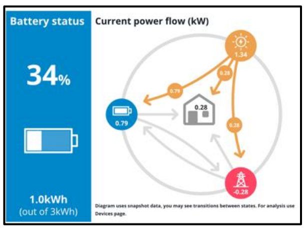
Domestic Batteries
Best Practice Guide – learnings from NEA's Technical innovation fund field trials



Paul Rogers and Michael Hamer
March 2019

Background

About National Energy Action

National Energy Action is the national fuel poverty charity working across England, Wales and Northern Ireland, and with sister charity Energy Action Scotland (EAS), to ensure that everyone can afford to live in a warm, dry home. In partnership with central and local government, fuel utilities, housing providers, consumer groups and voluntary organisations, it undertakes a range of activities to address the causes and treat the symptoms of fuel poverty. Its work encompasses all aspects of fuel poverty, but in particular emphasises the importance of greater investment in domestic energy efficiency.

About the Technical Innovation Fund

NEA believes that there is huge potential for new technologies to provide solutions for some of the 4 million UK households currently living in fuel poverty, particularly those residing in properties which have traditionally been considered too difficult or expensive to include in mandated fuel poverty and energy efficiency schemes. However, more robust monitoring and evaluation is needed to understand the application of these technologies and assess their suitability for inclusion in future schemes.

The Technical Innovation Fund (TIF) which was designed and administered by NEA, formed part of the larger £26.2m Health and Innovation Programme (HIP) along with the Warm Zone Fund and Warm and Healthy Homes Fund.

TIF facilitated a number of trials to identify the suitability of a range of technologies in different household and property types and had two strands: a large measures programme to fund the installation and evaluation of technologies costing up to a maximum £7,400 per household, and a smaller measures programme with up to the value of £1,000 per household. It launched in May 2015, with expressions of interest sought from local authorities, housing associations, community organisations and charities wishing to deliver projects in England and Wales.

Over 200 initial expressions of interest were received and NEA invited 75 organisations to submit full proposals. Applications were assessed by a Technical Oversight Group, chaired by Chris Underwood, Professor of Energy Modelling in the Mechanical and Construction Engineering Department at Northumbria University who is also a trustee of NEA. In total, 44 projects were awarded funding to trial 19 different types of technologies and around 70 products (although this number reduced slightly as some products proved not to be suitable and were withdrawn).

More than 2,100 households have received some form of intervention under this programme that has resulted in a positive impact on either their warmth and wellbeing, or on energy bill savings. Of course, the amount of benefit varies depending on the household make up and the measures installed. In a small number of instances we removed the measures and took remedial action.

Technical monitoring and evaluation

NEA has been working with grant recipients to monitor the application of these technologies and assess performance, as well as understand householder experiences and impacts.

A sample of households from each TIF project was selected for monitoring purposes. Participation was entirely voluntary and householders were free to withdraw at any time. This involved the installation of various monitoring devices within the home which collected data for analysis by NEA's technical team. Some residents were also asked to take regular meter readings. In some instances, a control group of properties that had not received interventions under TIF were also recruited and monitored for comparison.

The technical product evaluation was conducted alongside a social impact evaluation to inform our understanding of actual energy behaviour changes, perceived comfort levels and energy bill savings, as well as any other reported benefits. Householders were asked to complete a questionnaire both before and after the installation of the measures which captured resident demographic data including any health conditions. Small incentives in the form of shopping vouchers were offered to maintain engagement over the course of the evaluation period.

The HIP fund was principally designed to fund capital measures to be installed into fuel poor households. A small proportion of the funding enabled NEA to conduct limited research and monitoring of products installed and was restricted to ensure that the majority of funds were spent on the products. All products included in the trials were deemed to offer costs savings and energy efficient solutions as proposed by the delivery partners. The research and monitoring aimed to provide insights to inform future programme design and interested parties of the applicability of the product to a fuel poor household. We recognise that due to the limited number of households involved in the monitoring exercises and the limited period we were able to monitor a product's performance, we often recommend in project reports that further research is needed to better understand the application of these products in a wider range of circumstances over a longer period of time. Seven of the TIF projects involved battery storage, and the following report draws on the learnings from all of these.

The research was conducted according to NEA's ethics policy, which adopts best practice as recommended by the Social Research Association (SRA) Ethical Guidelines 2002.

An accompanying programme of training and outreach work was also delivered to 292 frontline workers to increase local skills and capacity.

Individual project reports are available (once finalised) on NEA's website.

Acknowledgements

NEA is grateful to all project partners who installed the battery systems, and for the contributions to this best practice paper from

Ed Gunn – Moixa
Charlie Vey – Powervault
Alexey Alexeev - Moixa

NEA team:

Bryony Holroyd, Technical Project Development Coordinator
Paul Rogers, Technical Project Development Coordinator
Josh Sawyer, Technical Project Development Coordinator
Paul Cartwright, Technical Project Development Coordinator
Michael Hamer, Technical Development Manager

National Energy Action
Level 6 (Elswick)
West One
Forth Banks
Newcastle upon Tyne
NE1 3PA
www.nea.org.uk

Table of contents

1 Introduction

Domestic energy storage is becoming a well-recognised technology and is often promoted by Photovoltaic Panel (PV) installers and associated companies, as a method of increasing benefits to householders by storing unused electrical energy produced during the day by PV panels for later use when household usage exceeds PV production. However, with the evolving role of the Distribution Network Operator (DNO) to Distribution Systems Operator (DSO), there may be a role for using domestic scale batteries as tools for balancing the local [DNO] network, to respond to extremes of load (high or low), local renewable generation levels, or to aid in the control of AC frequency. Distributed battery systems may therefore provide a tool to assist DSOs to respond to network challenges. Additionally, as battery technologies evolve, efficiencies improve, and costs reduce, there is also a potential role for using batteries in non-PV-related settings, where electricity is used to charge the battery during cheap-rate periods and use it later when electricity is more expensive, for example using Economy 7, Economy 10, or more innovative time-of-use (TOU) arrangements.

1.1 Theory

Although significant amounts of electricity can be generated by a domestic solar PV system during the day, a proportion is likely to be exported to the grid and not used in the home. Adding battery storage enables some of that electricity to be stored in a battery (chemically) for later use in the evening, or when household demand exceeds PV production. Reducing what electricity needs to be purchased from the supplier will consequently save households money and help to tackle fuel poverty.

