RENEWABLE
ENERGY SPECIALISTS

Locogen

Village Halls RCEF Project

Phase 1 report

For Ryedale Village Hall Consortium

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2.0	*17/12/20*	Updated following initial feedback

Executive Summary

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This executive summary will be completed following review of the report by the Consortium and the associated Phase 1 workshops.

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Table of contents

1. Introduction

1.1. Background

The Rural Community Energy Fund (RCEF) is a £10 million programme which supports rural communities in England to develop renewable energy projects, which provide economic and social benefits to the community. RCEF provides support to rural communities in two stages, for which this report falls within the first stage, which provides grants up to £40,000 to complete a feasibility study for a renewable energy project, or projects.

The Ryedale Village Hall Consortium, led by the Kirby Misperton Village Hall and supported by York & North Yorkshire Local Enterprise Partnership (LEP), were successful in their bid to the first stage of the RCEF grant administered by the North East Yorkshire and Humber Local Enterprise Partnership (LEP).

The Ryedale Village Hall Project was created with the aim of reducing the carbon footprint of village halls across the rural Ryedale area of North Yorkshire, primarily through solar PV and battery storage installations, with the idea to procure renewable energy installations on a group basis to achieve best value for money. Initially, interest from 29 village halls was received; however, throughout this Phase 1 project, a number of village halls chose to drop out of the study and six additional halls were invited to join the study. The resulting list confirms the 26 village halls and community buildings that now make up the focus of this study.

- Amotherby
- Allerston
- Brawby
- Cropton
- East Thirsk Community
- Farndale
- Foston & Thornton le Clay
- Ganton
- Kirkby Fleetham
- Kirby Misperton
- Kirkbymoorside Squash Club
- Lastingham and Spaunton
- Middleton and Aislaby
- Milton Rooms
- Old Malton
- Oswaldkirk
- Pickering
- Romanby WI
- Sand Hutton and Claxton
- Settrington
- Terrington
- Thixendale
- Weaverthorpe
- Welburn
- Wintringham
- Wrelton

The study area is shown in Figure 1.

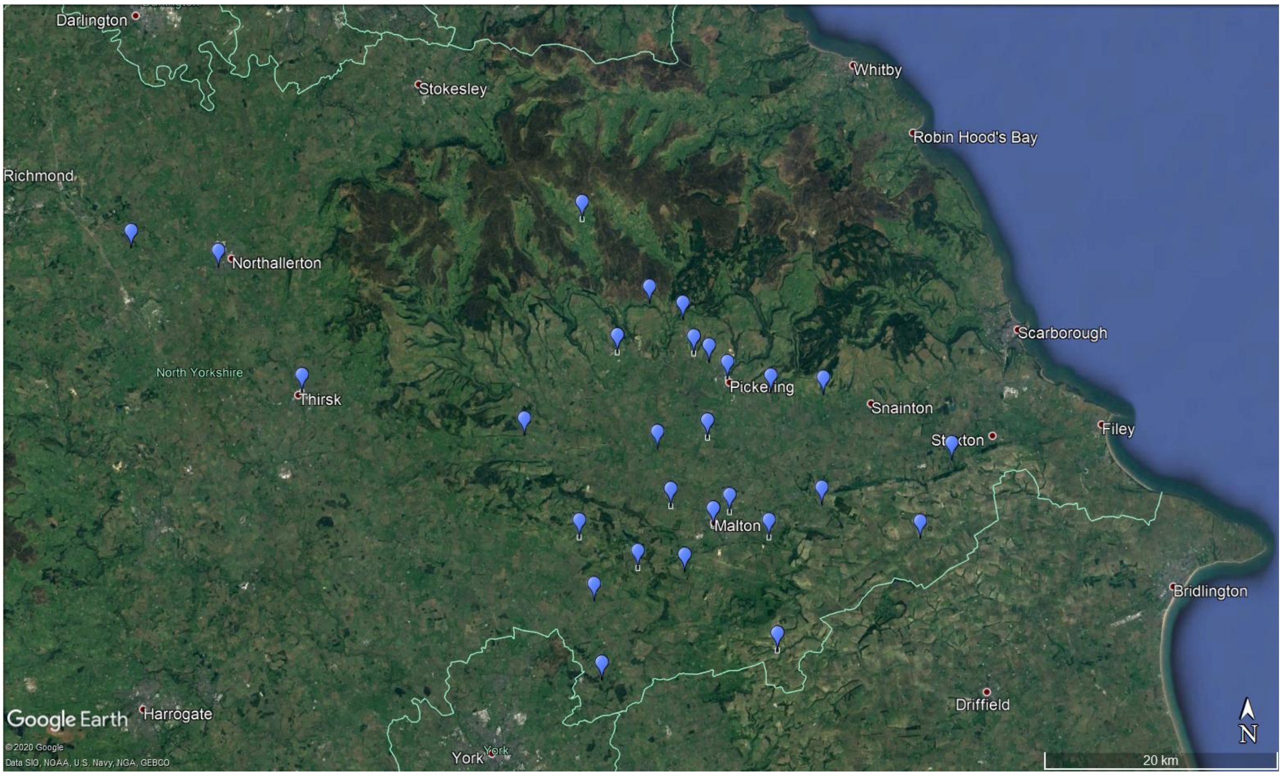

Figure 1: Project study area

1.2. Phase 1

To meet the requirements of the Consortium, the feasibility project has been divided into two phases. This report details the work completed in Phase 1, which has involved a desktop assessment of each of the project location to assess the local requirements, opportunities, and constraints. This has allowed viable energy technologies to be identified and matched with local demands. This Phase 1 feasibility report presents the most technically, financially and environmentally feasible options for each of the buildings under consideration.

Following the issue of this report, Locogen will continue to work alongside Ryedale Village Hall Consortium to select the energy systems to take forward for detailed assessment in Phase 2 of the project, which is also funded by the RCEF.

1.2.1. Aims

The Ryedale Village Hall project, led by a consortium of village hall representatives, aims to reduce the carbon footprint of several village halls across the rural area of Ryedale in North Yorkshire. This project will primarily assess the feasibility of adding roof-mounted solar PV and battery systems to each of the village halls involved. The group are looking to understand how to reduce the carbon emissions of these buildings, and intend for this project to serve as a showcase of the benefits of implementing renewable energy systems, which can then be replicated in similar communities.

1.2.2. Objectives

In order to help the Ryedale Village Hall Consortium achieve their goals for this project, Locogen has conducted a desktop review of the feasibility of implementing various renewable energy technologies to meet the energy demands of the 26 community buildings. Phase 1 entails a review of options solar PV and battery systems for electricity generation, as well as low carbon heating systems.

1.2.3. Report structure

This subsequent body of this report is divided into the following sections:

1. **Technology overview** – Details of the potential options available for the provision of renewable space heating, reduction of heat requirements, renewably heated hot water, and onsite electricity generation;
2. **Methodology** – outlining the processes used in the development of Phase 1, and key assumptions made in the initial stages of the project;
3. **Properties under consideration** – building-by-building analysis of potential energy/carbon saving opportunities for space heating, hot water and electricity generation;
4. **Other opportunities** – Additional potential energy or resource saving options, options to combine systems; and
5. **Summary and recommendations**

1.3. Phase 2

Following an interim meeting, all viable projects (up to a total of 20) will be taken forward to a Focused Assessment (Phase 2). This will commence with a site visit to further determine project viability, followed by detailed half-hourly energy modelling to further inform financial and carbon analysis. Locogen will then provide a specification for the preferred energy systems, accompanied by a detailed risk assessment, review of funding options and review of suppliers. The review of funding options is a key aspect of this phase as it will highlight opportunities to significantly reduce the financial burden on each organisation whilst also facilitating reduced payback periods for the PV systems.

Within Phase 2, Locogen also intend to support the Consortium in their procurement phase by producing draft tender documentation. Ultimately, the outcome of the feasibility study will be a comprehensive business case that allows viable energy system options to move forward towards development and to meeting the community's decarbonisation objectives.

2. Technology overview

2.1. Solar Photovoltaic (PV)

The primary opportunity for electricity generation in the community halls is through the use of solar PV systems. The primary options considered are roof-top mounted systems (RMPV), which directly supply the building on which they are installed. Larger, canopy mounted systems are also available for installation as carports or walkways but are not within the scope of this project as they are considerably more expensive than RMPV. RMPV can come in several forms, including as mounted or integrated panels, or as solar tiles (or slates). These three systems are illustrated in Figure 2 to Figure 4 below.

Figure 2: RMPV (mounted panels)

Figure 3: RMPV (solar slates)

Figure 4: Solar canopies

Recently, PV has been acknowledged as the best value renewable energy generation per kW of peak capacity (kWp) installed. This is especially apparent at scales below 1MW, which is most appropriate for community halls under consideration herein. As a proven technology, it is a reliable, low-risk and versatile option for renewable generation, thus it is the focus for this project.

What must be considered in solar installations is the seasonal and daily variation regarding output. Figure 5 below illustrates an average daily generation profile of a 1MW solar array in summer and in winter. This is complimentary to commercial consumers, as they are generally more active in daylight hours; however, these variable profiles highlight that it's unlikely for 100% of a site's demand being met in real time with PV. This can be bettered with the installation of energy storage technologies, discussed subsequently.

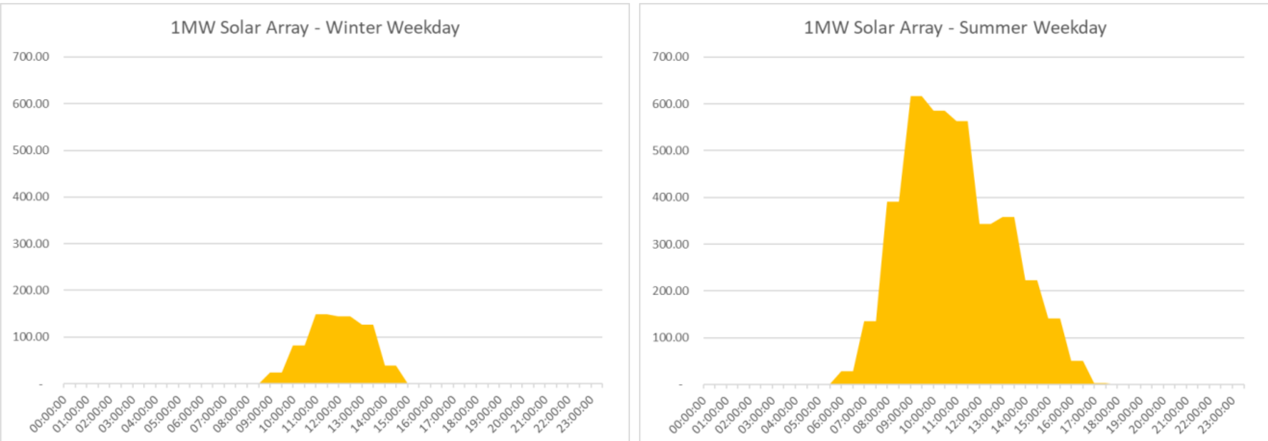

Figure 5: Summer vs Winter PV generation (kWh) for an illustrative 1MW array

2.1.1. The technology

Solar PV technology use cells made up of layers of semi-conducting material to convert sunlight into electricity. When light shines on the cell, it creates an electric field across the layers, causing electrons to flow, which in turn creates electricity. Cells are connected together to make modules (or panels), which are in turn connected together to form arrays. The solar PV arrays generated direct current (DC) electricity, which is then carried to an inverter which is required to convert the DC to alternating current (AC) electricity – the same form of electricity that is delivered to buildings from a standard mains electricity connection. The electricity can then be used directly to power appliances or lights within the building, stored in a battery or exported to the grid.

2.1.2. Benefits and constraints

The installation of a solar PV array can reduce annual electricity cost by offsetting the amount of electricity that needs to be purchased from the grid to supply the building. An installation can also reduce the carbon footprint of a building – solar PV generates electricity without emissions, whereas grid electricity has a carbon footprint as it is made up of an energy mix from renewable sources, nuclear and conventional fossil fuel. The current carbon footprint of the UK grid is around 0.225kg of CO_2 per kWh of electricity generated.

