The role of batteries in the optimisation of energy systems in community buildings in North East Scotland

A review of the literature

Vattenfall Unlock Our Future Fund

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1. Introduction

A literature review explored the current extent, use, and uptake of battery systems in village halls in the Scottish context. The literature on grid scale and household batteries is growing, from both a technical and engineering perspective and from a just transition, fuel poverty and community development perspective. While literature on village halls is minimal and not generally covered in the broader literature, this review draws upon arguments made in the context of household and local battery deployment, analogous to use in the community context. The review covers the development of the UK and international battery market, the current state of technology, the roles that batteries can play in halls and communities and a series of case studies of village halls using batteries in Scotland. Integrated renewable (solar PV) and battery storage projects are relatively new to market, having been installed after the Covid 19 crisis and lockdown. As much of the evidence is anecdotal and emergent, there is a further need for targeted quantitative evidence beyond a literature review. This would be useful to target how case studies for example have fared in the 1-2 years operation and if expectations on savings or opportunities such as local smart grids have emerged.

The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 legally binds Scotland to achieve net-zero greenhouse gas emissions by 2045, five years ahead of the UK's target.[1] By 2030, Scotland aims to reduce emissions by 75% compared to 1990 levels.[2] The climate strategy includes measures to promote renewable energy, increase energy efficiency, transition to electric vehicles, and enhance sustainable land use. In Scotland there are considerable challenges in resolving fuel poverty, heat in buildings, transport and just transitions of workforces and communities to Net Zero.

This review sourced material from selected journal titles and databases including from Science Direct, Google Scholar, Web of Science databases, and Research Gate. The databases were searched for keywords including: *battery energy storage, community batteries, community energy storage, system policies, community hall efficiency, solar panels and battery storage and batteries optimising energy systems.* The initial search screened journals with a focus on topics of relevance to either community halls or policies/projects from the last 5 years with relevant data. In addition, use was made of policy and industry reports, data and statistics of relevance to the battery market, use and deployment.

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[1] Scottish Government. Source: https://www.gov.scot/policies/climate-change/

[2] Scottish Government: https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/pages/2/

2. The battery market in the UK.

The battery market is showing signs of consistent growth. There are two distinct sections of the battery market, the utility scale network sector and the domestic energy sector. In order to meet the UK and Scottish targets for Net Zero (N-0) respectively by 2050 and 2045, there will need to be significant investment and deployment of storage systems (including but not limited to batteries) to able to store, manage and deploy power from a large number of intermittent and decentralised renewable energy systems at scale.

The use of batteries to support energy storage is rising in the UK with most growth in the large capacity grid firming market (Figure 1). The use of batteries in energy systems supports the intermittency of renewable energy sources, both at grid and network scale and in household or community systems that rely on solar or wind energy. In the UK, a 2019 report[3] identified that 10,000 homes in the UK were using battery storage, equating to 0.04% of households. Though demand for battery storage has grown in recent years, a sizeable gap between the number of homes with solar PV and the number of homes with storage batteries remains.