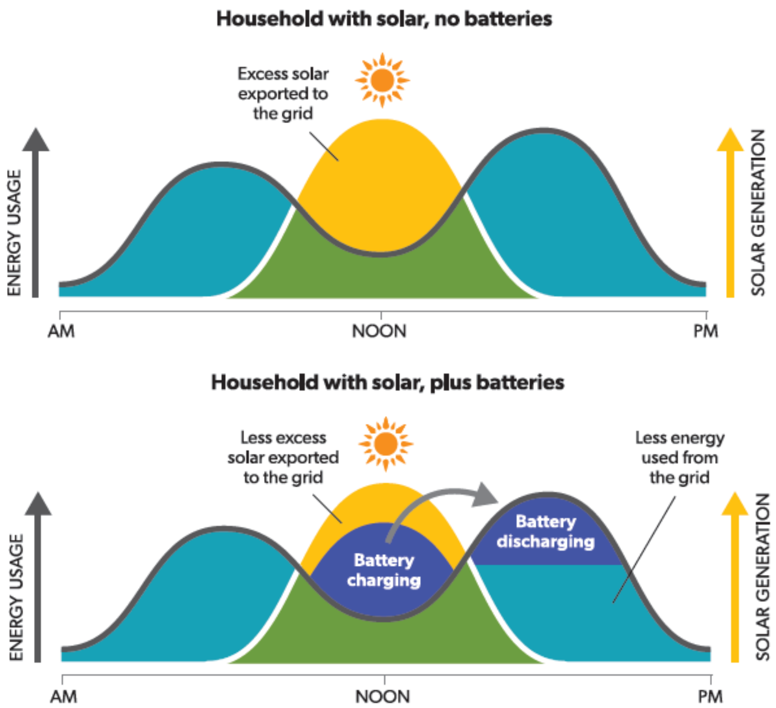


Figure 1.1 Illustration of the benefits of energy storage on a solar PV system[1]

[1] NSW Home Solar Battery Guide (2017),

1.2 Techologies trialled by NEA

- Maslow V3 battery with capacities of 2kWh and 3kWh
- Sonnen eco 8.2 with a usable capacity of 2kWh
- Growatt SP2000 controller and GBLI 5000 battery with a capacity of 4.875kWh
- PowerFlow Sundial SDM-2.0-500 with a capacity of 2kWh
- Victron MultiPlus C-12/800/35 Inverter/Charger with Colour Control GX
- Powervault G200 with 4kWh lead acid batteries
- SolaX X-hybrid inverter with a 4.8kWh Pylontech Lithium-ion battery
- Tesla Powerwall 2
- Nissan X-Storage

Most of the projects trialling the technologies above have an associated report detailing the project make-up and its conclusions, this paper aims to concentrate on experiences across these projects and aims to provide interested parties with a list of considerations to incorporate into any future battery storage project.

1.3 Practical Considerations

There is a large array of battery products on the market, each with their own specific characteristics, and great care should be exercised when selecting a particular system so that it meets the needs of the beneficiary. The section below aims to highlight some variations between systems, the implications for the end user and other key points to consider when selecting a product.

2 Battery systems

2.1 System type

The general makeup of a domestic battery storage unit is a physical battery [chemical storage of electrical energy], an inverter, and a control [management] system. There are two broad configurations – an AC Coupled (Figure 2.1) and a DC Coupled system (Figure 2.2). Table 2.1 briefly summarises the main characteristics of the two systems.

There are a large range of domestic energy storage products available, and an equally large range of physical battery (the electrical storage medium) utilised within the product. The different battery types have different efficiencies, life expectancies, physical sizes (energy densities), environmental sustainability and siting requirements. Some considerations include: ventilation, operating temperature range, discharge power, charging power, available physical space, suitability for outdoor use, number of charge/discharge cycles etc. These are fundamental requirements which must be established at the project feasibility stage or pre-install technical survey.

---

http://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0005/728816/NSW-Home-Solar-Battery-Guide_WEB.pdf (Accessed 15 Mar 2018)

It should be noted that some brands of battery systems (for example Growatt and Victron) require the purchase of a compatible battery separately to the controller, and in some NEA projects, these systems were linked to Absorbent Glass Mat (AGM) lead acid batteries with 50% discharge levels and limited to 700 charge/discharge cycles – meaning systems were constrained and have limited lifetimes.

Lead acid batteries are an established battery technology, used in many applications including conventional automotive batteries. While they have a relatively short life and lower depth of discharge (DoD) than some other battery types, they are quite heavy, but also relatively cheap.

Lithium ion batteries come in several types (chemistry and structure) and are common in new home battery technologies and are generally smaller, lighter, longer lasting and allow a greater depth of discharge (deep cycle) than their lead acid equivalents. As a guide, lead acid batteries exhibit efficiencies in the order of 80%, whereas Li-Ion exhibit round trip efficiencies around 95%[2].

The detailed characteristics and properties of each variant of battery is beyond the scope of this paper, but more details can be obtained from manufacturers or other authors' papers such as "Batteries and Solar Power: Guidance for domestic and small commercial consumers[3]"

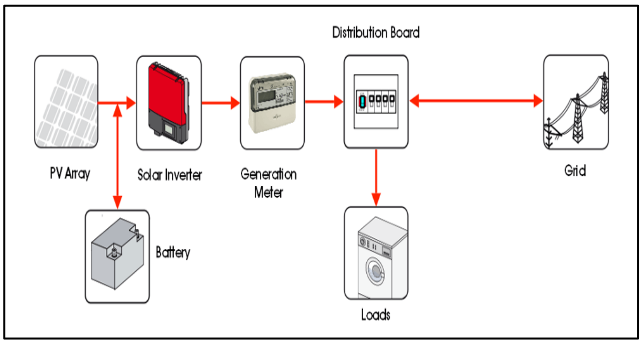


Figure 2.1

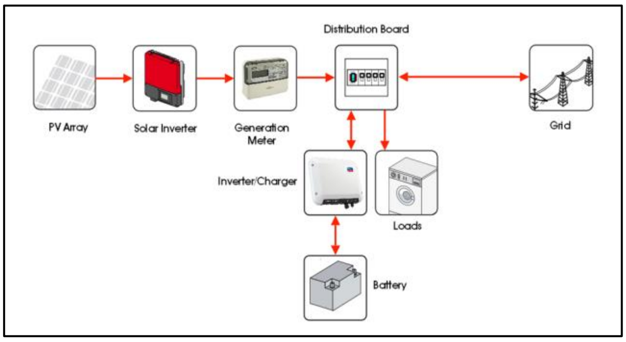


Figure 2.2

DC Coupled	AC Coupled
Potentially lower FITs generation payments	More expensive system
More efficient battery storage system as reduces losses	Does not affect FIT generation payments
More suitable for new builds	Less efficient method of storing electricity due to higher losses
May have compatibility issues with an existing renewables system	More suitable for retrofit
Can be used with a DC lighting system to improve efficiency	