Solar PV systems are limited by the available resource, and while modules will generate electricity on cloudy days or at lower light levels, the modules will only achieve maximum efficiency when it's very sunny and the sun is shining directly onto the panels. Trees or high buildings around solar arrays may cause shadows and shading across the array, which will also impact the amount of electricity generated, so careful consideration must be given to the location and design of the array. In addition, the efficiency of solar panels varies with their orientation and inclination (in this case, the pitch of the roof where they are located). This is illustrated in Figure 6, which indicates that, in the UK, solar PV will perform best on roofs that face due south and have a 35^{o} pitch.

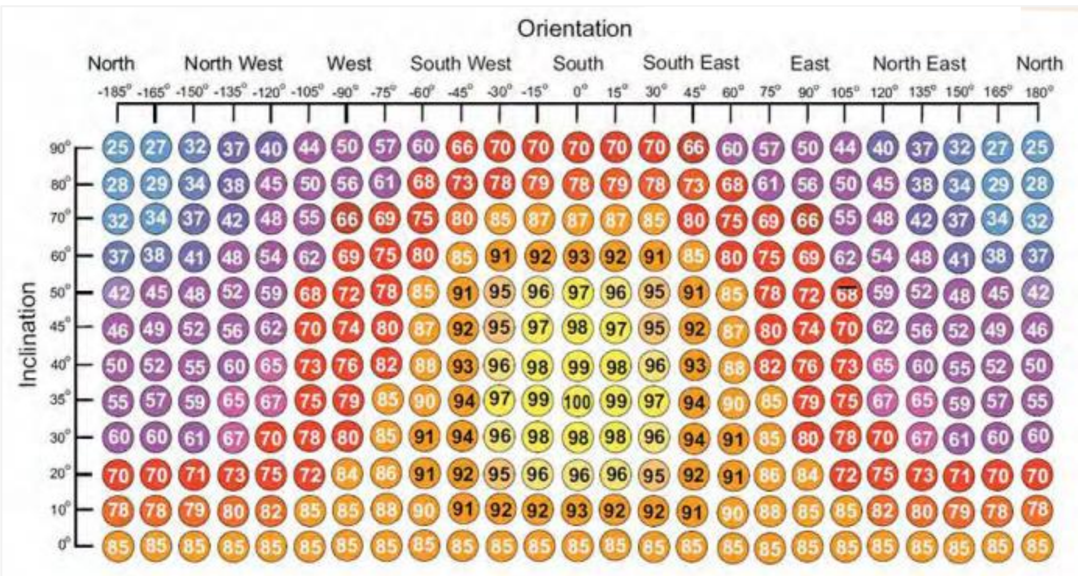

Figure 6: PV output vs orientation and inclination (MCS, 2012)

Solar PV installations can have quite a high capital cost attributed to them; however, considerate design can reduce the payback period of the initial investment and grant funding is widely available for renewable energy installations.

Solar arrays are quiet and are less visually obtrusive than most other renewable energy technologies, particularly when installed sensitively on rooftops. However, installations may be subject to planning approval (such as in Conservation Areas and in other designations) which can introduce delays or risks to a project. Integrated solar panels, alternative coloured modules and solar tiles can all be considered where planning restrictions are in place.

2.1.3. Additional considerations

Where roof-mounted solar PV systems are being considered, a structural engineer will need to ensure that the roof can accommodate the additional weight and loadings that would be imposed by its installation. Where ground mount systems are being considered the ground type/conditions and location of underground services need to be considered. The installation process itself is relatively quick and straightforward and there are no maintenance requirements beyond periodic cleaning with water.

2.1.4. Income mechanisms

The primary financial benefit from a PV installation arises from savings associated with reduced electricity bills. Income can also be generated by exporting surplus electricity generation to the grid under the Smart Export Guarantee (SEG). The SEG has replaced the Feed-In-Tariff has the Government's primary incentive for small scale renewable generation. Through the SEG, a PV array can sell generation to a licensed electricity supplier at a price that is set by the supplier. Presently, SEG prices range between 1 - 5.6p/kWh.

For larger PV installations and/or aggregated systems, power purchase agreement (PPA) contracts can be established with suppliers. These contracts can be more lucrative than the SEG – however, for this project, these opportunities were discussed with several suppliers and the PV capacity (even in aggregate) was deemed to be too small.

2.2. Energy storage

Given that SEG rates tend to be less than half of electricity import prices, it is much more economical to utilise as much energy on site as possible, before selling surplus electricity to the grid. Incorporating batteries to a solar PV system can further reduce dependency on grid electricity imports by storing electricity so that it can be used several hours or even days later. Therefore, batteries can increase the operational savings of PV by an additional 20-50%, depending on several factors, including the battery's storage capacity and the building's electricity demand profile.

The key performance aspects of batteries that vary between manufacturers are:

- Storage capacity – how much energy the battery can store
- Charging capacity – maximum power input from grid or renewables
- Discharging capacity – maximum power output to grid or building loads
- Round trip efficiency – energy losses between energy generation and usage

2.2.1. Benefits and constraints

The capital costs of batteries are relatively high, starting at £2,000-£3,000 for domestic-scale systems, meaning that they do not always guarantee a return on investment over a reasonable period. Where battery storage is identified for further consideration throughout this report, a recommendation will be made for the optimum battery size using energy flow modelling as part of the Phase 2 works.

2.2.2. Additional considerations

Most small-scale batteries are able to be wall mounted and require less than 1m^2 of wall area. Depth will vary from model to model but single units will tend to take up around 0.2-0.5m plus access space. A well-ventilated cupboard or storage room would be a suitable location for a battery, and although some models can be installed outdoors, this is not recommended to due to the potential of the development's local climate to affect performance. Installation itself is likely to take a few hours and should be performed in conjunction with, otherwise after, installation of a solar PV array.

2.2.3. Income mechanisms

As well as cost savings from the maximisation of onsite usage of PV generation, the implementation of energy storage technologies also opens up the possibility of accessing other benefits. Locogen is aware of incoming initiatives by new and existing energy suppliers that will offer higher SEG prices (in the region of 10p/kWh) to customers with batteries, although these are likely to tie customers to certain manufacturers.

Another source of income for batteries arises from payment from balancing services to the national grid and regional electricity networks. The opportunities for this are complicated to assess and are highly capacity and location specific. For small scale batteries, grid services benefits may only be realised if the battery is part of an aggregated system. However, this was discussed with several parties who indicated that there are limited opportunities for aggregation of batteries at the scale of this study. Currently domestic battery systems can enjoy these benefits, and as this is a fast-moving market, it is possible that these may be open to small scale non-domestic systems in coming years.

2.2.4. Heat batteries

In a similar way to electric batteries detailed above, heat batteries are a relatively new technology which allow heat to be stored via a phase change material (a similar principal to which hand warmers work by). These can be 'charged' by a thermal source, such as a heat pump, or by PV electricity to provide space heating and/or hot water. The batteries are compact, requiring no maintenance over a projected 50-year lifetime (according to manufacturers of the technology) and can replace domestic hot water cylinders, with which they are cost comparable whilst being more energy efficient. In the same way as an electricity battery, heat batteries can harness surplus electricity generated from PV to offset heat and/or hot water costs. Alternatively, heat batteries can be used to reduce boiler loads as an interim step to decarbonising heating within existing systems.

This phase of the study has not considered the use of heat batteries, but Locogen would recommend that they are considered where buildings have a large hot water demand. If the Village Hall Consortium wish to explore the opportunities provided by heat batteries, this can be undertaken during Phase 2 of the works.

2.3. Renewable heating systems

2.3.1. Overview

In addition to investigation renewable electricity generation options, there is a requirement to investigate means of decarbonising the heating systems within the community centres. Heat pumps will be the primary focus of this study for heat generation; however, biomass and direct electric systems will also be considered in order to accurately capture the range of low carbon heating technologies available in the market at this time.

2.3.2. Heat pumps

Heat pumps involve a heat exchanger unit, essentially amplifying the difference between the ambient source and the heat emitter temperature within the building, with electricity as the controllable energy input. Heat pumps can be air, ground or water sourced. The key consideration in heat pump technology is the heat pump's coefficient of performance (COP). For example, a COP of 3 would mean that for every 1kW of electricity input to a heat pump, there will be 3kW of heat output. Therefore, there are significant fuel savings compared with electric heating options. The carbon footprint of a heat pump is therefore proportionate to the carbon intensity of the electricity input. In theory, a wholly renewable system can therefore be accomplished by pairing a heat pump system with PV and a battery. Similarly, direct electric heating options, when combined with PV and potentially energy storage, are also considered means of decarbonise an existing heating system.

The type of heat pump is defined by where the ambient heat for the system is gathered. This can be from either the air, taken from the ground (through either a direct or indirect collector system) or from a water source (such as a river, lake or sea).

Air-to-Water (A2W) Heat Pumps

Air source heat pumps (ASHPs) provide a simple and relatively inexpensive renewable heating system. An A2W system essentially involves an exchanger unit, usually in a box outside the property, which will use electricity to heat up an internal wet heating system (radiators or underfloor heating) as well as for hot water. A2W heat pumps are very common in Scandinavian countries and are becoming increasingly popular in the UK especially for newbuilds or where gas is not available. Where ASHPs are considered within villages, care will be needed in relation to the siting of the external unit(s), as units emit some noise when they are running, therefore consideration should be given to the final position to ensure that the noise does not become a nuisance to anyone both internally and externally to the building. A2W systems are able to provide heat as required, with a short delay for radiators to warm up. demand Also, they have minimal maintenance costs. As such, they have been considered for all halls in this study.

Air-to-Air (A2A) Heat Pumps

A2A heat pumps are similar to traditional ASHPs in that they extract the heat from ambient air via an external unit and heat exchanger system. However, they differ in that the heat collected is not transferred to a wet heat distribution system, but directly to the air within a room - essentially resembling an air conditioner operating in reverse. Due to the lack of an intermediate step between the heat pump and the air to be heated, the efficiency of the units is higher. However, the A2A units are not able to provide hot water, so a further system is required to provide this. They can be cheaper and easier to install as there is no requirement to connect them to new or existing wet heating systems. They can also be utilised where there is an existing wet heating system, where additional space heating is required. A2A heat pumps can be reversed in summer months to provide cooling in place of heating. A2A systems are also able to provide heat on demand and have minimal maintenance costs. As such, they have been considered for all halls in this study.

Ground Source Heat Pumps (GHSPs)

GSHP systems are generally more complicated and expensive to install than ASHP systems. However, the benefits of GSHPs are the consistent heat output they can produce due to the stable ground temperature, and plant equipment can all be installed internally within a larger building, or adjacent to a building in a packaged plant room. In order to draw heat from the ground, the heat pump utilises a ground collector loop which can be installed vertically (using boreholes) or horizontally (using loops of plastic pipe) as shown in Figure 7 and Figure 8 below.

Figure 7: GSHP with borehole collector loop

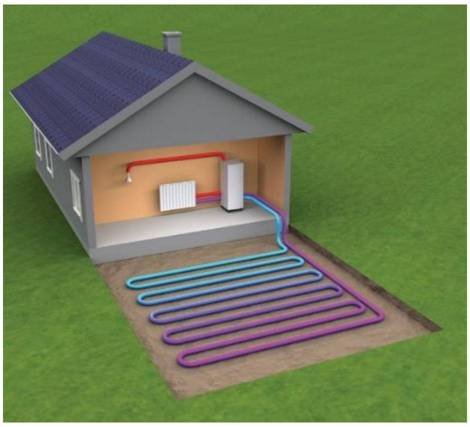

Figure 8: GSHP with horizontal (slinky) collector loop

Boreholes require a significantly smaller ground area for their installation and requires less civils works. In addition to these factors, boreholes tend to provide a more efficient collector system as they are extracting heat from a greater depth where the temperature is slightly higher and more stable. The installation of boreholes would require testing to be completed on the ground where the system would be installed, and to determine the thermal performance of the type of ground, which would then be used to produce a final design of a ground collector system.