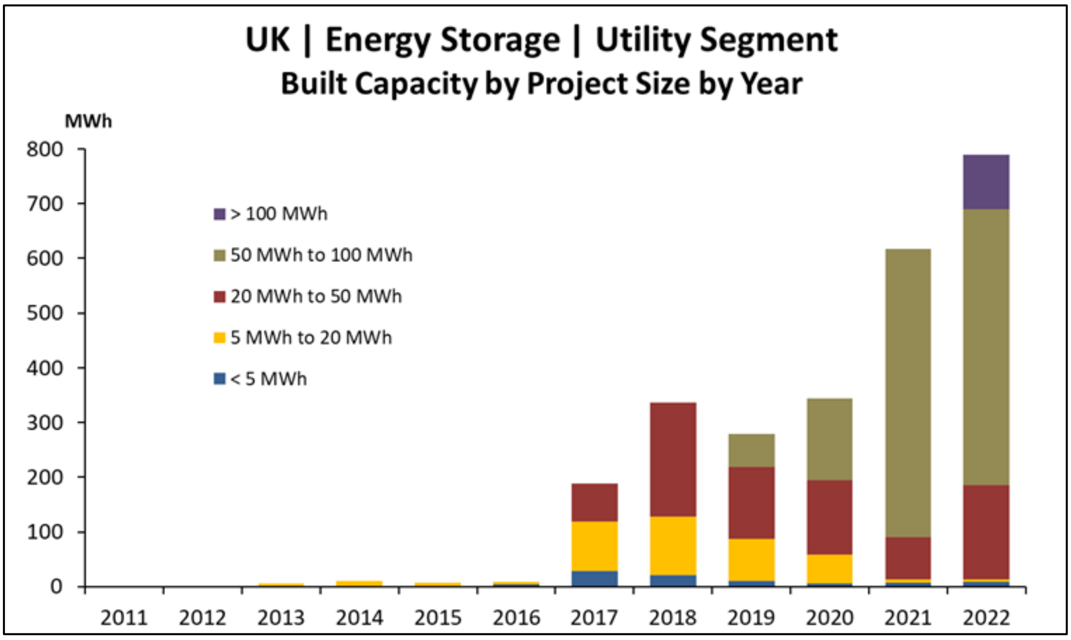

Figure 1 Built capacity of energy storage in the UK by project size by year Source: UK Battery Storage Project Database 2023

[3] Whitespace Strategy 2019. Source: https://whitespacestrategy.com/wp-content/uploads/2020/02/Domestic-Energy-Storage-Insights-Implications.pdf

3. Battery energy storage systems.

BESS are essential for improving efficiencies in small scale and grid scale energy systems; however, they must be appropriately managed to meet energy demand. Battery storage systems are used to regulate voltage and frequency, reduce peak demand charges, integrate renewable sources, and provide a backup power supply.

Lithium-ion (L-O) batteries are experiencing increasing demand in the energy storage market from initially declining prices that have levelled out in recent years (Figure 2).

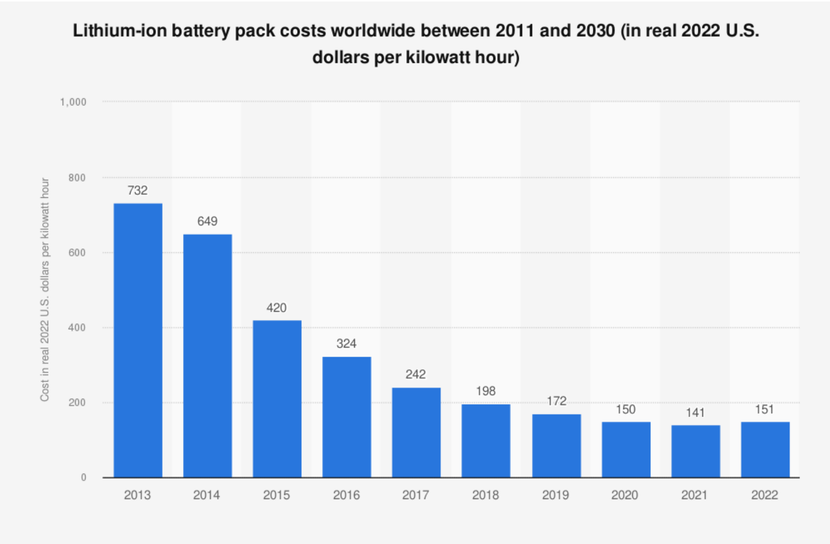

Figure 2. Lead vs lithium battery small scale (Source GreenMatch UK)

Figure 2 Lithium-ion battery costs. Source: https://www.statista.com/statistics/883118/global-lithium-ion-battery-pack-costs/

Lithium-ion batteries are more efficient than traditional lead acid batteries with a higher depth of discharge[4], a longer life cycle[5] and improved cost efficiency. (Figure 3). L-O-batteries are expected to hold a growing share in the energy market and increasingly are of interest to residential customers, cooperatives, regional power providers and new market entrants.[6]

4kW lead-acid batteries vs lithium-ion batteries overview

Characteristics	Lead-Acid Battery	Lithium-ion battery
Preliminary solar battery price	£2,000	£4,000
Storage capacity (kWh)	4 kWh	4 kWh
Depth of Discharge (DoD)	50%	90%
Life cycle	1,800	4,000
Cost/kWh/ Cycle*	£0.556	£0.278

** Cost/kWh/cycle = preliminary cost/(storage capacity×DoD×life cycle)*

[4] Self-discharge time is the time for a fully charged system to discharge to a defined depth when it does not supply any useful energy. Source: https://www.sciencedirect.com/topics/engineering/depth-of-discharge.
[5] The cycle life of batteries is the number of charge and discharge cycles that a battery can complete before losing performance. See: https://www.sciencedirect.com/science/article/pii/B9780124095403000025
[6] See: https://linkinghub.elsevier.com/retrieve/pii/S0301421519302149