Table 2.1 – Characteristics of AC and DC coupled systems

2 Strathclyde uni paper available at http://www.esru.strath.ac.uk/Documents/MSc_2015/Dodds.pdf [PP36] - Accessed 15/10/2018]
3 Available at https://www.bre.co.uk/filelibrary/nsc/Documents%20Library/NSC%20Publications/88031-BRE_Solar-Consumer-Guide-A4-12pp.pdf [Accessed 09/10/2018]

Considerations

1. Lead acid batteries can release Hydrogen (H_2), particularly when overcharging occurs. This was an issue on one project where some of the lead acid batteries used were installed internally. The H_2 given off by the batteries activated carbon monoxide alarms resulting in the call-out of emergency services. The batteries were later relocated in a purpose-built outdoor enclosure.

2. The efficiency (Round Trip Efficiency) of a system is influenced partly by the battery storage medium employed. Generally, the impact of the battery efficiency is low compared to other inefficiencies in a system. Quantifying this efficiency level was outside of the scope of NEAs projects. Expensive invasive monitoring would have been required to measure [relatively] small energy losses. However, it's worth considering alongside other factors – using manufacturers' datasheets during the project design or procurement phase.

3. Check the actual battery medium being proposed on systems where charge controllers and inverters are purchased separately to the battery storage medium and verify the performance of the proposed battery – some inferior batteries will only supply 50% of rated energy (depth of discharge) and have lifetimes of less than 2 years (700 cycles).

4. Check the lifetime of a system at the purchase point and factor this into any "payback" calculations – many systems on the market will fail before they break even.

5. Check that systems are used within manufacturers' recommended levels and are cycled (allowed to discharge to preset levels) according to their recommendations.

2.2 Usable Capacity

This is a key consideration as it has a major influence on the impact of a system on the end user, whether domestic household or distribution network operator (DNO). In brief, one kWh of stored capacity equates to one kWh of energy which would have been purchased by a householder had the battery not been present. In a simple example, 2kWh of PV generated (electrical) energy stored by a battery and then used in the evening by the householder (where there is no PV generation) will save 2 X cost of a unit of electricity (circa 16p), saving ≈ 32p. Whilst some battery "use" may take place during daylight hours to supply periods where household demand which exceeds PV production, but bear in mind the reasonable savings which may be attributable to battery systems and seek clarity on claims made by sales literature.

In addition, product literature often quotes battery capacity from the physical battery manufacturers specification, whereas in practice, this does not reflect the "usable capacity" available to a householder. Frequently a battery must not be discharged below a certain level, so "usable capacity" is the value of interest. One current example is for a product which is marketed as a 2kWh system, has a usable capacity of 1.6kWh.

According to BRE in their publication "Batteries and Solar Power" - typical Lead-acid battery systems may be set up to limit the 'depth of discharge' to around 50%, Lithium-ion systems to 75% or more[4]. Some manufacturers recognise this, and quote "usable capacity" as the headline figures in product literature – in these cases, batteries are larger than this to allow for depth of discharge. Some manufacturers don't quote these usable figures, and quote installed battery capacity, inflating realistic capacities available for householder use.

The usable capacity of a battery system being considered should be matched to the PV generation capacity (kWp) and the inverter size of a solar system, as well as ensuring that the domestic consumption profile means that there is excess PV energy to be stored, and a period for its use later in the day. In some cases, in NEA's trials, the inverter capacity was so small and household consumption so high that there was little excess solar generation that could be stored.

[4] Available at https://www.bre.co.uk/filelibrary/nsc/Documents%20Library/NSC%20Publications/88031-BRE_Solar-Consumer-Guide-A4-12pp.pdf [Accessed 15/10/2018]

Considerations

1. Battery capacity should be considered alongside the cost of the system (business case and "payback"), and the ability of a system to lift households out of fuel poverty. Larger batteries may allow for a larger household energy cost saving).

2. Pay particular attention to batteries procured separately to the charge controller and inverter (e.g. SolaX and Victron). Some low-cost batteries (the storage medium) are poor performing in terms of available capacity and lifetime.

3. Household consumption patterns should be closely scrutinised, and a battery size selected which is matched to consumption in the relevant period where the battery is planned to supply most of the demand. Some households (especially those in fuel poverty) could have small energy requirements compared to more affluent households – one size does not fit all.

4. "Usable Capacity" is an important parameter to consider. Some battery manufacturers quote actual battery capacity – which is not all available to the end user, leaving residual charge levels to protect the battery. Other manufacturers effectively oversize the battery to quote actual capacity available to the end user.

5. PV size should be considered, as battery should be matched to the predicted energy production levels kW(p) and household consumption levels to maximise storage and use of the "free" electricity.

6. Battery inverters should be sized appropriately to allow for appropriate battery discharge rates and household consumption (supply), to ensure maximum benefits from the battery (within battery design parameters) to be achieved.

7. If a project is using "off peak" charging of the batteries, great care should be taken to ensure that the additional charging load imposed by the battery will not jeopardise the integrity of the main supply fuse and take the demand above the permitted levels for the property (generally 63A, 80A or 100A). It is also recommended that the DNO be consulted on supply limits as fuse labels on distribution boards in properties are often inaccurate.