GSHP systems have very low maintenance costs and are not dependent on fuel delivery or require any fuel storage. However, they operate most effectively where there is a consistent heat demand and typically, cost more to install than conventional heating systems due to the extensive groundworks required. As such, these have only been considered for halls in this study that are occupied for at least 30 hours per week.

Ground source heat pumps work best with heating systems which are optimised to run at a lower water delivery temperature than is commonly used in radiator systems, which does mean that in existing buildings, the existing heating infrastructure is likely to need redesigned to achieve the required heating demands within rooms; however, GSHPs are safe, silent and unobtrusive. Where air heating is used, ground source heat pumps can be reversed in summer months to provide cooling. Consideration should be given to available plant room space and the plant equipment required to form a GSHP system. A specialist heat pump installer can advise further on the specific installation requirements and on the most suitable heat pump model.

2.3.3. Biomass

Generally, biomass heating systems utilise wood as a fuel, with wood pellets better suited to the scale of installations relevant to this study. Biomass boilers are widely installed as low-carbon heating system alternatives in large commercial applications, where there is a consistent high demand for heat.

Biomass boiler systems are large pieces of machinery, requiring a fuel store and space for associated plant equipment. They also require regular fuel handling for refilling of the fuel store and regular maintenance. Therefore, they typically tend to be installed in a stand-alone boiler house with associated fuel store. Fuel deliveries are made through tinkered blown deliveries or tipped woodchip supply. Both options require large footprints and carefully considered access arrangements.

Pellet stoves are also available for systems between 10-25kW that can be located within a space as a focal point stove. These systems benefit from providing a visual fire and can produce both radiant heat and operate wet systems such as radiators. The fuel is typically contained within a hopper inside the stove itself and requires to be monitored and filled daily, usually via 10kg bags. A covered storage area is required to accommodate the pallet delivery of these pellets.

Biomass installations generally involve considerable additional expense and permitting requirements and as such, generally need high heat demands to justify the costs of installation, maintenance and ongoing fuel delivery contracts. They work most effectively where there is a consistent, high demand for heat, rather than variable heating profiles. Furthermore, biomass is not recommended in urban settings or settlements due to potential impact on air quality.

However, there are benefits. The cost of biomass fuel has remained largely steady and is not subject to the price increases seen in traditional gas and oil fuel. Biomass is also considered to be a carbon-neutral option for providing heat, as the carbon trapped by the growing trees during photosynthesis is then released back into the atmosphere when burnt. Providing that cutting down the trees, processing the wood into fuel and the fuel delivery is done in a sustainable way, the whole process can be carbon neutral.

Ultimately however, the irregular nature of usage of the community buildings considered within this study is not well suited to the installation of biomass technology and as such, biomass has not been considered suitable for any of the sites in this study.

2.3.4. Direct electric heating

Although not a renewable energy technology, electric radiators are a simple option for commercial use and can utilise electricity generated from solar PV. Electric heaters are easily controlled individually and so the cost of heating is directly related to how often and for how long they are used. The dimensions and volume of the property is the key determiner of the number and size of radiators needed to heat the space.

Electric heating is suited most to small buildings with inconsistent use. For buildings with consistent or large heat loads, electric heating would likely be the most expensive system to run; however, this will be considered on a building-by-building basis throughout the course of this study. The cost of imported electricity used for heating could be offset using PV-generated electricity if demand and generation profiles pair well together, but where this is not the case, electrical storage may provide some benefits.

Using electric room heaters at any site will also mean that hot water demand will require further technology. This is traditionally an electric boiler or point-of-use electric water heating, but alternatives such as heat batteries and hot water dedicated heat pumps are considered more efficient.

2.4. Heating system emissions

The key measure of the operating environmental impact of a heating system is its emissions intensity, i.e. the carbon dioxide emissions released per unit of heat demand. For heat pump and direct electric systems, emissions intensity will decrease as the UK grid decarbonises in line with the Government's legislation for net zero emissions by 2050. This is shown graphically in Figure 9, against the constant emissions intensity of gas, oil and biomass heating.

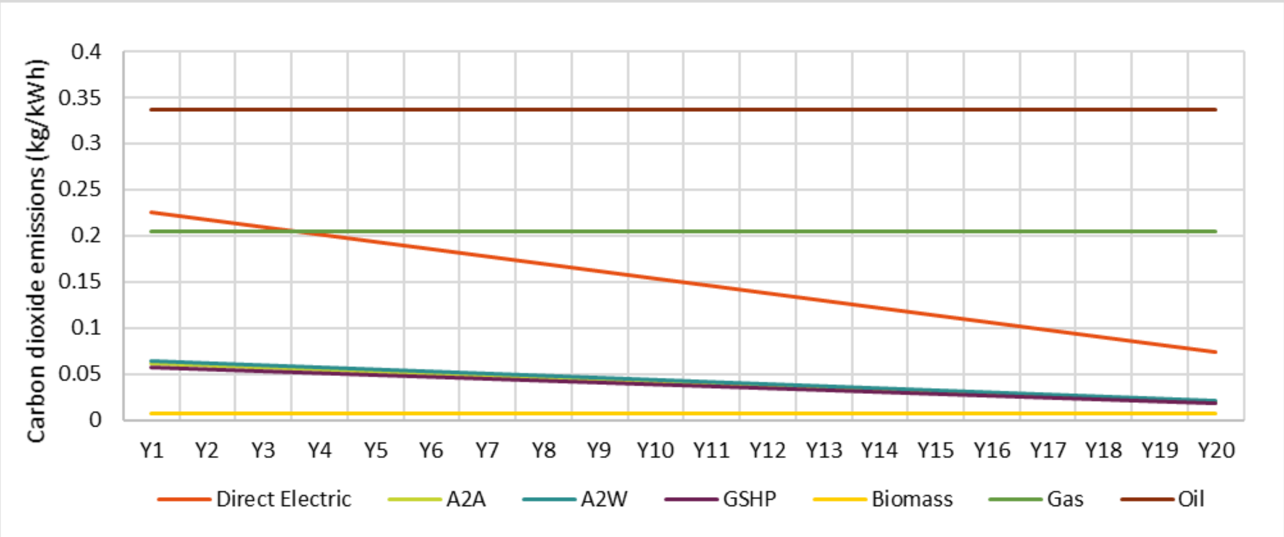

Figure 9: Emissions intensity of heating systems

Owing to their slightly higher energy performance, the GSHPs systems operate at a slightly lower emission intensity than ASHPs. The decarbonisation of the grid in the coming decades will lead to a tail-off in the cumulative emissions of all the heat pump systems, meaning that the differences between their emissions intensity become less significant over time.

Figure 10 demonstrates the huge carbon savings that heat pumps offer compared to gas, oil and even direct electric heating systems a 20-year horizon. It also shows the cumulative emissions of biomass system to be significantly smaller than those of heat pumps. For this figure, an illustrative annual heat demand of 10,000kWh was used, which is comparable to that of the buildings within this study.

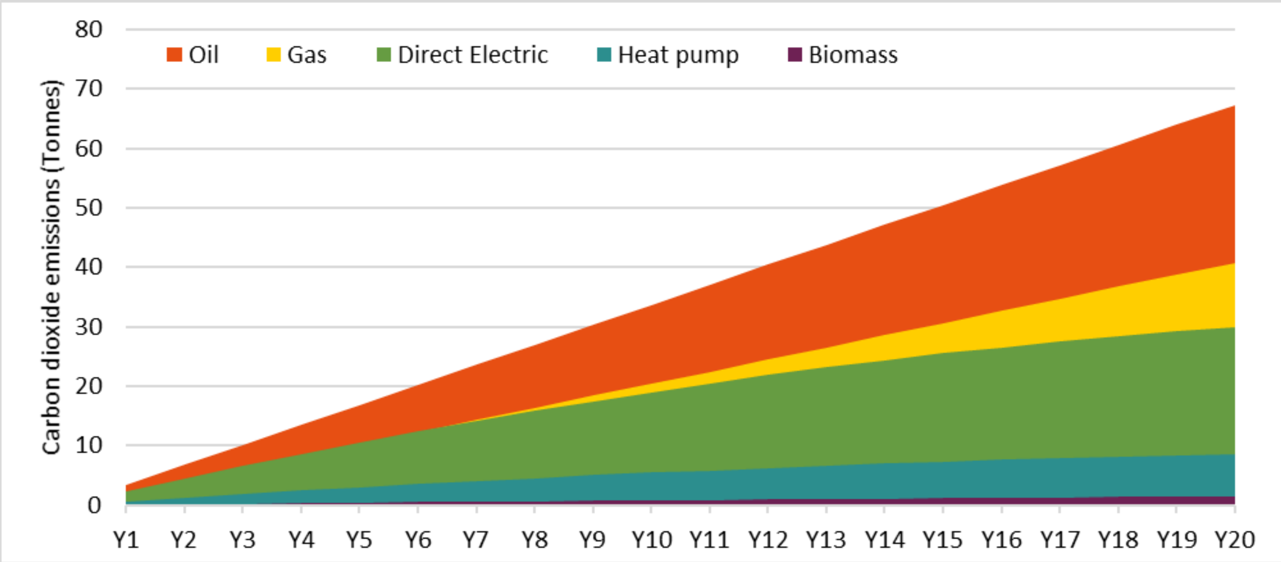

Figure 10: Cumulative emissions of heating systems (10,000kWh annual demand)

3. Methodology

3.1. Energy demand

In order to assess the potential impacts of novel renewable energy systems, an energy baseline has been established for each building, based on annual heat and electricity usage and cost data. Where either the annual energy demand was not provided or deduced from bills, this was estimated from annual costs and fuel prices; and vice versa. Where fuel costs were not provided, the following values were used:

- Electricity: 17p/kWh unit price; 30p/day standing charge
- Gas: 4p/kWh unit price; 25p/day standing charge
- Oil: 45p/litre

If a building's heat demand could not be provided from costs or read from bills, an estimate was taken based on its size and occupancy information. Gas and oil boiler systems were assumed to have a system efficiency of 75%, unless noted to be new, in which case efficiency of 90% was assumed. The peak heat demand (used to provide an estimated renewable heating system size) also estimated based on each building's footprint and construction information.

3.2. Constraints mapping

3.2.1. Planning

Small scale (>50kWp), roof mounted solar PV systems generally to not require planning permission in the UK. However, there are notable exceptions to this that are relevant to this study. These extra controls are designed to preserve or enhance the character of the area and the quality of design. Therefore, we have identified the following constraints that are likely to mean that planning permission will be required:

- Listed buildings;
- Conservation Areas;
- Howardian Hills Area of Outstanding Natural Beauty; and
- The North York Moors National Park.

Where one or more of these constraints applies to a given village hall, we have noted this and added costs for planning applications to the total cost of the solar PV system. If conventional solar PV systems are not accepted in these locations, solar slate/tiles may be permitted as an alternative. However, these are, at present, only available from a handful of suppliers in the UK, and as such, are considerably more expensive (over twice the cost of conventional PV). Therefore, conventional PV only has been considered in the subsequent sections of the report.

3.2.2. Grid impacts

The grid impacts of the solar PV systems in this study have been considered through the presentation of two array sizing options. This is because renewable generation up to a certain size can be connected to the national grid without any connection costs being charged by the local electricity Distribution Network Operator (DNO), in this case, Northern Powergrid.

The size of an installation impacts upon the interactions with the DNO, costs and permissions. For inverter systems of up to 16A per phase, the system can be installed without prior consultation with the DNO and no grid costs would be incurred. For buildings with a single-phase electricity supply, this equates to approximately 3.9kWp of PV generation. For a building with a three-phase supply, approximately 11.6kWp can be installed without grid costs. In this case, a G98 connection form would need to be submitted to the DNO after the installation has taken place. For PV arrays larger than this, a G99 application would need to be submitted in advance of the installation to assess whether grid connection capacity is available and whether upgrade charges would be incurred. The minimum cost of £550 for submitting this form would be incurred at the time of application.

As the buildings considered herein are (unless otherwise stated) assumed to have three phase supplies, the first option presented is the maximum G98 option. Where there is further roof space available, a second option is presented, which is inclusive of grid application costs. This latter option therefore carries a risk that the G99 application could either be rejected or it may indicate that local grid infrastructure improvements are required at cost to the applicant. However, Northern Powergrid have advised that arrays of the scales considered in this study are not likely to be rejected, and it is possible for the G99 application to be an iterative process such that costs associated with grid improvements can be avoided through resizing the PV array.