Figure 3 Comparison of L-O and LA batteries . Source. www.https://www.greenmatch.co.uk/blog/2018/07/solar-battery-storage-system-cost)

A range of factors impact battery performance. The lifetime of the batteries can be affected due to operating conditions, such as the level of renewable energy sources (RES) penetration, cyclic operation, temperature, discharge/charge rate, and depth of discharge[7]. Furthermore, the overall battery lifetime may be different depending on the local conditions of installation, such as temperature and environment. North-East Scotland is prone to fluctuating weather conditions and cold winter periods. With these prevailing conditions in Scotland there will be significant seasonal variances in rooftop solar production and storage. It is important to note that production in Winter is not zero in Scotland[8], with production still occurring albeit at lower levels. Additional local renewable systems, including local wind, micro-hydro, bioenergy and heat networks will need to be integrated at the local scale in addition to the need for grid connections and / or local networks[9].

Battery energy systems are largely dependent on their charging and discharging capacity, and despite the average lifetime being more than 10 years, capacity fading throughout the lifetime can be affected by environmental and use conditions. Idling is one factor which would need to be taken into consideration when installing batteries to be used with community halls, which can lie unused for periods of time. Depth of discharge (DOD) plays a significant factor when considering battery usage. Various studies suggest installing more battery storage capacity than needed to reduce the average DOD. Fluctuation of solar generation and larger variation will increase the rate of degradation of the batteries. A recurrent suggestion whilst studying the literature, was that accurately predicting the lifespan of the battery would optimise the performance of the system.[10] However as of yet there is limited research carried out on the specifics for batteries in the optimisation of energy systems in community buildings. A limited number of studies identify the battery optimisation 'ecosystem'. In figure 4 the mind map [11] identifies factors such as battery degradation, technologies, design constraints, and objective function as effecting efficiency and life. However, there is little targeted primary research carried out on community buildings or similar in the UK or Scottish context.

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[7] (Shamarova et al., 2022).
[8] Do solar panels work in winter? | Homebuilding
[9] Chao et all (2018).
[10] Apribowo et al., 2022
[11] Apribowo et al 2022.