2.3 Minimum (cut in) and maximum power (rated) output

The battery systems tested by NEA had varying characteristics, with “cut in” power varying widely across the technologies. These levels are pre-set by manufacturers to reduce unnecessary inverter losses at low supply levels (low efficiencies). Some systems did not supply power to the property until the demand had exceeded 300W, so a low-consuming household could not benefit from the battery until after demand had risen above 300W, which was rare in some cases. Conversely, the maximum power supplied by another system was 430W, meaning that a high using household may only have a small proportion of energy supplied by the battery at any one time - limited to 430W.

Considerations

1. Battery cut-in power should be matched to battery recipients’ energy use characteristics – some batteries with high “cut-in” power levels may not benefit low energy consuming households.

2. Battery system maximum supply power should be considered when selecting a product, so the majority of energy can be supplied by the product in any 24-hour period. Some products tested by NEA had modest supply levels [around 400W], limiting benefit to some households.

3. Consider the min and max supplied power alongside other factors such as usable capacity, checking that usable capacity is matched to the consumption patterns.

4. Check with manufacturers whether the operating bands (cut-in and maximum power) can be changed to suit household characteristics – some of the models used in NEA’s trials were changed during the project once the impact of the preset levels became apparent.

2.4 Power-cut functionality

Often termed "island mode" among the battery industry, some battery systems provide functionality for providing power during a power cut, and the authors are aware that several are considering this as a future development to their system. A simple system (as the Powervault G200) provides a standard 13A socket on the front of the battery case which remains energised during a power outage. More complex systems (requiring DNO permissions and some protective electrical engineering work[5]) such as the Tesla Powerwall 2[6], can provide mains power in the event of a power cut through their "gateway", another system providing this functionality being the Sonnen ecoLinx[7].

Often prospective purchasers of a battery system are incorrectly informed that a battery will provide power in the event of a power cut.

In NEA projects involving the PowerVault system, some batteries were located in purpose-built outdoor enclosures (due to the lack of space in the small properties selected for the project). This arrangement prevented the householder having access to the 13A socket, mounted on the front of the powervault unit, which provides mains power in the event of a power cut. As a result, householders could not take advantage of the mains supply available during a power outage.

Considerations

1. Whether or not a battery is required to provide energy during a power cut should be considered early in the project scoping – which will limit the systems in scope. Household circuits may require some reconfiguration.

2. Whilst it is possible to design a third-party supporting mechanism to utilise a battery to supply a property during a power outage, it is considered cost prohibitive and less reliable than using a system designed to provide this as part of its inherent design.

3. Check with the local Distribution Network Operator what requirements are needed to allow for a battery which provides island mode (power cut) functionality during a power outage. Batteries are regarded as "generation" by the DNO, meaning some permissions may be required to connect them to the network. Minimum standards are required to be met to protect linesmen working on a fault on the cables feeding the property/area, generally falling under the G83 or G89 engineering standard (available from the relevant DNO).

[5] Available at http://www.energynetworks.org/electricity/engineering/distributed-generation/engineering-recommendation-g83.html [Accessed 15/11/2018]
[6] Available at https://www.tesla.com/en_GB/powerwall [Accessed 08/10/2018]
[7] Available at https://sonnen-batterie.com/en-us/ecolinx [Accessed 08/10/2018]

2.5 Round-trip efficiencies

A battery's round-trip efficiency is the amount of energy that can be used as a percentage of the energy that was provided to charge it. The diagram (Fig 2.3) below illustrates this. A DC coupled system will generally be more efficient as there are no losses from an inverter.

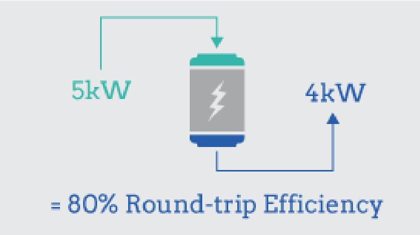


Figure 2.3

Manufacturers usually quote this point which should be considered along with other parameters before making a product choice. Round trip efficiencies are impacted by the "cut-in" power levels, as inverters use energy to perform their role of converting DC energy from the battery to AC mains voltages. Ensuring the inverter does not operate until household demand rises above a level is sensible as it only switches on when energy savings exceed the energy required to operate the inverter and improves efficiency. However, this prevents very low energy consuming households benefiting from the battery for much of the time.

When the battery is charged by free solar electricity which would otherwise be exported to the grid, the round-trip efficiency of the battery system is not critical to the owner. However, when the battery charges using off-peak electricity and discharges at a time when electricity is more expensive (price arbitrage), it is more important that the round-trip efficiency is as high as possible to maximize the savings.

The generation feed-in tariff (FiT) is paid for every kWh generated by the solar PV system, and is recorded by the solar generation meter. When a battery is installed on the solar PV (DC) side of the generation meter (i.e. DC-coupled), the solar electricity that charges the batteries is not recorded by the generation meter, and lower FiT payments result.

Considerations

1. Check the round-trip efficiency of a system and consider along with other parameters. There is a trade-off between battery cut in power and efficiency.

2. Consider installing DC lighting circuits if efficiency is paramount, or the households are particularly low users of energy. This removes the need for the inverter to supply relatively low levels of power for lighting only.

3. DC coupled systems will reduce the FIT payments paid to owners. Consider the merits of this when selecting a system – lost FIT vs. increased efficiency.

4. A high round-trip efficiency is particularly important if charging off the electricity grid.

2.7 Connectivity

Connectivity to external systems and monitoring platforms was the **single most important challenge** seen in the NEA trials. The need for WiFi connectivity, and complexity in providing it should not be underestimated. Every NEA battery trial suffered from internet connectivity issues – whether WiFi, 3G, 4G, GPRS. On some projects, domestic batteries were fitted in properties which did not operate for over 2 years whilst broadband or mobile network-based connectivity was arranged. In some cases, project partners had not recognised that their chosen battery product required a WiFi (or similar) internet connection to function. Using “powerline adaptors” to couple battery systems to more remote WiFi routers had limited success and presented several issues over the course of the project lifetimes, requiring attendance on site or household intervention.