3.3. Solar PV considerations

3.3.1. Location

As Figure 6 illustrates, and as may be intuitively expected, a solar PV array will exhibit the highest energy yield on a pitched, south-facing roof. Therefore, these are the preferred location for PV on each of the buildings considered. Where there is no suitable south-facing roof, or where there are multiple roofs, an alternative location has been suggested based on an assessment of the size, accessibility, potential yield, and shading. Orientation and dimensions of roof have been measured using Google Earth Pro.

Another important factor affecting the suitability of a roof for PV is whether its structure is able to support the load of a PV installation. This has not been taken into consideration for the purposes of this report, but a structure survey would be required for any installations taken forward at detailed design stage.

3.3.2. Sizing

For projects that progress to Phase 2 of this study, an energy flow modelling exercise will be used to determine the cost-optimal size of PV array for each site. At this Phase of the project, the following two options have been presented:

G98 compliance

A 11.52kWp array was considered to represent the maximum size allowed under the G98 grid connection for a three-phase system. This is based on 320Wp panels (which represent the upper limit in terms of affordable, conventionally size PV panels at the time of writing), equating to an array of 36 panels at ~1.6m^2 each.

Maximum generation

This option investigates the impact of installing the maximum scale of PV that can realistically fit in the area available. Where this significantly exceeds on-site demand, it provides a basis for assessing potential export to adjacent sites or third parties. It also allows the contribution of the system towards local and national decarbonisation to be maximised.

3.3.3. Energy yield

PVSol energy modelling software was used to calculate the energy generated by a PV system at each location considered. The resulting annual yield is based on 'typical' weather for the location and is specific to the orientation and pitch of each roof considered.

3.4. Battery sizing

The UK battery market is still very new, which means that the cost of storage capacity varies widely from manufacturer to manufacturer. Therefore, it is very important to select a cost-effect model and appropriate capacity for any given system. For this study, a 5.8kWh battery was selected for consideration, with a cost of £2,000 per unit. This is representative of a real model that is currently available, which Locogen considers to provide good value for money. The number of these batteries suggested for each building was determined by analysing the weekly usage pattern and estimated weekly electricity demand. For the projects taken forward to Phase 2, this capacity assessment will be supplemented with insights from half-hourly energy flow modelling.

3.5. Cost-benefit analysis

3.5.1. Solar PV & battery systems

The cost-benefit analysis for each potential PV and battery system is presented in the form of a bar graph. Each bar represents a different percentage of the system's electricity generation that is utilised by the building (i.e. onsite). Therefore, each bar has a different contribution of *reduced electricity bills* and of *SEG income from exporting surplus electricity*, in order to give the total annual financial benefit. This benefit influences the payback time for each onsite utilisation rate, which is the number of years after which the system will have paid for itself and begins to facilitate a net profit. These are shown as points on each graph and the numbers presented account for future inflation and degradation of the performance of the panels. If a point is not shown, this is because the payback period would be greater than 25 years.

The financial benefit and the payback period of each system are dictated by the size, energy yield and capital cost of the installation; electricity tariffs; SEG rates for export; as well as the utilisation of each buildings in terms of and occupancy patterns and electricity demand. A SEG rate of 5p/kWh was chosen as a conservative representation of the higher end of the currently available, technology-agnostic SEG offerings in the UK.

3.5.2. Heating systems

For each building, alternative heating system costs have been presented. These are high-level estimates based on Locogen's experience of installing such systems and are not inclusive of any costs that may be necessary to replace or upgrade existing heating systems. For the heat pump options, running costs are based on assumed seasonal Coefficient of Performance (sCOP) values, which are a measure of the ratio of electricity demand to heat generation.

The cost analysis is does not account for any government measures to incentivise the uptake of renewable heating. The current scheme, the Renewable Heat Incentive (RHI) is due to close to new applications in April 2021. An option for the RHI's replacement, called the Clean Heat Grant, has been put forward for consultation but the legislation is not yet in place.

Cost analyses provided for Ground Source Heat Pumps have been undertaken using capital costs for horizontal (slinky) collector arrays (as shown in Figure 8) which are generally cheaper to install, but do require a larger ground area than vertical collectors. As such, the feasibility of a GSHP system has only been considered where Village Halls have been confirmed to have significant external space. Where buildings have limited external space, the installation of vertical (or borehole) collectors could be considered; however, this is significantly more expensive and presents much bigger risks with regards to additionally testing required and the wider development process.

In order to demonstrate the beneficial impact of solar PV and battery storage on the renewable heating systems considered, a scenario is presented wherein 30% of the electricity demand for heating each building is produced by solar PV, or delivered from stored energy within the battery. This therefore reduces the quantity of electricity to be imported from the grid, which provides increased cost savings.

Finally, where Halls are currently heated by electricity (through storage heaters, electric panels or infrared heaters), we have assumed that 70% of the annual electricity bill is attributed to space heating.

4. Site assessments

4.1. Amotherby Village Hall

4.1.1. Overview

Amotherby Village Hall, built in 1930, is located in the south of Amotherby, 4km north-west of Malton. The building is of brick construction with an original tiled roof, which is noted to contain asbestos. The hall has double glazing throughout and comprises a large hall with a smaller committee room, a kitchen, toilets and store rooms.

Figure 11: Amotherby Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	None identified
Usage	~15 hours/week
Footprint	~210m^2
Existing Solar PV installation?	No
Heating system	Electric

Table 1: Amotherby Village Hall overview

The hall is heated throughout with electric convection heaters with a number of infra-red heaters installed in the main hall and committee room for instantaneous heat.

4.1.2. Energy demand

The heat and electricity demand of Amotherby Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Daytime electricity price	15.3 p/kWh
Annual electricity cost	£960
Annual electricity demand	8738 kWh
Annual electricity emissions	1.97 Tonnes CO_2

Table 2: Amotherby Village Hall energy demand

4.1.3. Energy opportunities

Electricity generation

With a large south facing roof area, Amorbethy Village Hall is well suited to a solar PV installation. However, the roof tiles are noted to contain asbestos. This is not a deal-breaker, but a specialist installation process would be required at a premium. If this project is taken forward into Phase 2, a cost estimate for this specialist process will be sought. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system is presented below.

Component	Value
Roof material	Tiles
Orientation	185°
Roof slope	40°
Shading	Moderate
Annual irradiation	947 kWh/m²
Suitable roof area	~95 m²

Table 3: Amotherby Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on two options and 320Wp PV modules. The first option is an array sized for a G98 grid application and the second is for the practical maximum array size. The costs presented are inclusive of battery and PV installation and (for Option 2) grid application fees.

Component	Option 1	Option 2
Array size	11.52 kWp	40.64 kWp
Array area	61 m²	216 m²
Battery capacity	11.6 kWh	11.6 kWh
installation cost	£14,370	£35,295
Annual generation	11640 kWh	41060 kWh
Annual emissions offset	2.6 Tonnes CO_2	9.3 Tonnes CO_2

Table 4: Amotherby Village Hall solar PV & battery system outputs

The figures below demonstrate the payback periods for these options, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Amotherby Village Hall, the maximum possible usage by the hall of electricity generated onsite under Option 1 could be as high as 80%. For Option 2, this would be around 58%.

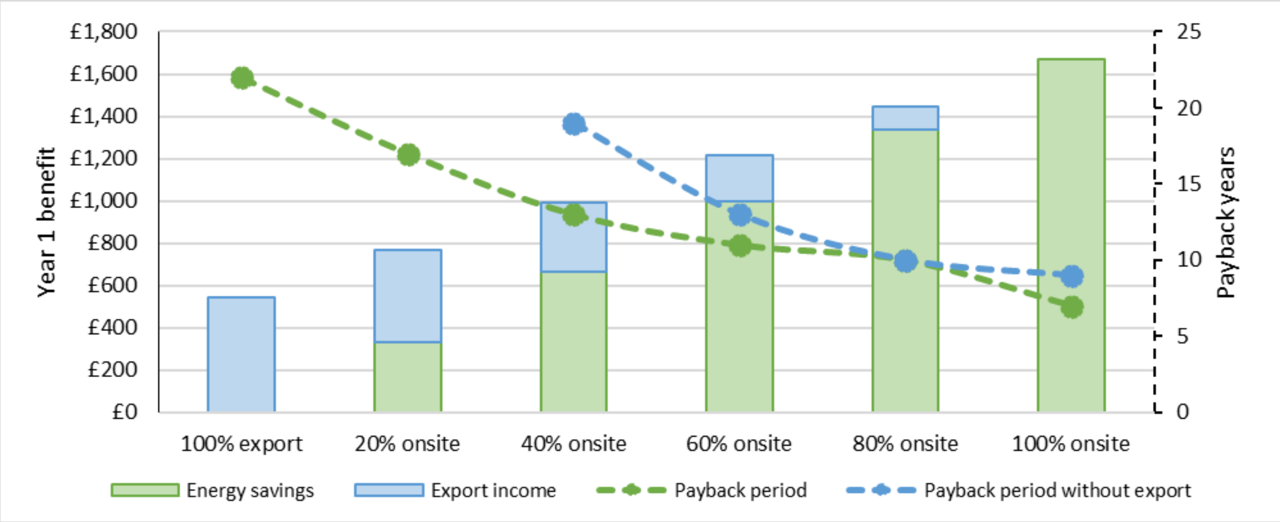

Figure 12: Amotherby Village Hall - Option 1 benefit & payback

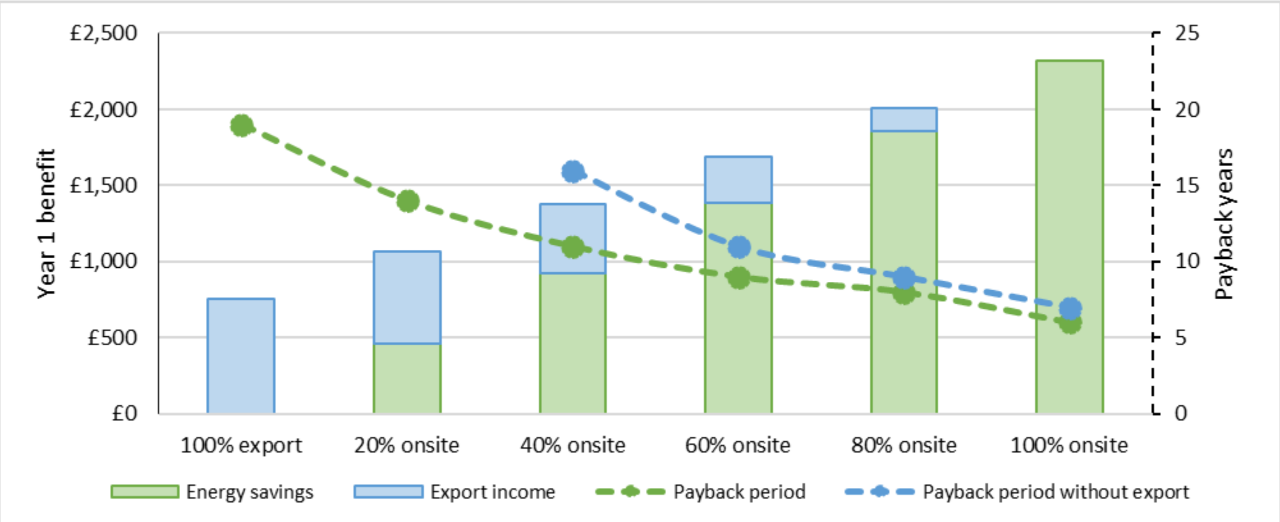

Figure 13: Amotherby Village Hall - Option 2 benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Amotherby Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the peak and annual heating demand and current fuel costs.