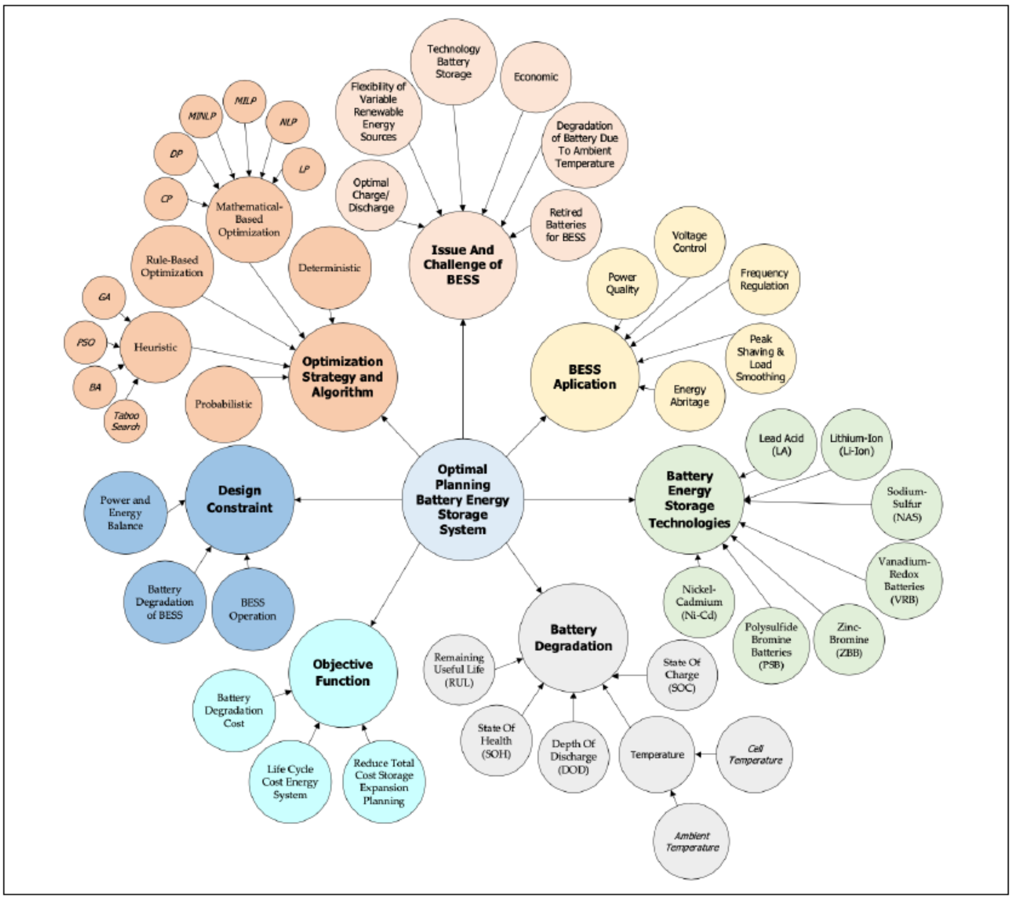

Figure 4 Figure 1. Mind map of BESS optimisation (Apribowo et al., 2022).

4. Energy storage in the context of village halls.

Village hall retrofits with storage and renewable power systems is a recent trend. Batteries offer a source of energy security and stability for village halls, and in the case studies (appendix 1) repeated comments identified the opportunities that integrated battery and small- scale PV could offer for community ownership and local energy efficiencies.

A large number of providers are now in the market, including established energy names such as Shell, BP, E.ON EDF, and other brands including Tesla, Duracell and Powervault. The cost of battery systems in small scale and residential contexts varies between £2,500 to over £10,000, dependant on the storage capacity, usable capacity (measured in kw/h) and lifecycle required.[12] [13] Installation charges could be an additional £500 to £2,000+ depending on the complexity of the system.[14]

[12] https://www.greenmatch.co.uk/blog/2018/07/solar-battery-storage-system-cost
[13] UK Government BEIS. Domestic Battery Energy Storage Systems A review of safety risks BEIS Research Paper Number 2020/037 2020. Source: Study on domestic battery energy storage (publishing.service.gov.uk)
[14] Ibid. UK Government BEIS.

Lithium-ion solar battery costs

Usable capacity (kWh)	Estimated solar battery price (Lithium-ion)
3 – 4 kWh	From £3,410
4 – 7 kWh	From £4,288
7 – 9 kWh	From £5,185
9 – 13.5 kWh	From £5,920

Figure 2 Lithium ion UK 2023 costs (Source GreenMatch UK)

Many community halls are used at times when solar panels are not working at their optimal conditions, for example evening activities versus solar collection through the day. In this context, storage can be used to optimise the solar PV generation from earlier in the day and can be discharged for use in peak times.

In the selected case studies, and in most of the literature and web-based sources, battery use in village halls was coupled with a solar PV system. In several cases heat pumps were also included in the system set up for the decarbonisation of heat. In all cases a mains grid connection was required for energy security over the winter period, and broader decarbonisation of the grid at scale.

In the case studies and in broader practice, the installation of energy efficiency measures such as insulation and building fabric was seen as an important first step prior to installation of a renewable and storage system (e.g., in Newburgh and Archaracle halls). Notably, in Scotland many older community hall buildings have not been designed with energy efficiency in mind which can pose issues for cost, installation, and performance of small renewable and storage systems. The case studies and the literature demonstrate that combining energy efficiency / insulation, solar PV, battery storage and heat pumps (in that order) can provide multiple benefits for village halls. BESS will work most effectively in halls where energy efficiency and insulation has been upgraded.

Another benefit identified in the case studies and literature was the broader societal benefit of low carbon infrastructure. This played a role in demonstration of renewable energy systems for residents, sharing of information, catalysing local networks and providing income back into the community or 3rd sector organisations. This points to a social capital contribution from village hall battery systems as a foundation for local energy justice and practice (eg. in the Edinburgh and Crawfordjohn cases).

5. Smart grids, virtual power plants, community energy.

A subset of the literature, and a relatively recent phenomenon, is the role of community energy systems in the context of smart local energy grids where households and communities become not only consumers of energy but prosumers.[15] Prosumers is a term that refers to local economic actors, from households to SMEs to public agencies, acting as both consumers and producers of electricity. This can be for reasons of environmental concern, energy security and financial opportunity and are

[15] See Long *et al (2018)* on prosumers and P2P microgrids. https://doi.org/10.1016/j.apenergy.2018.05.097

tapping into the integration of different small-scale generation and storage technologies, including battery storage systems, that offer potential new benefits to communities and can address energy security, social and decarbonisation strategies.