The need for WiFi varies across the systems, with some systems providing a basic functionality in the absence of internet connectivity (often in a less optimal way). Others may switch to a standby mode after an event such as the PV system tripping out. With the battery offline, the manufacturer cannot detect the battery is not operational and resolve the issue

Another frequent finding from the battery storage trials, was through PV system failures which were long term and generally not followed up by householders and/or system owners. Multiple failures were observed before, during and after monitoring. When there is no PV energy production, households cannot benefit from “free” PV energy, or the subsequent supply from the battery. In addition, system owners do not benefit from feed-in tariff or export revenue from the system, undermining business models and losing revenue.

considerations

1. At project inception and technical survey stages – thoroughly investigate the status of any WiFi present and/or conduct feasibility study on providing reliable WiFi.

2. If a dedicated landlord-supplied WiFi solution is planned, consider where it is sited, the range, the location (and signal strength) for outlying installations and if "daisy chaining" is used by the battery systems in a locality – carefully consider the implications if there is a tenancy change or a battery is removed. Factor in backup systems.

3. Check how the battery handles WiFi outages – many systems lose data when WiFi goes down, whilst others store data in internal [buffer] memory for later transmission to systems once WiFi connectivity has been restored.

4. Check if backup connectivity can be linked to the battery product using alternative networking options such as 3G 4G GPRS etc. and check signal strength **AT THE INTENDED BATTERY LOCATION** – in the property or in enclosure. Don't rely on Ofgem (or other provider) mapping of mobile network signal strengths.

5. Check with resident how the WiFi is operated in the property – many residents turn off the router at night and at times they are not requiring internet. The battery may require continual connection – **CHECK**.

6. Obtain householder consent for broadband (WiFi) use by the battery system, and commitment that routers will be left connected. Check if there is any "alarm" signal whereby householders can be alerted to a WiFi problem.

7. Don't rely on standard "powerline adaptors" or other WiFi range extenders as they did not prove reliable in NEA trials, requiring frequent resetting and re-pairing, which residents are often uncomfortable with, or irritated by. Hardwired was the most reliable method.

2.8 DNO permissions and notifications

The local Distribution Network Operator (DNO)[8] is responsible for the local distribution network (low voltage up to 33kVA) supplying homes and businesses. In order to manage the networks safely and efficiently, the installations must meet engineering standards[9] which must be adhered to.

DNOs categorise electricity storage (including domestic scale battery storage), as non-intermittent generation as set out in Appendix 1 of the DNO distribution charging statements[10], and as such, the following main standards are applicable. This does not include the electrical works in the property which are governed by other standards as defined in 18th edition[11] IET wiring regulations and manufacturer's instructions.

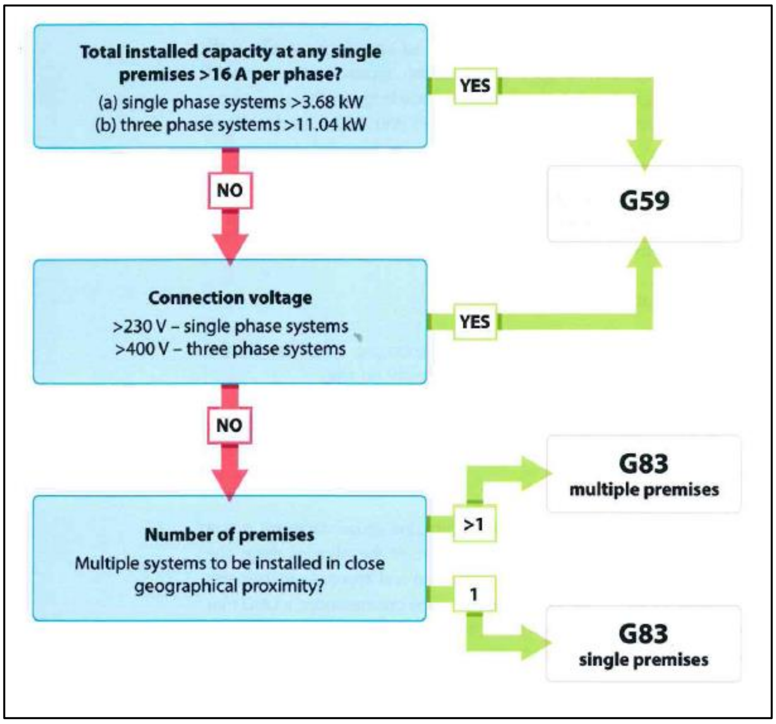


Figure 2.4

Engineering Recommendation G83 relates to the connection of Type Tested Small-Scale Embedded Generators (Up To 16 A Per Phase) In Parallel with Public Low-Voltage Distribution Networks (3.68 kilowatts (kW) on a single-phase supply and 11.04 kW on a three phase Supply).

Engineering Recommendation G59/3 Amendment 3 – relates to the connection of generating plant to the distribution systems of licensed distribution network operators where generation is above 3.68kW or and/or >230v. Figure 2.4 summarises the criteria.

---

[8] http://www.energynetworks.org/info/faqs/electricity-distribution-map.html [Accessed 22/10/2018]

[9] http://www.energynetworks.org/electricity/engineering/engineering-documents/engineering-documents-overview.html [Accessed 22/10/2018]

[10] http://www.energynetworks.org/electricity/regulation/distribution-charging/distribution-charges-overview.html [Accessed 19/11/2018]

[11] https://electrical.theiet.org/wiring-matters/issues/61/bs-7671-the-18th-edition-report/ [Accessed 23/10/2018]

Considerations

1. Thoroughly investigate peak electricity use – several situations where larger batteries were fitted in properties which were heated electrically (and charged by "off peak" or time-of-use tariffs) risked drawing currents above the rated supply limit for the property (DNO fuse), and charging had to be limited.

2. Plan to submit applications to DNO as soon as possible allowing for discussions and modified applications. Some situations where NEA fitted batteries were initially refused, resulting in site visits and subsequent delays to the installation process.

3 User Considerations

3.1 User interfaces

Most battery systems had no user-configurable parameters. Some systems had indications of charge levels, or “indicator lights” to indicate health, but in some cases, it was not clear what the indicators meant, with flashing light, steady state light or different colours representing different health states.

Battery charge indicators on some systems were inaccurate, and in some cases, residents were told by product representatives to ignore them. Users need to be confident that systems are operating normally and have clear indications of what indicators mean.