Factor	A2W HP	A2A HP
Capacity	17 kW	
Capex	£12,600	£5,880
Running costs	£201	£190
Savings vs now	£405	£419
Simple payback	-	14 years
Y1 CO_2 offset	1 Tonnes	1 Tonnes
Y20 CO_2 offset	23 Tonnes	23.3 Tonnes

With 30% of heat demand offset by PV generation:		
Running costs	£187	£177
Savings vs now	£485	£495
Simple payback	-	12 years
Y1 CO_2 offset	1.1 Tonnes	1.1 Tonnes
Y20 CO_2 offset	24.4 Tonnes	24.6 Tonnes

Table 5: Amotherby Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.2. Allerston Village Hall

4.2.1. Overview

Allerston Village Hall was the former village school, built in 1874, which re-opened as the village hall in 1955 following the closure of the school in 1950. The hall is approximately 14km north-east of Malton in North Yorkshire. The building is brick-built, with an asbestos-containing grey slate tiled roof which was installed in 1930. In 2005, thermal roll insulation was fitted within the attic space of the hall and kitchen; however, there is no insulation in the walls or floor.

Figure 14: Allerston Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	Conservation Area
Usage	~20 events/month
Footprint	~90 m²
Existing Solar PV installation?	No
Heating system	Electric

Table 6: Allerston Village Hall overview

Heating within Allerston Village Hall is through electric heaters in the form of convection heaters, portable oil radiators and electric bar heaters. While not confirmed, it is anticipated that heaters are only turned on when needed.

4.2.2. Energy demand

The heat and electricity demand of Allerston Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Daytime electricity price	24 p/kWh
Annual electricity cost	£840
Annual electricity demand	2861 kWh
Annual electricity emissions	0.65 Tonnes CO_2

Table 7: Allerston Village Hall energy demand

4.2.3. Energy opportunities

Electricity generation

The building has a small south-facing roof to the rear that is most suitable for a PV installation. Additionally, an installation in this location would minimise the visual impacts to the main road. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Allerston Village Hall is presented below.

Component	Value
Roof material	aluminium
Orientation	180°
Roof slope	30°
Shading	Trees affecting south east side
Annual irradiation	977 kWh/m²
Suitable roof area	~250m²

Table 8: Allerston Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation as well as planning fees.

Component	Option 1
Array size	3.52 kWp
Array area	19 m²
Battery capacity	5.8 kWh
Installation cost	£7,185
Annual generation	3260 kWh
Annual emissions offset	0.7 Tonnes CO_2

Table 9: Allerston Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Allerston Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 88%.

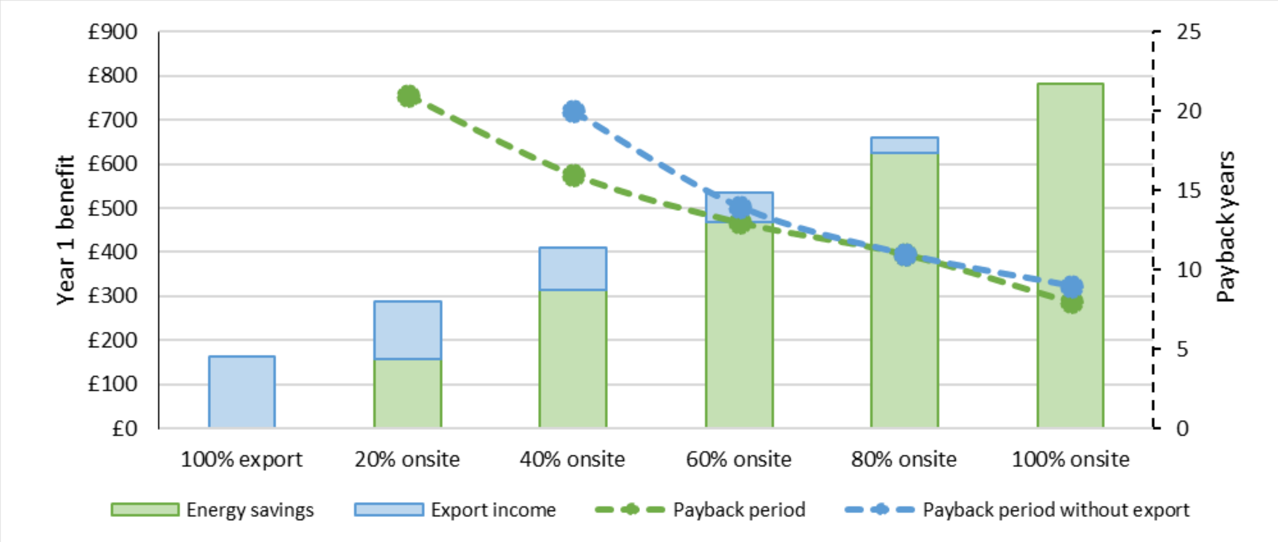

Figure 15: Allerston Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Allerston Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP
Capacity	7 kW	
Capex	£5,400	£2,520
Running costs	£103	£97
Savings vs now	£485	£491
Simple payback	12 years	6 years
Y1 CO_2 offset	0.3 Tonnes	0.3 Tonnes
Y20 CO_2 offset	7.5 Tonnes	7.6 Tonnes
With 30% of heat demand offset by PV generation:		
Running costs	£72	£68
Savings vs now	£516	£520
Simple payback	11 years	5 years
Y1 CO_2 offset	0.4 Tonnes	0.4 Tonnes
Y20 CO_2 offset	8 Tonnes	8 Tonnes

Table 10: Allerston Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.3. Brawby Village Hall

4.3.1. Overview

Brawby Village Hall, located at the eastern end of Brawby, a small village 7.5km north-west of Malton, was built in the 1850's. The hall is home to 'The Shed', a music and arts venue which hosts world-class music, comedy and poetry events. The building comprises a stone-built structure with a slate roof on felt.

Figure 16: Brawby Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	None identified
Usage	~2/3 hires per month
Footprint	~100 m²
Existing Solar PV installation?	No
Heating system	Electric

Table 11: Brawby Village Hall overview

Heating and electricity within Brawby Village Hall is entirely electricity-driven, with wall mounted and free-standing electric heaters meeting the heat demand of the building.

4.3.2. Energy demand

The heat and electricity demand of Brawby Village Hall is summarised below, based on information provided to Locogen.

Component	Value
Daytime electricity price	17 p/kWh
Annual electricity cost	£310
Annual electricity demand	1179 kWh
Annual electricity emissions	0.27 Tonnes CO_2

Table 12: Brawby Village Hall energy demand

4.3.3. Energy opportunities

Electricity generation

Although Brawby Village hall has a modest electricity demand, there is room to accommodate a PV installation which could provide income to the building. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Brawby Village Hall is presented below.

Component	Value
Roof material	Slate on felt
Orientation	185°
Roof slope	30°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~35 m²

Table 13: Brawby Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	6.08 kWp
Array area	32 m²
Battery capacity	5.8 kWh
Installation cost	£9,300
Annual generation	5710 kWh
Annual emissions offset	1.3 Tonnes CO_2

Table 14: Brawby Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Brawby Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 21%.

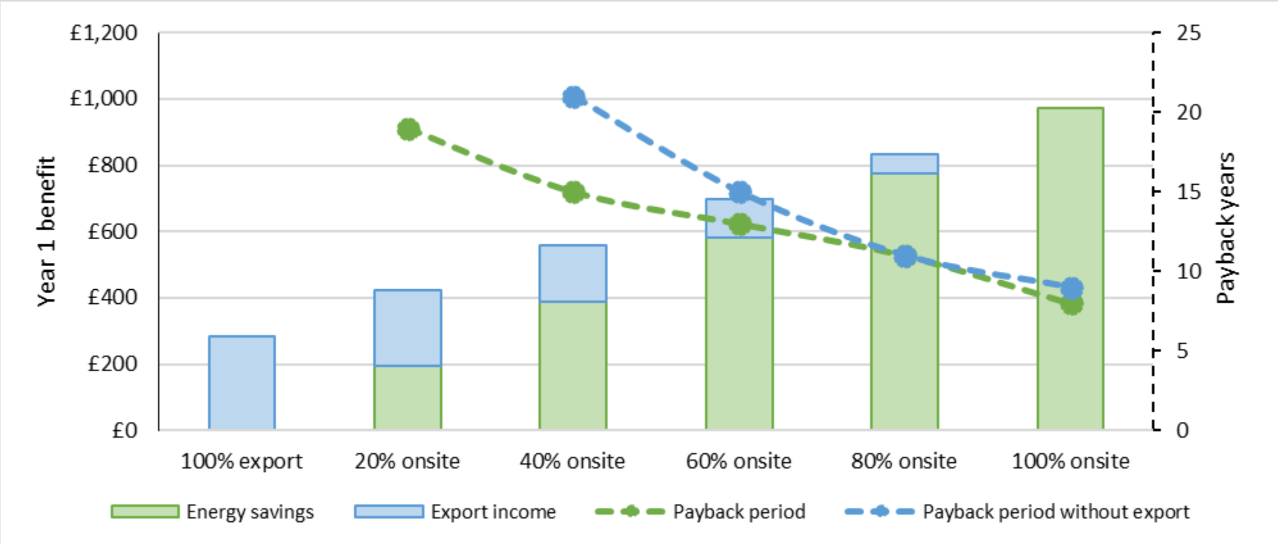

Figure 17: Brawby Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Brawby Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	Electric
Capacity		8 kW	
Capex	£6,000	£2,800	£3,200
Running costs	£40	£38	£140
Savings vs now	£177	£179	£77
Simple payback	-	16 years	-
Y1 CO_2 offset	0.1 Tonnes	0.1 Tonnes	0 Tonnes
Y20 CO_2 offset	3.1 Tonnes	3.1 Tonnes	1.6 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£28	£27	£98
Savings vs now	£189	£190	£119
Simple payback	-	15 years	-
Y1 CO_2 offset	0.1 Tonnes	0.2 Tonnes	0.1 Tonnes
Y20 CO_2 offset	3.3 Tonnes	3.3 Tonnes	2.2 Tonnes

Table 15: Brawby Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.4. Cropton Village Hall

4.4.1. Overview

Cropton, a village and civil parish in the Ryedale district of North Yorkshire, is on the border of the North York Moors National Park, 5km north-west of Pickering. It is home to Cropton Village Hall which was formally a chapel in the late 1890's and was added to over time. Constructed from stone and brick-work, it was most recently refurbished in 2004.

Figure 18: Cropton Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	North York Moors National Park
Usage	~6 hours/week
Footprint	~250 m^2
Existing Solar PV installation?	No
Heating system	Oil

Table 16: Cropton Village Hall overview

All heating with Cropton Village Hall is through an oil boiler. Details of this, including the age of the installed boiler, are unknown, but it is anticipated that this was installed when the hall was refurbished in 2005.

4.4.2. Energy demand

The heat and electricity demand of Cropton Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Daytime electricity price	20.4 p/kWh
Annual electricity cost	£690
Annual electricity demand	2297 kWh
Annual electricity emissions	0.52 Tonnes CO_2
Heat unit price	5.1 p/kWh
Annual heating cost	£410
Annual heat demand	8000 kWh
Annual heat emissions	1.8 Tonnes CO_2

Table 17: Cropton Village Hall energy demand

4.4.3. Energy opportunities

Electricity generation

As the building's south-facing roof appears to be heavily shaded by the adjacent building, the east-facing roof to the rear has been deemed more suitable for a PV installation. Placing PV here would also be a more accessible option whilst having a lower visual impact on the main road.

A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Cropton Village Hall is presented below.

Component	Value
Roof material	Tiles
Orientation	105°
Roof slope	45°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~55 m²

Table 18: Cropton Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation as well as planning fees.

Component	Option 1
Array size	9.28 kWp
Array area	49 m²
Battery capacity	5.8 kWh
Installation cost	£10,355
Annual generation	7190 kWh
Annual emissions offset	1.6 Tonnes CO_2

Table 19: Cropton Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Cropton Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 32%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly.