The increasing use of local smart grids offers potentially significant benefits.[16] They enable efficient energy distribution,[17] optimizing local renewable sources like solar panels and distributed battery storage.[18] This reduces electricity costs and improves energy reliability and security. Smart grids also enhance grid resilience, enabling rapid response during outages or emergencies. Communities can sell excess energy back to the grid, generating revenue at peak times or use the energy within their own networks via peer-to-peer trading.[19] Through data based analytical systems, smart grids can empower consumers to make informed decisions about energy use and participate as individuals or via virtual local networks. Application of virtual power plants[20] is promising as means of supporting and moderating a renewables dominated grid, providing sustainable options for communities and a more democratic energy system.

In the UK there are emerging examples of smart grid projects and associated mechanisms such as peer to peer trading. ReFLEX[21] (Responsive Flexibility) Orkney is a £28.5 million project aiming to create an integrated energy system (IES) that links decentralised and intermittent generation, storage and demand. The project aims to integrate the production of local electricity, transport and heat networks into one overarching system that can connect renewable generation to flexible demand. Batteries play a key role in this system, including community halls, domestic and car batteries in addition to flexible storage from vectors such as green hydrogen. Community based village hall battery storage, in coming years, may focus on this dimension of local power networks as the application of the technology increases and there is further participation in virtual local power networks.

[16] See Parra et al 2017 https://doi.org/10.1016/j.rser.2017.05.003
[17] See Zhang et al 2022. https://doi.org/10.1016/j.apenergy.2022.120182
[18] Ibid
[19] Ibid 11 Long et al (2018).
[20] See https://www.energy-storage.news/revolutionising-the-uk-grid-with-localised-virtual-power-plants/
[21] https://www.reflexorkney.co.uk/about-reflex

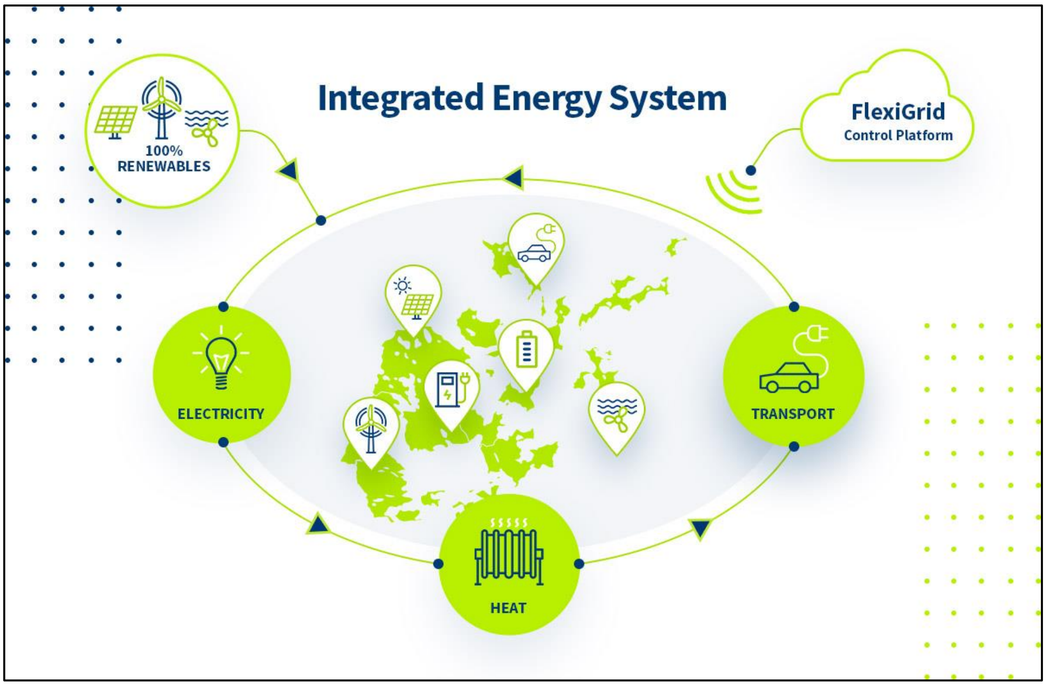

Figure 3 A snapshot of the reFELX integrated energy system in Orkney. Source: https://www.reflexorkney.co.uk/about-reflex

6. Summary of opportunities and challenges.

Opportunities

Renewable Energy Integration: When coupled with solar PV panels or other renewable energy sources, batteries can store excess energy generated during peak times for use when energy demand is higher or when the renewable sources aren't producing. In summer peak periods there is the potential for significant cost savings.