Some systems have associated “online” portals or smart phone “apps” which presented data in different ways. Whilst the data was often useful to NEA project evaluation staff, it was sometimes complex and confusing to residents and system users, and few ever accessed it.

In several cases (across multiple projects), systems were installed in lofts or outside cabinets, making regular inspection difficult. Some residents did not have the necessary smart device on which to install an app, and many did not have broadband, meaning that when systems failed, householders did not know.

In terms of data availability to the project team for analysis, ability to download data varied widely across the systems. Some systems did not allow raw data to be downloaded, providing graphs and other information on screen, with the only mechanism to capture data for reporting was through a “screen shot”, taken laboriously on a daily basis. Some manufacturers provided data under a separate agreement, and a few product interfaces did allow access to the data as standard.

In some projects, despite assurances being given to project staff that data would be shared at the reporting stages of projects, data was generally difficult to obtain. This was partly due to concerns over data-sharing – possibly compounded by the implementation of the General Data Protection Regulations (GDPR) which came into force during some of the project timescales.

Considerations

1. Consider the on-site displays (or ability of recipients to check an app or portal) or ensure provision is made to allow remote monitoring (interrogated periodically by a third party) and/or set up automated alerts to highlight failures or system underperformance.

2. Advise users of what to do in the event of a query, fault or emergency situation.

3. Install systems and user interfaces in accessible locations. In some projects, inverters, metering and batteries were fitted in lofts, and householders had no physical or authorised means to access them. High temperatures in lofts also reduces the lifespan of battery systems and inverters.

4. Consider the quality and interpretability of the user interface and whether it is accessible, usable and meaningful to the proposed audience.

5. Consider whether landlords, project evaluation staff and other interested parties require data from the systems and agree/set up robust data-sharing agreements and system access agreements BEFORE purchasing systems. In several projects, data availability was "promised" and written into project contracts, but when it was requested, several months of negotiations were required to secure access.

3.3 Workmanship

NEA saw a broad range of quality issues with regard to the installations across some of the projects. Battery systems are required to be installed according to current IET standards, but installations are often restricted to a manufacturer's network of approved installers, trained and certified on the installation and setup of the product. There were less issues with these situations than those installed by other electricians less familiar with renewable installations.

The Renewable Energy Consumer Code (RECC) is a customer protection scheme approved by the Trading Standards Institute (TSI). The Code covers within its scope battery storage systems and other products typically sold alongside solar panels and helps to provide confidence to customers. Some battery manufacturers have "signed up" to the RECC scheme. RECC provides confidence that there is a dispute resolution service if situations become difficult with installers.

RECC's document – "*Battery Storage for Solar power: guidance for sellers/installers*[12] is a useful reference for a prospective battery system customer and provides a list of facts (pp 6-10) to consider when choosing a system.

The Microgeneration Certification Scheme (MCS)[13] is a nationally recognised quality assurance scheme, supported by the Department for Business, Energy & Industrial Strategy (BEIS), whose

[12] https://www.recc.org.uk/pdf/guidance-on-battery-storage.pdf [Accessed 24/10/2018]
[13] https://www.microgenerationcertification.org/ [Accessed 24/10/2018]

website provides a list of accredited installers. Whilst battery systems currently do not require installation by an MCS-registered installer, it is good practice to do so. Battery storage is closely interfaced with PV systems which does require MCS registration (if government incentives or funding is involved); it is a useful way to ensure that installers are familiar with the domestic systems they will need to work on.

The Publicly Available Specification (Standard) known as PAS2030[14] provides guidance for the design, commissioning and installing of energy efficiency measures in existing buildings. Any installation of insulation, renewable generation (including PV) must be installed by a company complying with PAS2030, and the standard is recognised by government-led programmes. Whilst this standard does not specifically cover battery installation currently, it does ensure a quality-controlled installation from planning and specification to installation. It is therefore recommended that it is good practice to instruct installers holding this certification if possible, as it provides enhanced confidence that quality standards and adequate planning is in place.

Considerations

1. Check with manufacturers whether the product has a quality assurance scheme, and approved list of installers - trained on the **specific product** and who are monitored for quality by the product manufacturer.

2. Advise householders of the process for reporting a fault and the contact details of the organisations to contact in which circumstances.

3. Check guarantees carefully before committing to purchase a product, including the warranty on a battery. Sometimes warranties allow for significant degrading of the battery during the warranty period, reducing usable capacity and end-user benefit over time. Whilst battery degradation is inevitable – it's the threshold allowed under the warranty which should be noted.

4. Use MCS-accredited installers with a proven track record of installing batteries in domestic situations.

5. Consider instructing installers operating under PAS2030(2017) standards where possible (although this is not critical).

[14] https://shop.bsigroup.com/ProductDetail?pid=000000000030353572 [Accessed 19/11/2018]

3.4 Guarantees and Warranties

A domestic battery should have a written warranty that guarantees a certain number of cycles and/or years of useful life. Because battery performance degrades over time, manufacturers should also guarantee that the battery keeps a certain amount of its capacity over the course of the warranty. Battery degradation is influenced by the battery technology and its use pattern, but manufacturers should provide an estimate of lifetime and specify any special conditions required to be met (such as the requirement for reliable WiFi or requirements around battery "cycling").

The aim of the Renewable Energy Consumer Code (RECC) is to ensure that consumers wishing to install a small-scale heat or power generation unit for their homes have the necessary confidence and service standards so that they can make an informed choice.

The *Code of Practice for Electrical Energy Storage Systems*[15] was published on 7 August 2018 by the Institution of Engineering and Technology (IET) and is designed to provide detailed information on the specification, design, installation, commissioning, operation and maintenance of an energy storage system.

RECC publishes a checklist - *Battery storage for solar power: guidance for sellers/installers*[16] which provides a good basis on which to question prospective installers. The joint BRE and RECC document *Batteries and Solar Power: Guidance for domestic and small commercial consumers*[17] also provides good overview of systems and suggests 20 questions to ask installers (pp8). It is recommended that prospective purchasers are familiar with these documents.

Considerations

1. Check with manufacturers whether the product has a warranty, and whether the installation is through a list of approved installers.