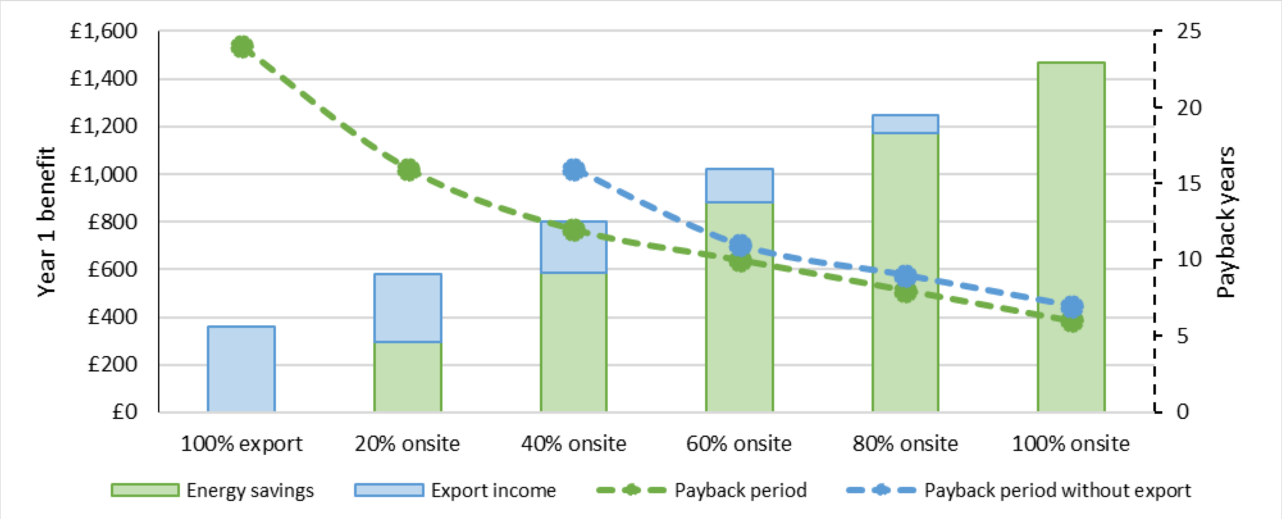

Figure 19: Cropton Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Cropton Village Hall is presented below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	Electric
Capacity	20 kW		
Capex	£15,000	£7,000	£8,000
Running costs	£350	£331	£1,224
Savings vs now	£60	£79	-£814
Simple payback	-	-	-
Y1 CO_2 offset	2.1 Tonnes	2.1 Tonnes	0.8 Tonnes
Y20 CO_2 offset	46.4 Tonnes	46.7 Tonnes	31.4 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£245	£232	£857
Savings vs now	£165	£178	-£447
Simple payback	-	-	-
Y1 CO_2 offset	2.3 Tonnes	2.3 Tonnes	1.4 Tonnes
Y20 CO_2 offset	48.1 Tonnes	48.4 Tonnes	37.7 Tonnes

Table 20: Cropton Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.5. East Thirsk Community Hall

4.5.1. Overview

Located in Thirsk, 37km north-west of Malton, East Thirsk Community Hall is of brick built construction with a plastic covered steel (known as Plasterol) roof.

Figure 20: East Thirsk Community Hall

Key Details	
Local Authority	Hambleton District Council
Designations	None identified
Usage	35 hours/week
Footprint	~460 m²
Existing Solar PV installation?	No
Heating system	Gas

Table 21: East Thirsk Community Hall overview

The hall is used approximately 33 hours per week, mostly during weekdays in the mornings and evenings; although there is some mid-day usage on Mondays and Tuesdays and usage varies seasonally with reduced usage in summer months (down to approximately 24 hours/week).

It is understood that heating of the building is done via gas, but it has not been confirmed what form this heating takes.

4.5.2. Energy demand

The heat and electricity demand of East Thirsk Community Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	17.9 p/kWh
Annual electricity cost	£2,380
Annual electricity demand	13289 kWh
Annual electricity emissions	3 Tonnes CO_2
Heat unit price	6 p/kWh
Annual heating cost	£1,660
Annual heat demand	27825 kWh
Annual heat emissions	6.28 Tonnes CO_2

Table 22: East Thirsk Community Hall energy demand

4.5.3. Energy opportunities

Electricity generation

Reduced usage levels of the village hall generally in summer months indicate that PV may not be a particularly suitable energy generating technology for East Thirsk Community Hall and the orientation of the roof and shading to the rear present real generation risk; however, a summary of the key considerations affecting the technical and financial feasibility of a solar PV system is presented below for completeness.

Component	Value
Roof material	Plasterol
Orientation	155°
Roof slope	60°
Shading	Minimal
Annual irradiation	995 kWh/m²
Suitable roof area	~340 m²

Table 23: East Thirsk Community Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	11.52 kWp
Array area	61 m²
Battery capacity	17.4 kWh
Installation cost	£16,370
Annual generation	10700 kWh
Annual emissions offset	2.4 Tonnes CO_2

Table 24: East Thirsk Community Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for this option, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of East Thirsk Community Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 100%.

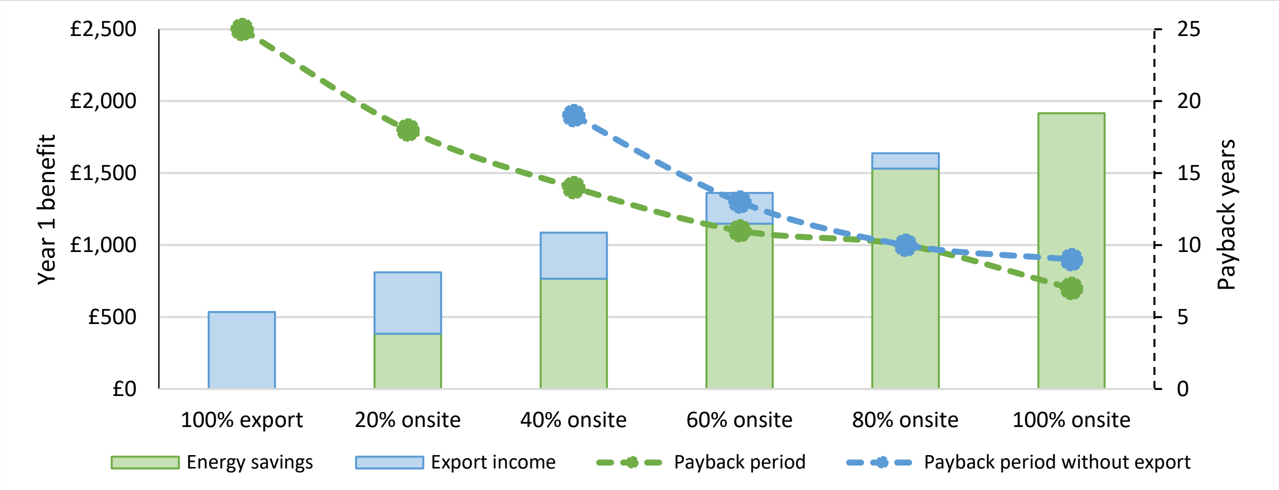

Figure 21: East Thirsk Community Hall - benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for East Thirsk Community Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	GSHP	Electric
Capacity	37 kW			
Capex	£27,600	£12,880	£46,000	£14,720
Running costs	£1,281	£1,212	£1,121	£4,483
Savings vs now	£379	£448	£539	-£2,823
Simple payback	-	-	-	-
Y1 CO_2 offset	3.9 Tonnes	4 Tonnes	4.1 Tonnes	-0.6 Tonnes
Y20 CO_2 offset	92.8 Tonnes	93.9 Tonnes	95.4 Tonnes	40.9 Tonnes
With 30% of heat demand offset by PV generation:				
Running costs	£897	£848	£784	£3,138
Savings vs now	£763	£812	£876	-£1,478
Simple payback	-	16 years	-	-
Y1 CO_2 offset	4.4 Tonnes	4.5 Tonnes	4.6 Tonnes	1.3 Tonnes
Y20 CO_2 offset	99 Tonnes	99.8 Tonnes	100.8 Tonnes	62.7 Tonnes

Table 25: East Thirsk Community Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.6. Farndale Village Hall

4.6.1. Overview

Farndale Village Hall, located in Farndale, 30km east of Northallerton in the heart of the North York Moors National Park was built in 2018. The hall is a steel frame building, with conventional insulated cavity block construction and timber cladding on the outside. Windows throughout are double glazed. The roofing material is zinc, with metal encased insulation.

Figure 22: Farndale Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	North York Moors National Park
Usage	~10 hours/week
Footprint	~210 m^2
Existing Solar PV installation?	Yes - 4kWp
Heating system	Electric

Table 26: Farndale Village Hall overview

Heating of Farndale Village Hall is through overhead ceramic electric heaters, while hot water is generated through electric point-of-use water heaters.

4.6.2. Energy demand

The heat and electricity demand of Farndale Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	**Value**
Daytime electricity price	15.2 p/kWh
Annual electricity cost	£1,560
Annual electricity demand	9726 kWh
Annual electricity emissions	2.19 Tonnes CO_2

Table 27: Farndale Village Hall energy demand

4.6.3. Energy opportunities

Electricity generation

The Farndale Village Hall already has a PV array connected to one of its three phases and has indicated that it does not wish to cover its south-facing roof in PV. This has been taken into account subsequently.

A summary of the key considerations affecting the technical and financial feasibility of an additional solar PV system is presented below.

Component	Value
Roof material	Zinc
Orientation	165°
Roof slope	36°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~120 m²

Table 28: Farndale Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a system of the same size as the current electric one, such that maximises the generation connected to a subsequent phase, utilising 320Wp panels. The costs presented are inclusive of battery and PV installation as well as planning fees.

Component	Option 1
Array size	3.84 kWp
Array area	20 m²
Battery capacity	5.8 kWh
Installation cost	£6,610
Annual generation	3596 kWh
Annual emissions offset	0.8 Tonnes CO_2

Table 29: Farndale Village Hall solar PV & battery system outputs

The figure below demonstrates the paybacks periods for the new array, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Farndale Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 90%.

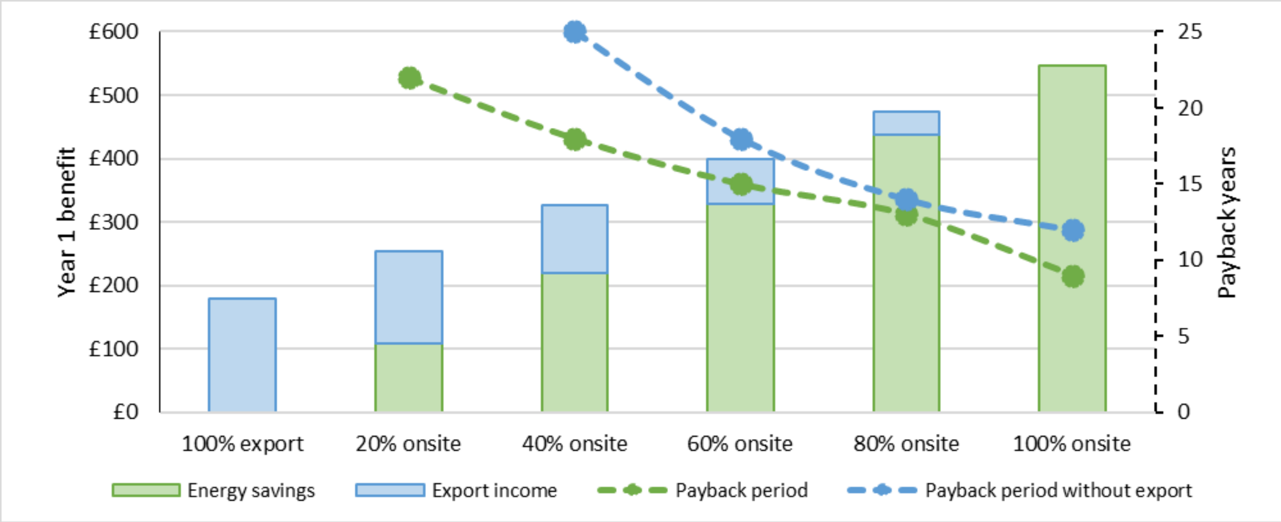

Figure 23: Farndale Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Farndale Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP
Capacity	17 kW	
Capex	£12,600	£5,880
Running costs	£296	£280
Savings vs now	£796	£812
Simple payback	16 years	7 years
Y1 CO_2 offset	1.1 Tonnes	1.1 Tonnes
Y20 CO_2 offset	25.6 Tonnes	25.9 Tonnes
With 30% of heat demand offset by PV generation:		
Running costs	£207	£196
Savings vs now	£885	£896
Simple payback	14 years	7 years
Y1 CO_2 offset	1.2 Tonnes	1.2 Tonnes
Y20 CO_2 offset	27.2 Tonnes	27.4 Tonnes

Table 15: Farndale Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.7. Foston & Thornton-Le-Clay Village Hall

4.7.1. Overview

Foston & Thornton-Le-Clay Village Hall, built in 1930, is located at the south-eastern corner of Thornton-Le-Clay, approximately 16km north-east of York. The hall is of timber construction, with a metal roof and large, single glazed windows throughout. It is noted that there is no insulation within the building.

