key DNO personnel can liaise. If these are not available, then time and expertise are required to develop entities and people. Section 5.1.1 outlines the situations where engagement is important. Whilst time spent with engaging a community requires considerable commitment, this engagement may reduce costs elsewhere within the business in terms of planning and reinforcement.

11.2 Monitoring

Sufficient monitoring is required for replication, however in future a more targeted approach may be more appropriate as knowledge of specific data requirements becomes clearer with experience. It is also worth noting that since this project's inception there have been significant developments in the market for LV network monitors and these are now being assessed under several LCN Fund projects.

11.3 Analysis

Section 5.3 highlights how the different outputs can be used. Most of them require further tests on different networks before being incorporated in to planning techniques or policy.

11.4 IPR

- The community engagement processes are open source and available for use by any party.
- The patents for the subnet products are held by eMS and were background IP to the project.
- The monitoring data is owned by SPEN but will be available on an open source basis.
- Data provided by the village residents collated under village run projects is owned by the community and is background IP.
- Information used within this project from work undertaken under the Strategic Technology Programme was background IP to the project.
- The domestic load model is owned by the University of Loughborough and is background IP but available on an open source basis.
- The Real Time Thermal Rating Model was developed and funded by EA Technology outside of the Tier 1 project, available on a commercial basis.

12 Example Report

SP ENERGY NETWORKS

Ashton Hayes Smart Village

going carbon neutral Ashton Hayes

Community Update

March 2013

Who are SP Energy Networks?

SP Energy Networks is the company responsible for the distribution of electricity to your property. Via our network of substations, cables and power lines, we serve 3.5 million homes and businesses across Central & Southern Scotland, Cheshire, Merseyside, North Shropshire and North Wales. Regardless of who you pay for your electricity, it is our job to make sure you get it.

Project Background

IET AWARDS The Institution of Engineering and Technology
INNOVATION FINALIST 2011

We have installed power monitoring devices in the four secondary substations that feed the village of Ashton Hayes, which measure a number of parameters and transmit daily reports to SP Energy Networks' engineers. As well as electricity consumption, the power generated by one of the village's photovoltaic cell arrays is monitored. All this data, coupled with our knowledge of the Ashton Hayes Low Voltage Network, has allowed us to produce reports for the village on their electricity usage and habits.

What am I reading?

This leaflet is a quick update for the village of Ashton Hayes, and a reminder of the information which you can access through SP Energy Networks.

You will find information on consumption in the village in the 3rd and 4th quarters of 2012, highlights from a report written on the potential of photovoltaics (solar panels) in the village and details on how to keep up to date with SP Energy Networks.

In partnership: SP ENERGY NETWORKS | ea technology | LCN Fund Low Carbon Networks | University of Chester

SP ENERGY NETWORKS

Ashton Hayes Smart Village

Why Ashton Hayes?

With its carbon reduction achievements, future goals and investment in low carbon technology such as photovoltaic generation, Ashton Hayes is setting an example for UK communities to follow to play their part in achieving the UKs carbon reduction and renewable generation targets for 2020 and beyond.

Ashton Hayes' transition into a carbon neutral village provides the UK's electricity network operators with an excellent opportunity to observe how the use of electricity may change in the next 30 years and understand the requirements for future electricity networks.

Electricity Monitoring

2012 Quarter 3 and 4 Consumption

399,615kWh* The total electricity consumed by the village in July, August, September 2012

Which resulted in carbon emissions totalling **197 tonnes**

598,608kWh The total estimated** electricity consumed by the village in October, November, December 2012

Which resulted in carbon emissions totalling **296 tonnes**

In 2012 Ashton Hayes consumed **1.942GWh**

* kWh is a standard measurement of electrical consumption; 1kWh is the equivalent of 1000 Watts of electricity being consumed for 1 hour, e.g. a plasma TV being used for 3 hours or a 2kW kettle for 30 minutes.

** Due to device malfunctions, much less data was collected in the last quarter of the year. However, at least one monitor was operating throughout the quarter, giving us enough data to make calculations on the consumption.

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SP ENERGY NETWORKS

Ashton Hayes Smart Village

going carbon neutral Ashton Hayes

282kWp of PV could be safely installed... ...producing **223MWh** of electricity annually.

This would meet **12%** of the community's electricity consumption.

We estimate a total of **452kWp** of PV cells could physically fit onto the roofs of Ashton Hayes.

With adaptations to the network an extra **150 kWp** could be installed...

...meaning up to **17.5%** of the village's electricity consumption could be met by PV.

And there's more...

You can find much more information by checking our website. Go to
www.spenergynetworks.com/innovation
and click on 'Ashton Hayes' under 'Low Carbon Networks' for

- Studies
- Community reports
- Brochures
- Info on our other LCNF projects

Or, even better, talk to us! You can contact our team at SPInnovation@spenergynetworks.com

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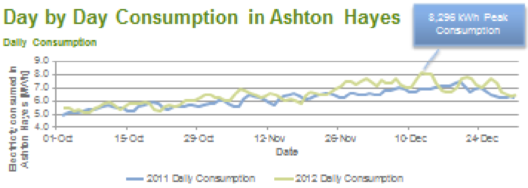
SP ENERGY NETWORKS

Ashton Hayes Smart Village

going carbon neutral Ashton Hayes

Day by Day Consumption in Ashton Hayes



The graph above shows the electricity consumption of Ashton Hayes each day in the last quarter of 2011 and each day in the last quarter of 2012. From it we can see that in 2012 consumption was consistently greater than it had been the previous year. This increased electricity usage during winter pushed the total electricity consumption last year 60MWh above the predicted values. That is a considerable increase – the equivalent of every single household in the village running 300 extra loads of washing. However, the difference could also be down to a difference in ecological conditions – this is not necessarily a like-for-like comparison.

Photovoltaics Review

ScottishPower Energy Networks has been analysing the maximum potential photovoltaic generation in the village. The limiting factors on connecting generation to low voltage networks include:

a) avoiding the maximum capacity that the cables and other equipment are manufactured to carry,
b) maintaining the voltage at all points on the network between legal limits and
c) minimising reverse power flow, where houses on one circuit are generating more than they consume.

Overleaf you will find a summary of the most significant figures, but the full report, complete with explanations of the conclusions made, data charts and maps showing the electricity network, can be found on our website.

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13 Appendices

Material and outputs from the project are available in five appendices available from SPENs Ashton Hayes website[12]:

A. Community Reports
B. Monitoring Specification
C. Dissemination Material
D. Technical Reports
E. Tier 1 Registration Document

[12] http://www.spenergynetworks.com/pages/ashton_hayes.asp