2. Investigate warranty requirements – some manufacturers require internet connectivity to qualify, and some require householders to register for the warranty themselves (even if financed by a project or landlord), so support and follow-up is required to ensure this is completed in a timely manner.

3. Check if the warranty is "on site" as there is a considerable expense associated with removing and shipping units to service points. Lithium-ion batteries are regarded as hazardous material and command very high carriage and insurance charges by couriers.

---

15 https://www.theiet.org/resources/standards/eess-cop.cfm [Accessed 15/11/2018]
16 https://www.recc.org.uk/pdf/guidance-on-battery-storage.pdf [Accessed 23/10/2018]
17 https://www.bre.co.uk/filelibrary/nsc/Documents%20Library/NSC%20Publications/88166-BRE_Solar-Consumer-Guide-A4-12pp-JAN16.pdf [Accessed 23/10/2018]

3.5 Financial

Monetary savings on energy bills is a prime factor in deciding whether to install systems in domestic properties. There are lots of factors affecting savings, as mentioned previously including household electricity consumption patterns, PV sizing and output, size of battery etc. In brief, the size and usable capacity of the battery dictates the potential savings which can be achieved, if sufficient PV energy (or low-cost energy) is available to charge them fully, and consumption in the charge – discharge cycle to use it. Previous sections covered sizing considerations, but it is important to pay attention to this area. In NEA trials, savings ranged from 20p per day (for a small PV-connected system) to £1.20 per day (for a large “off peak” charged system with high household consumption). Small systems will provide smaller potential savings as < 2kWh can be stored.

It is worth considering the loss of FIT in the case of some system types – mainly through system inefficiencies. In certain circumstances, the FIT is paid on the amount of energy the generation meter shows your PV system to have generated. With ‘AC-coupled’ batteries, the output of the PV system is registered by the generation meter before any battery is charged from it. But ‘DC-coupled’ batteries sit on the other side of the generation meter. In effect, they charge from the PV system before that output has registered on the meter. When the batteries discharge, that output is registered on the generation meter. Since all batteries lose energy in the charge-discharge cycle, some of the original PV output, and the FIT that would have been paid on it, is lost.

“Grid Services[18]” are a new concept at the domestic level. Multiple batteries can be aggregated together to provide a resource which can be sold to the grid services markets but requires an administrative body to provide this service. Some manufacturers have their own platforms and arrangements to allow this, and it is possible this will become more prevalent in the future.

Considerations

1. Perform calculation to check claims over potential savings – 1 kWh ≈ 16p saving on energy bill if all other factors are satisfied (PV energy availability, household consumption outside of PV generation times.

2. Consult installers’ projections and check they provide the necessary detail (as shown in the RECC checklist “*Battery storage for solar power; guidance for sellers/installers*”, or the 20 questions to ask your installer as found in “*Batteries and solar power: Guidance for domestic and small commercial consumers*” referenced earlier.

3. Consider any implications on FIT (if applicable). Lost FIT is likely to be small but should be factored in for the system being considered.

4. Consider the business case and payback timescales (factoring in product lifetimes)

5. Consider (if appropriate) revenue available from providing “grid services” to DSOs and/or National Grid – through a manufacturers system. Check which systems provide this service and capability.

[18] http://powerresponsive.com/wp-content/uploads/pdf/Power%20Responsive%20Guide%20-%20v8.pdf

3.6 Training and support

A cross-cutting theme found in varying degrees through all NEA's trials was the lack of understanding by the residents of the battery technology, and the PV systems themselves. Often PV had been installed some time before the battery system was installed, and householders frequently did not know what the PV systems did, or how to maximise the benefits of them to reduce electricity bills. All projects delivered some level of training and guidance but findings from social questionnaires showed that more was required.

Considerations

1. Provide independent guidance to the resident on best practices to maximise benefits of the systems.
2. Provide residents with written "quick start" guides how to check systems are working.
3. Provide detailed instruction on how to set up, access and interpret information on portals (if any), including installing APPs (if applicable).
4. Provide contact number for future support needs.
5. Provide continuing support and follow-up visit/contact after approximately 8 weeks of stable use to check understanding and whether benefits have been realised.
6. Householder instruction on how to optimise the savings on energy bills from the battery are essential – followed up with periodic reminders.
7. A process should be in place in rented property situations whereby training is provided to new tenants moving into a property on the optimal use of the systems.
8. Provide list of contact numbers for residents to use in the event of a query/report issue.
9. Consider installing remotely monitored systems and provide process within the organisation to regularly check systems. Follow up and rectify failures and provide user support where a need is identified. Many PV systems were found to be inoperative or failed during projects and were not repaired.

4 Product Evolution – Incorporated Learnings

During the course of NEA's projects, and ongoing work with manufacturers, some learnings have been incorporated into product design and best practice for installing systems in low-income and vulnerable households.

Some of these improvements are listed below – grouped into Social (engagement) and Technical.

4.1 Technical

Throughout the project lifetimes, several factors were observed where changes to the product could improve usability, monitoring or performance of systems. Many points are highlighted in previous sections, but those improvements made to products during the project are listed below.

Considerations

1. In some projects and with some products, cut-in power was reduced to allow systems to provide benefits to low-consuming households.
2. In the third-generation Powervault battery - *Powervault 3* – product evolution ensures better energy savings to tenants and householders through improved power architecture and better round-trip efficiencies.
3. Some manufacturers such as Moixa (initially with their Maslow battery) and Powervault have investigated and developed systems to generate an income for tenants, system owners or homeowners if they allow their battery to support the grid when it is under stress.
4. Some manufacturers developed improved "online platforms" allowing monetary savings to be seen by householders.
5. Some manufacturers developed platforms allowing the visualisation and monitoring of multiple installations to make it easier for landlords and other interested parties to check system health and performance easily.

4.2 Social aspects & resident engagement

Several of the projects suffered issues in the engagement and selection of householders to be involved in the study, along with continued support from households to enable the socio-technical evaluation to be effectively conducted. Table 4.1 below lists the key considerations to employ in any future projects.

1. In any grant-funded programme involving evaluation – provide detailed and clear requirements to applicants to commit to assist with the evaluation of technologies.

2. Include a monetary retention in any grant programme – payable on satisfactory completion of the **evaluation phase** of the project – not just installation phase.