Figure 24: Foston & Thornton le Clay Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	None identified
Usage	~7hours/week
Footprint	~110 m²
Existing Solar PV installation?	No
Heating system	Oil

Table 30: Foston & Thornton le Clay Village Hall overview

Heating of the space is through an oil-fired boiler, which is operated when needed by users by selecting a 'one hour' run time so the boiler doesn't remain on when the hall is not in use. Frost protection also brings the heating on when internal temperatures fall below 6°C.

4.7.2. Energy demand

The heat and electricity demand of Foston & Thornton le Clay Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Daytime electricity price	17 p/kWh
Annual electricity cost	£410
Annual electricity demand	1500 kWh
Annual electricity emissions	0.34 Tonnes CO_2
Heat unit price	5.1 p/kWh
Annual heating cost	£700
Annual heat demand	13750 kWh
Annual heat emissions	3.1 Tonnes CO_2

Table 31: Foston & Thornton le Clay Village Hall energy demand

4.7.3. Energy opportunities

Electricity generation

The rear roof of Foston & Thornton le Clay Village Hall is perfectly oriented for a solar PV installation, indicating that energy yield would be high. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system is presented below.

Component	Value
Roof material	Metal
Orientation	180°
Roof slope	30°
Shading	Minimal
Annual irradiation	977 kWh/m²
Suitable roof area	~65 m²

Table 32: Foston & Thornton le Clay Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	10.88 kWp
Array area	58 m²
Battery capacity	5.8 kWh
Installation cost	£11,795
Annual generation	10480 kWh
Annual emissions offset	2.4 Tonnes CO_2

Table 33: Foston & Thornton le Clay Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Foston & Thornton le Clay Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 14%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly.

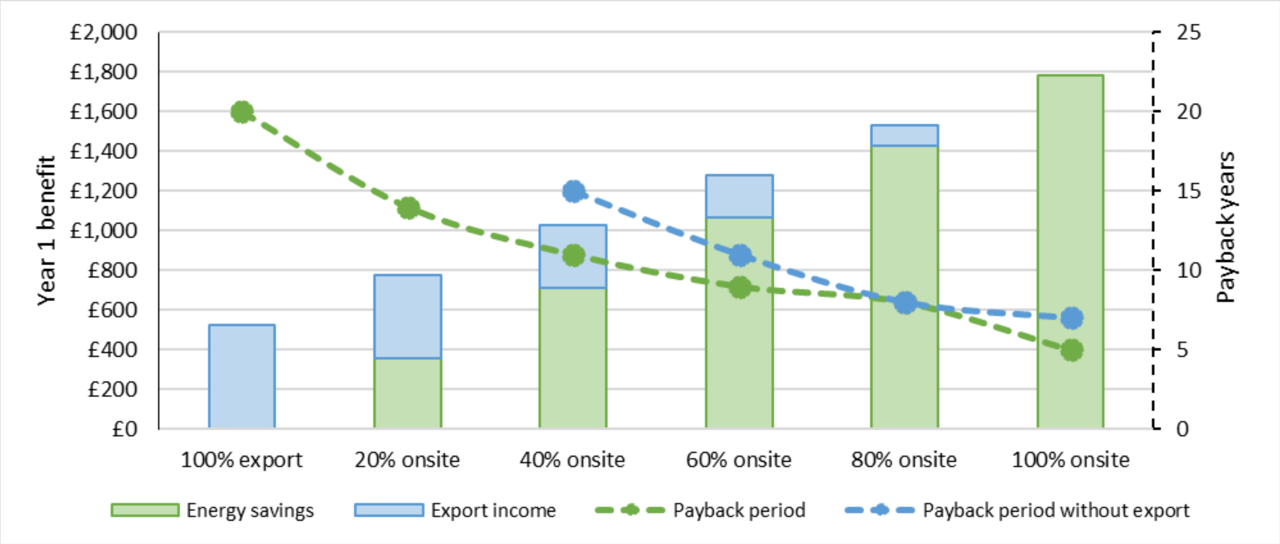

Figure 25: Foston & Thornton le Clay Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Foston & Thornton le Clay Village Hall is presented below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	Electric
Capacity		9 kW	
Capex	£6,600	£3,080	£3,520
Running costs	£501	£474	£1,753
Savings vs now	£199	£226	-£1,053
Simple payback	-	14 years	-
Y1 CO_2 offset	3.6 Tonnes	3.7 Tonnes	1.4 Tonnes
Y20 CO_2 offset	79.7 Tonnes	80.2 Tonnes	54 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£351	£332	£1,227
Savings vs now	£349	£368	-£527
Simple payback	19 years	8 years	-
Y1 CO_2 offset	3.9 Tonnes	3.9 Tonnes	2.3 Tonnes
Y20 CO_2 offset	82.7 Tonnes	83.1 Tonnes	64.8 Tonnes

Table 34: Foston & Thornton le Clay Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand below is illustrative only).

4.8. Ganton Village Hall

4.8.1. Overview

Ganton Village Hall, located at the southern end of Ganton, approximately 21km east of Malton, was built in 1993 and is of brick construction with a tiled roof, of which the roof and walls are insulated, and windows are double glazed.

Figure 26: Ganton Village Hall

Key Details	
Local Authority	Hambleton District Council
Designations	None identified
Usage	~ 16 hours/week
Footprint	~ 280 m²
Existing Solar PV installation?	No
Heating system	Electricity

Table 35: Ganton Village Hall overview

There is seasonal variation in the usage of Ganton Village Hall as it is used by the cricket club in the summer but by other groups to hold winter meetings. Generally, bookings are split between daytime groups and evening groups as well as all day events at the weekend, including the village show, parties, weddings and also use of the venue for elections.

The heating system is by individually switched infrared heaters in the main hall. There are also frost stat heaters used in the winter which are controlled by a thermostat. The water heating is by instantaneous point-of-use electric units as well as an electron water heater which is turned on for 15mins, prior to use, to heat the small tank of water. There are also electric showers in the changing rooms which are used occasionally in the summer.

4.8.2. Energy demand

The heat and electricity demand of Ganton Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	16.9 p/kWh
Annual electricity cost	£740
Annual electricity demand	3806 kWh
Annual electricity emissions	0.86 Tonnes CO_2

Table 36: Ganton Village Hall energy demand

4.8.3. Energy opportunities

Electricity generation

A summary of the key considerations affecting the technical and financial feasibility of a solar PV system at Ganton Village Hall is presented below.

Component	Value
Roof material	Tiles
Orientation	125°
Roof slope	30°
Shading	Negligible
Annual irradiation	947 kWh/m²
Suitable roof area	~115 m²

Table 37: Ganton Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	11.52 kWp
Array area	61 m²
Battery capacity	5.8 kWh
Installation cost	£12,370
Annual generation	9890 kWh
Annual emissions offset	2.2 Tonnes CO_2

Table 38: Ganton Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Ganton Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 38%.

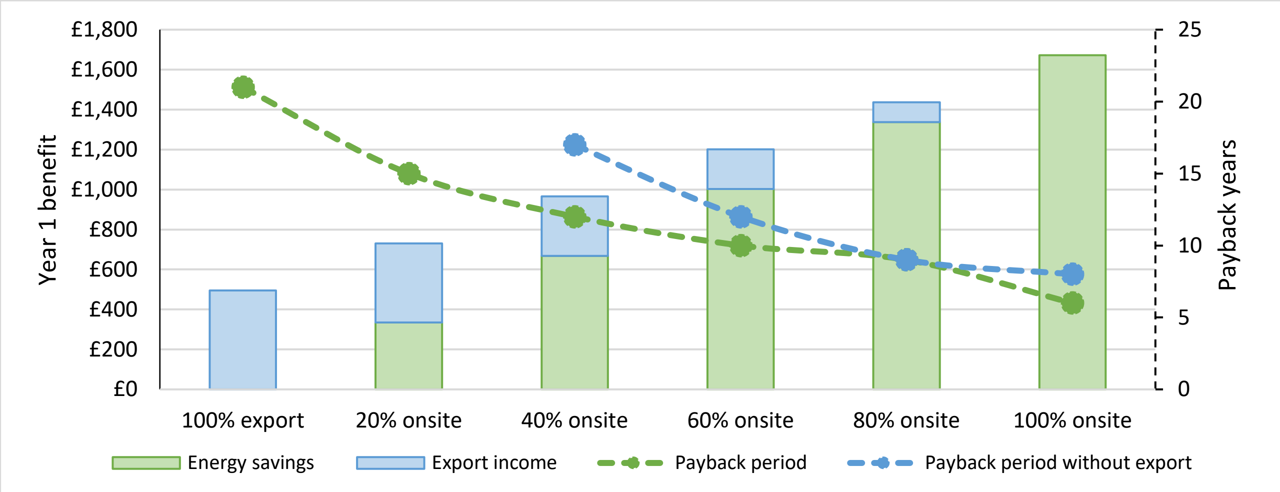

Figure 27: Ganton Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Ganton Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	GSHP
Capacity	22 kW		
Capex	£16,800	£7,840	£28,000
Running costs	£129	£122	£113
Savings vs now	£389	£396	£405
Simple payback	-	20 years	-
Y1 CO_2 offset	0.4 Tonnes	0.4 Tonnes	0.5 Tonnes
Y20 CO_2 offset	10 Tonnes	10.1 Tonnes	10.3 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£90	£85	£79
Savings vs now	£428	£433	£439
Simple payback	-	18 years	-
Y1 CO_2 offset	0.5 Tonnes	0.5 Tonnes	0.5 Tonnes
Y20 CO_2 offset	10.6 Tonnes	10.7 Tonnes	10.8 Tonnes

Table 39: Ganton Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.9. Kirkby Fleetham Village Hall

4.9.1. Overview

Kirkby Fleetham Village Hall located 9km west of Northallerton, North Yorkshire, is a brick-built building with rough cast rendering constructed in 1929. An extension, comprising a library, entrance foyer and toilet areas was added in 2015. The building has a pitched tiled roof which, while originally fitted along with the building in 1929, may have been retiled subsequently, although details of this are unknown. The building is double glazed throughout and in 2018, the Trustees installed internal insulation to the main hall (walls and ceiling) and a new oil-fired central heating system throughout the building.

Figure 28: Kirkby Fleetham

Key Details	
Local Authority	Hambleton District Council
Designations	None identified
Usage	~ 30 hours/week
Footprint	~180 m²
Existing Solar PV installation?	No
Heating system	Oil

Table 40: Kirkby Fleetham Village Hall overview

Other than the month of August being generally quiet, there are no significant seasonal variations in the usage of Kirkby Fleetham Village Hall. The building is used approximately 26 hours per week, with most usage occurring on weekdays in the mornings and evenings.

Heating of the hall is by an oil-fired boiler, which serves radiators throughout, including the main hall, library, kitchen, entrance foyer and toilets. The use of air source heat pumps to heat the hall was previously considered; however, such a system was found to be unfeasible.

4.9.2. Energy demand

The heat and electricity demand of Kirkby Fleetham Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	28 p/kWh
Annual electricity cost	£890
Annual electricity demand	2675 kWh
Annual electricity emissions	0.6 Tonnes CO_2
Heat unit price	5.1 p/kWh
Annual heating cost	£1,230
Annual heat demand	24059 kWh
Annual heat emissions	6.54 Tonnes CO_2

Table 41: Kirkby Fleetham Village Hall energy demand

4.9.3. Energy opportunities

Electricity generation

Usage levels of the village hall generally throughout the week indicate that PV would be a suitable energy generating technology at Kirkby Fleetham Village Hall. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system is presented below.