Energy Cost Savings: By storing excess energy during low-demand periods and using it during high-demand times, village halls can reduce peak energy consumption and potentially save on electricity costs. This must be integrated with the various uses and activities in halls.

Grid Support and local power networks: Village halls with battery systems can participate in grid stabilization programs, providing grid services like frequency regulation and peak load shaving. This might generate additional revenue or incentives for the community sector and diversify the role that village halls play in local smart grid networks via peer-to-peer trading.

Backup Power: Batteries can provide backup power during outages, ensuring essential services like lighting, heating, and communication systems remain functional. This can enhance the resilience of village halls as community gathering spaces.

Environmental and social Impact: Adopting battery storage in village halls contributes to sustainability goals by reducing reliance on fossil fuels and promoting cleaner and more efficient energy use. It can increase social capital in communities and more democracy in the energy system.

Challenges:

Initial Cost: The upfront cost of purchasing and installing battery systems can be a significant challenge for village halls with limited budgets. As costs indicate, an individual battery could cost between £4-9k plus installation in addition to other infrastructure. In addition, BESS systems operate more efficiently when energy efficiency upgrades have been made in village halls which will add to the overall cost.

Technical and Maintenance: Implementing battery systems demands technical knowledge for proper sizing, installation, and management. This might necessitate hiring experts or partnering with companies experienced in battery technology. Several cases noted the challenges associated with navigating quotes and advice on systems. Batteries require regular maintenance and monitoring to ensure optimal performance and longevity. This might require additional resources for village halls.

Pioneering Developments. In our examination of the literature and case studies, we can observe that the adoption of batteries in a domestic and village hall context is at an early stage but one that shows signs of increasing in the effort to address building and residential aspects of carbon emissions. Indications are that when there is local renewable infrastructure investment this can support new local energy networks, capacity and demand side strategies.

Battery Lifespan: Batteries have a finite lifespan and will degrade over time. Replacing batteries can be an additional cost that needs to be planned for in the long term.

Space Limitations: Depending on the available space, finding suitable locations for battery storage equipment could be challenging, especially for smaller village halls.

Regulatory and Permitting Hurdles: Local regulations, permits, and building codes may impact the installation and operation of battery systems. Navigating these requirements can be time-consuming. A single point of contact and dedicated officer was noted in case studies as assisting in the permitting, design and implementation of battery systems.

Appendix 1: Case studies

Initiative	System	Cost	Location	System benefits / lessons	Website
Newburgh Village Hall	Battery (1) Solar Heat Pump Energy efficiency	220k initial refurbishment. Further Vattenfall Unlock our Future Fund £15,000 specifically	Newburgh Aberdeenshire	*"The inclusion of a battery maximises electricity generation, which can be used directly by the hall rather than sold back to the grid."* *"Funding was specifically to reduce the carbon footprint of the hall, and consisted of four elements: Insulating the building fabric, LED lighting, Upgrading the windows, General building works."* *"This will mean we should be able to generate and store enough energy to power the hall for all our daily and evening activities, making the hall pretty much self-sufficient. This is an amazing achievement for such an old building and our hall will be inspiration to others as an example of best practice for how to renovate an old building in as sustainable a way as possible."* 1.Anecdotal evidence of benefits to efficiency, maximising power production and flexibility. 2. Fabric first approach and energy efficiency further supported by renewables / storage. 3. Community innovation and inspiration.	https://www.foundationscotland.org.uk/our-impact/case-studies/energy-efficient-transformation-for-newburgh-hall https://newburghvillagehall.org/renovation
Acharacle Community Centre	ACC installed: Air source heat pump solar (PV) panels battery (1) new heaters insulation	£63,727.75 capital grant	Highland	*"The centre is generally warmer and more pleasant to be in as the heat pump keeps all the rooms at a constant warm temperature. During the summer months, it is hoped a significant cost saving will be felt."* *"Unfortunately the cost saving has been minimal – largely due to the increased costs in electricity and rise in the energy price cap."*	https://localenergy.scot/casestudy/acharacle-community-centre/