3. In any grant-funded programme, hold detailed initiation meetings covering technical evaluation requirements, and involve a product representative.

4. Ensure projects involving multiple delivery partners have clear documented roles and contractual responsibilities.

5. Ensure grant recipients/project delivery bodies have strong project management capabilities and understand the technologies and recipient audience.

6. Allow sufficient time (3-6 months) for the resident selection and engagement phase of a project.

7. Select households where there is a commitment to providing the necessary data (energy bills) and to work with the researcher to obtain data from energy companies (such as smart metering data) – it is not enough to rely on small incentive payments.

8. Select households who can benefit from the technology.

9. Select properties where there is space to install the kit in a sensible and agreed place.

10. Select properties where there is reliable Internet, WiFi or availability of mobile networks. Availability of network should be established early in the selection process – before engagement with householders commences so that the required communications networks for the products under consideration are confirmed to be available, or technical solutions available. Connectivity is essential to maintain battery performance, monitor its operation and allow data to be collected for analysis.

11. Understand the individual households involved, provide bespoke advice and support to allow for optimal benefits of the technology to be realised – tailored to energy profile, battery characteristics and expected savings.

12. Use incentives carefully at the recruitment stage of projects– pre-select the "ideal" candidates to target for installations and/or to be part of a monitored group and only offer incentives (shopping vouchers etc.) once negotiations and agreements have advanced, otherwise the shopping vouchers often become the **focus** of discussions. Use them to incentivise ongoing project support and provide them (or some of them) at the **END** of the project when information is supplied.

13. Locate and engage with "local" energy/project champions (who are known and trusted locally) to assist with issues such as support with best practice and accessing monitoring portals, obtaining utility meter readings from energy companies for evaluation purposes, and to investigate and RECTIFY CONNECTIVITY ISSUES as they occur.

Table 4.1 – Key social considerations for future residential battery evaluation projects

5 External References and Guidance

Title	Brief	Source
Batteries and Solar Power: Guidance for domestic and small commercial consumers	Guidance for interested parties on fitting small scale battery storage	http://www.bre.co.uk/filelibrary/nsc/Documents%20Library/NSC%20Publications/88166-BRE_Solar-Consumer-Guide-A4-12pp-JAN16.pdf
Electrical energy storage – an introduction	Key considerations for the selection of electrical energy storage systems	https://www.theiet.org/resources/standards/eesstb.cfm?origin=/energy-storage-intro
Upgrading our Energy System	High level & historical information on licensing, planning, connections and charging for storage, and co-locating on the same site as renewable generation.	https://www.ofgem.gov.uk/system/files/docs/2017/07/upgrading_our_energy_system_-_smart_systems_and_flexibility_plan.pdf
Energy Storage – A guide towards a commercial model	Regen SW published easy to read guide on community energy storage	file:///C:/Users/mhamer.NEA/Downloads/P2P%20-%20Energy%20storage%20-%20Towards%20a%20commercial%20model.pdf
NSW Home Solar Battery Guide	Published about Australian systems, but good description with easy to read descriptions	https://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0005/728816/NSW-Home-Solar-Battery-Guide_WEB.pdf
Guide to Installing A Household Battery Storage System	Published about Australian systems, but good, easy-to-read descriptions and overview of DC and AC coupled systems and battery chemistry	https://www.solaraccreditation.com.au/dam/cec-solar-accreditation-shared/guides/guide-to-installing-a-household-battery-storage-system.pdf
Battery storage for solar power: guidance for sellers/installers	Checklist on standards and protections from the renewable Energy Consumer Code	https://www.recc.org.uk/pdf/guidance-on-battery-storage.pdf

Table 5.1 – Useful External Publications

6 NEA reports incorporating battery storage

NEA funded several projects to install batteries in specific situations and conduct evaluations on a small sample of those installed properties. Table 6.1 below lists those projects. The report (where available) and status of the reports are available at:
http://www.nea.org.uk/hip/projects/?s=&hipprogramme=technical-innovation&hiparea=&sortBy=

Enter the Project reference in the keyword search box.

Project Ref	Project Description	Battery Technologies	Report Status
CP745	Project to install and compare 3 battery systems in various property types owned by social housing providers, in London	Moixa Sonnen Growatt	Published
CP748	Project to install Moixa batteries and separate electric heating technologies	**Moixa** (with Dimplex Quantum and Infra-Red heating)	NOT PUBLISHED
CP755	Project to install batteries in communal buildings	PylonTech	Published
CP775	Project to install 3 battery types in private housing	Moixa Victron Powerflow	Published
CP776b	Project to install PowerVault in small social housing situation	PowerVault	To be published March 2019
CP782	Project to install Battery storage and separate PV energy share system	Moixa	To be published March 2019
CP1139	Project to install (larger) battery (tesla Powerwall 2) in electrically heated properties – charging off peak.	Tesla Powerwall 2	To be published March 2019

Table 6.1 List of NEA project funded 2016--18

7 Glossary

A	Ampere or AMP- the unit of electrical current
AC	Alternating Current
AGM	Absorbent Glass Mat (a lead acid battery type)
APP	A software application Programme), often installed on a mobile device
BEIS	The Department for Energy and Industrial Strategy
BRE	Building Research Establishment
DC	Direct Current
DNO	Distribution Network Operator
DSO	Distribution System Operator
EAS	Energy Action Scotland
FIT	Feed-in Tariff
GDPR	General Data Protection Regulations
GPRS	General Packet Radio System
HIP	Health and Innovation Programme
H_2	Hydrogen (the gas)
IET	Institution of Engineering & Technology
kWh	Kilowatt Hour (unit of electrical energy)
kW(p)	Kilowatt Peak (peak electrical production)
MCS	Microgeneration Certification Scheme
NEA	National Energy Action
OfGEM	the Office of Gas and Electricity Markets - The Energy Regulator
PV	Photo Voltaic (Panels)
RECC	Renewable Energy Consumer Code
SRA	Social Research Association
TIF	Technical Innovation Fund
TOU	Time-of-Use (tariff)
W	Watt (Unit of electrical power)
WiFi	WiFi – wireless internet commonly found in buildings (wireless networking)

NEA Technical
March 2019

NEA
Action for Warm Homes