	energy efficient lighting.			*"It was challenging getting quotes! I'm not sure if there is a good suggestion or lesson learned here, but it was quite tricky to get a company that was local enough, in our very remote and rural area."* 1. Fabric first - efficiency 2. Full time single Point of contact, capacity. 3. Challenges in sourcing quotes.	
Edinburgh Community Solar Cooperative (ESCS)	Solar Battery (multiple – unknown) Solar PV installed across 24 public buildings - City of Edinburgh Council.	£108,000 innovation grant	Edinburgh	*"Each site producing more than their initial estimated generation in the first year of operation. The electricity generated also provides an income to ESCS".* *"Batteries would ensure that more solar generated electricity is used, improving the efficiency of each site, as well as reducing their carbon footprint. The project would also provide grid services to assist the development of a smart local energy system."* *Expected* benefits: 1.More locally generated electricity reducing the amount of electricity imported from the grid. 2. Lower its carbon footprint and improve energy efficiency. 3.Potemtial for batteries aggregated with other storage sites, develop smart grids. Provide services to the national grid such as fast frequency response (FFR) and demand side management (DSM) in the future. 4. Increased sales of generated electricity, together with the grid service, will increase the ECSC's revenues.	https://localenergy.scot/casestudy/edinburgh-community-solar-cooperative/ Edinburgh Community Solar Co-operative | Solar Energy Shares, Edinburgh, Scotland (edinburghsolar.coop)

Crawfordjohn Village Hall	111 PV solar panels Four Tesla Powerwall batteries	£166,000 grant, 75% Renewable Energy Fund (REF) 25% of wind industry community funding.	South Lanarkshire	*"Robin Winstanley, sustainability and external affairs manager at Banks Renewables said: "This is not your typical solar array – with rising fuel costs this will turn a community facility into something that can run sustainably and enable communities themselves to make the transition to renewable energy."* *"To have received such a huge grant has made this possible. Not only will the hall save money and continue to host events, it will also be part of a much more sustainable future."* *"We are still struggling to get the hall back to being used as it was pre-pandemic. We're hoping that with the boost to lower energy bills, it will enable us to increase the number of events at the hall so we can continue to offer the space as an important community facility."* *"Anticipates generating enough electricity to slash running costs by an estimated 80% with any surplus energy going back into the grid and providing an additional income stream."* 1. Innovative use of industry supported funds to develop community infrastructure CAPEX and capacity. 2. Acknowledges possibility for integration into smart local networks and income generation. 3. No further monitoring reports, many projects in early phases. Further evidence required.	South Lanarkshire village hall aiming to become UK's greenest | Scottish Construction Now Village hall bidding to be one of UK's greenest after £166,000 grant - Scottish Business News

Appendix 2: Literature Review

This review gives a snapshot of available evidence at the end of February 2023.

For each report below relating to the role of batteries in the optimisation of energy systems in community buildings in North East Scotland, comments are given on any extra information and the relevance to the panel.'

Ambrosio-Albala, P., Upham, P., Bale, C.S.E. and Taylor, P.G. Exploring acceptance of decentralised energy storage at household and neighbourhood scales: A UK survey 2020. https://www.sciencedirect.com/science/article/pii/S0301421519307797#bib57

Key findings Level of awareness was very low for community energy storage, 43% of respondents not being aware. Support for public funding with energy storage schemes. Respondents were more in favour of the energy storage system benefitting communities, rather than just households. Obvious need to increase public awareness. A questionnaire survey was undertaken in February 2018 with 949 UK public, in order to determine the acceptance of battery energy storage at both household and community level. Study is not directly linked to the use of solar panels and batteries in community halls, but gives an idea of how communities would accept the installation of new energy systems.

Apribowo, C.H.B., Sarjiya, S., Hadi, S.P. and Wijaya, F.D. Optimal Planning of Battery Energy Storage Systems by Considering Battery Degradation due to Ambient Temperature: A Review, Challenges, and New Perspective December 2022. http://dx.doi.org/10.3390/batteries8120290

Key findings. Battery degradation reduces power efficiency in BESS, and therefore the deterioration needs to be considered. Systematic literature review and meta-analyses approach. Not specific to community halls, however relevant information regarding the lifespan of batteries when used as energy storage systems.

Business Energy Scotland Could batteries power your business for less? 2018 https://businessenergyscotland.org/could-batteries-power-yourbusiness-less/

Key findings. Hotels and other businesses, like B&Q, are installing battery packs to store solar energy to save money. The Premier Inn in Edinburgh is expected to save £20,000 per year in energy costs with the new batteries. More security of energy supplies with batteries. Payback from the grid is dependent on the market price of energy which is constantly changing. Not specific to community halls, however relevant information regarding why batteries were chosen.

Change Works. Solar Panels and Battery Storage. Date 2022., Home Battery Storage |UK | Changeworks.

Key findings The need for insulating a building first is essential. The amount of energy used in the evenings (i.e. predominantly when community halls are in use) needs to be calculated first, so see if batteries are more cost effective than selling the excess day-time solar energy back to the grid. Smart meters could be used to gauge the amount and cost of energy being used when the community halls in use. Need to sign up to the energy supplier's Smart Export Guarantee (SEG) scheme to be paid for the energy sold back to the grid. Relevant suggestions for insulating any building before the addition of more expensive adaptions, such as solar panels and batteries.

Author Moore, J. and Shabani, B. Title A Critical Study of Stationary Energy Storage Policies in Australia in an International Context: The Role of Hydrogen and Battery Technologies Date August 2016 https://www.mdpi.com/1996-1073/9/9/674

Key findings An energy storage capacity of 10%–20% of the total intermittent renewable energy generation would need to be installed to effectively integrate it into the grid. Policies are needed to reach the renewable energy targets. Battery storage has grown almost 300% between 2014 and 2016.

Sani, S.B., Celvakumaran, P., Ramachandaramurthy, V.K., Walker, S., Alrazi, B., Ying, Y.J., Dahlan, N.Y. and Rahman, M.H.A. Title Energy storage system policies: Way forward and opportunities for emerging economies December 2020
https://www.sciencedirect.com/science/article/abs/pii/S2352152X20317394

Key findings. ESS policies around the world are relatively new, and not well researched. ESS policies are necessary to progress the technology for battery storage systems. Consistent policy support is necessary.

Seyfang, G., Park, J.J. and Smith, A. Title A thousand flowers blooming? An examination of community energy in the UK. October 2013
https://www.sciencedirect.com/science/article/abs/pii/S0301421513005156

Key findings. Large energy companies need to engage with community groups, as there is a limit to how much community groups can achieve in their own. Appropriate policy support is needed. UK-wide survey of community energy projects; web-based survey between June and October 2011. Slightly outdated article, Information regarding why policies are important.

Shamarova, N., Suslov, K., Ilyushin, P. and Shushpanov, I. Review of Battery Energy Storage Systems Modeling in Microgrids with Renewables Considering Battery Degradation September 2022
https://www.eriras.ru/files/_skan_stati_energies_15_06967.pdf

Key findings. Battery energy storage systems remains poorly researched. Most energy storage system studies do not take into account degradation. The service life of the battery is a non-linear nature due to degradation. Not specific to community halls, however relevant information regarding the lifespan of batteries when used as energy storage systems.

Yang, Y., Bremner, S., Menictas, C. and Kay, M. Modelling and optimal energy management for battery energy storage systems in renewable energy systems: A review October 2022
https://www.sciencedirect.com/science/article/abs/pii/S1364032122005639

Key findings. Management approaches that operate the BESS are required to fully realise the benefits. Not specific to community halls, however relevant information regarding why management needs to be considered when installing a BESS.

Yazdani Mehr, S. and Wilkinson, S. Technical issues and energy efficient adaptive reuse of heritage listed city halls in Queensland Australia September 2018.
https://www.emerald.com/insight/content/doi/10.1108/IJBPA-02-2018-0020/full/html

Key findings. Energy efficiency and climate change impacts are improved by adaptions to the city halls. However, aspects such as ownership an interests of the local communities can create difficulties with these adaptions. City halls are often heritage listed in Australia making technical improvements harder to undergo. Retrofitting existing buildings, such as community halls, proves to be problematic however in order to be energy efficient it is necessary. Suggestion that not just solar panels and battery storage systems are needed. Fairly relevant information regarding city halls, however based in Australia not the UK, therefore different issues with the buildings.

Chao Long, Jianzhong Wu, Yue Zhou, Nick Jenkins, Peer-to-peer energy sharing through a two-stage aggregated battery control in a community Microgrid, Applied Energy, Volume 226, 2018, Pages 261-276, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2018.05.097

Findings: Peer-to-peer (P2P) energy sharing allows the surplus energy from distributed energy resources to trade between prosumers in a community Microgrid. P2P energy sharing is being becoming more attractive than the conventional peer-to-grid (P2G) trading. However, intensive sensing and communication infrastructures are required either for information flows in a local market or for building a central control system. It was revealed that P2P energy sharing is able to reduce the energy cost of the community by 30% compared to the conventional P2G energy trading.