Component	Value
Roof material	Tiles
Orientation	200°
Roof slope	40°
Shading	Significant
Annual irradiation	998 kWh/m²
Suitable roof area	~55 m²

Table 42: Kirkby Fleetham Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	9.28 kWp
Array area	49 m²
Battery capacity	5.8 kWh
Installation cost	£10,355
Annual generation	9170 kWh
Annual emissions offset	2.1 Tonnes CO_2

Table 43: Kirkby Fleetham Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Kirkby Fleetham Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 24%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly.

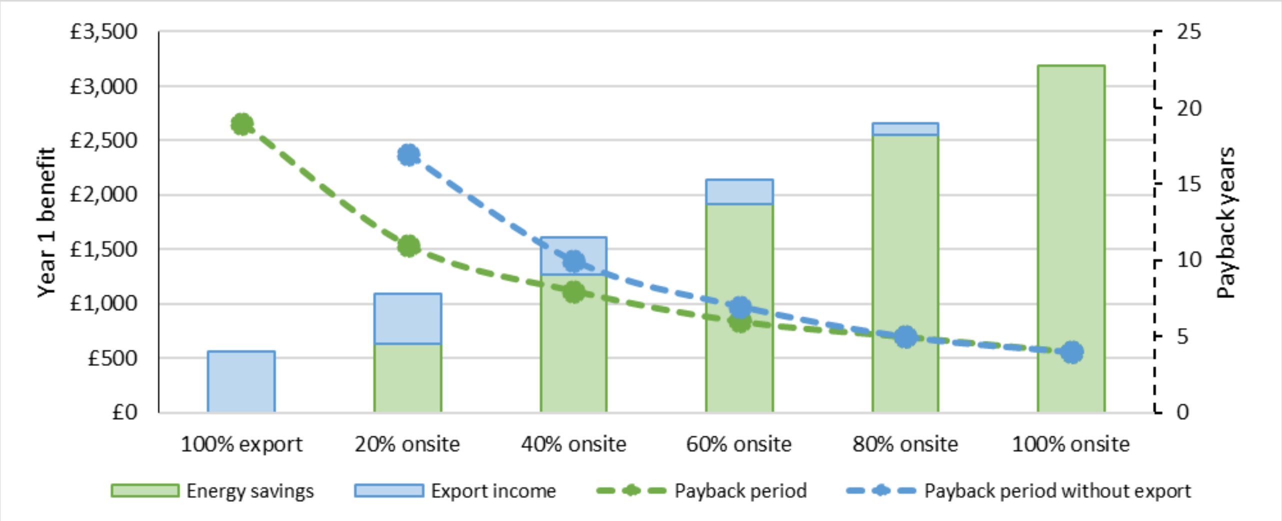

Figure 29: Kirkby Fleetham Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Kirkby Fleetham Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs. Given that the oil boiler was only installed very recently, it is understood that the installation of a new heating system may not be particularly desirable; however, the following demonstrates that there are heat pumps available that would be able to meet the flexibility and hot water demands of the hall.

Factor	A2W HP	A2A HP	GSHP	Electric
Capacity	14 kW			
Capex	£10,800	£5,040	£18,000	£5,760
Running costs	£1,732	£1,639	£1,516	£6,063
Savings vs now	-£502	-£409	-£286	-£4,833
Simple payback	-	-	-	-
Y1 CO_2 offset	5 Tonnes	5.1 Tonnes	5.2 Tonnes	1.1 Tonnes
Y20 CO_2 offset	112.9 Tonnes	113.9 Tonnes	115.2 Tonnes	68.1 Tonnes

With 30% of heat demand offset by PV generation:				
Running costs	£1,213	£1,147	£1,061	£4,244
Savings vs now	£17	£83	£169	-£3,014
Simple payback	-	-	-	-
Y1 CO_2 offset	5.5 Tonnes	5.5 Tonnes	5.6 Tonnes	2.7 Tonnes
Y20 CO_2 offset	118.3 Tonnes	119 Tonnes	119.9 Tonnes	86.9 Tonnes

Table 44: Kirkby Fleetham Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

It is noted that all of these options demonstrate negative cost savings against the current cost of oil heating; however, the unit price of electricity paid by Kirkby Fleetham Village Hall is very high in comparison with other halls within this study, which is adversely affective the cost savings calculated. Sand Hutton and Claxton Village Hall (as detailed in Section 4.18) has a similar building footprint and usage profile and presents much more positive cost savings for renewable heat installation. It is recommended that the trustees of Kirkby Fleetham Village Hall review their electricity tariff if they wish to determine whether a renewable heat installation would be viable.

4.10. Kirby Misperton Village Hall

4.10.1. Overview

Kirby Misperton Village Hall was built in 1991 and is of brick construction with a tiled roof. All windows are double glazed and the building is generally well insulated. The building is located at the southern end of Kirby Misperton village, approximately 7.5km north of Malton in North Yorkshire.

Figure 30: Kirby Misperton Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	None identified
Usage	~ 40-50 hours/week
Footprint	~320 m²
Existing Solar PV installation?	No
Heating system	Gas/electric

Table 45: Kirby Misperton Village Hall overview

Four large electric heaters are installed in the main hall of the building. The remaining rooms within the hall are heated by a new gas boiler which was installed in August 2020.

4.10.2. Energy demand

The heat and electricity demand of Kirby Misperton Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	**Value**
Daytime electricity price	16.9 p/kWh
Annual electricity cost	£520
Annual electricity demand	2430 kWh
Annual electricity emissions	0.55 Tonnes CO_2

Heat unit price	4.4 p/kWh
Annual heating cost	£920
Annual heat demand	20719 kWh
Annual heat emissions	4.23 Tonnes CO_2

Table 46: Kirby Misperton Village Hall energy demand

4.10.3. Energy opportunities

Electricity generation

The building's rear roof offers a slightly more favourable orientation than at the front, and therefore has been suggested for consideration. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Kirby Misperton Village Hall is presented below.

Component	Value
Roof material	Tiles
Orientation	260°
Roof slope	40°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~120 m²

Table 47: Kirby Misperton Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on two options and 320Wp PV modules. The first option is an array sized for a G98 grid application and the second is for the practical maximum array size. The costs presented are inclusive of battery and PV installation and (for Option 2) grid application fees.

Component	Option 1	Option 2
Array size	11.52 kWp	20.48 kWp
Array area	61 m²	109 m²
Battery capacity	5.8 kWh	5.8 kWh
installation cost	£12,370	£17,770
Annual generation	9030 kWh	16050 kWh
Annual emissions offset	2 Tonnes CO_2	3.6 Tonnes CO_2

Table 48: Kirby Misperton Village Hall solar PV & battery system outputs

The figures below demonstrate the payback periods for these options, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Kirby Misperton Village Hall, the maximum possible usage by the hall of electricity generated onsite Under Option 1 could be as high as 27%. For Option 2, this would be around 15%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly in each case.

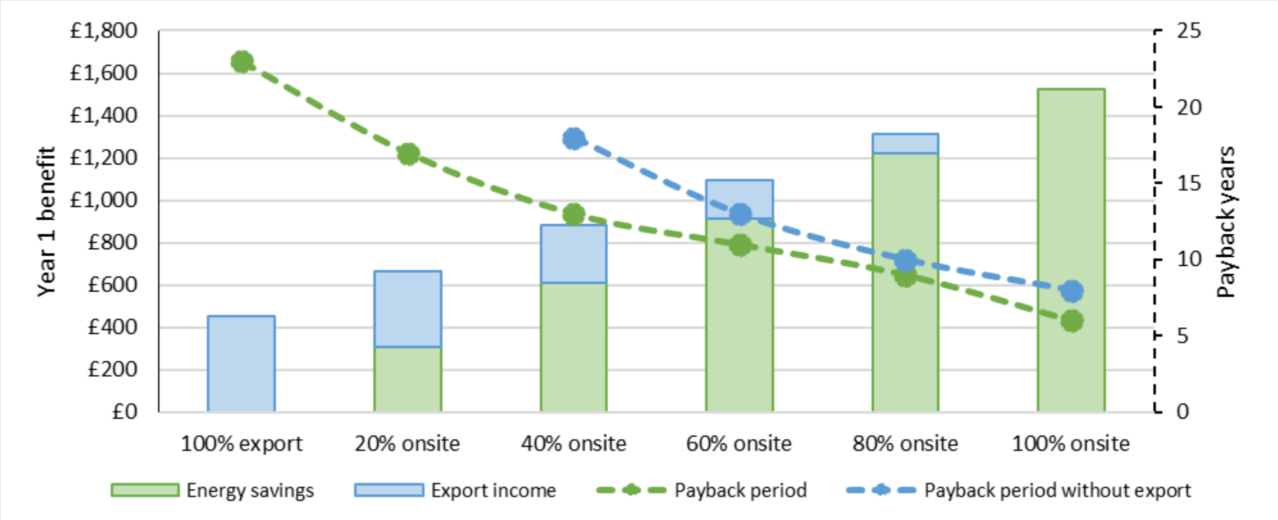

Figure 31: Kirby Misperton Village Hall - Option 1 benefit & payback

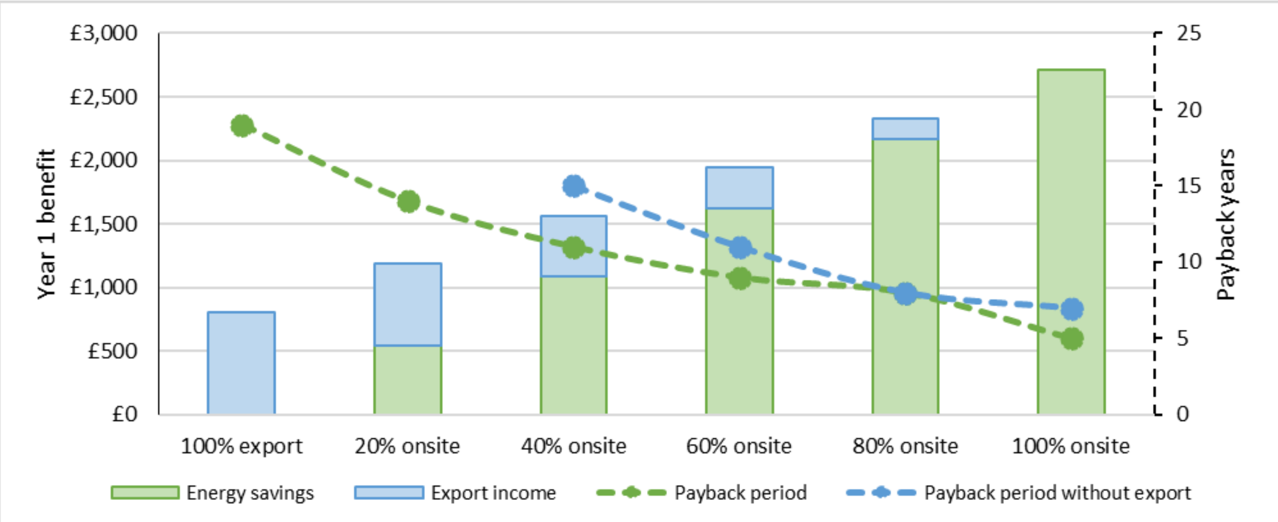

Figure 32: Kirby Misperton Village Hall - Option 2 benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Kirby Misperton Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	GSHP	Electric
Capacity	26 kW			
Capex	£19,200	£8,960	£32,000	£10,240
Running costs	£900	£852	£788	£3,151
Savings vs now	£20	£68	£132	-£2,231
Simple payback	-	-	-	-
Y1 CO_2 offset	2.9 Tonnes	3 Tonnes	3.1 Tonnes	-0.4 Tonnes
Y20 CO_2 offset	69.1 Tonnes	69.9 Tonnes	71 Tonnes	30.5 Tonnes
With 30% of heat demand offset by PV generation:				
Running costs	£630	£596	£551	£2,206

Savings vs now	£290	£324	£369	-£1,286
Simple payback	-	-	-	-
Y1 CO_2 offset	3.3 Tonnes	3.3 Tonnes	3.4 Tonnes	1 Tonnes
Y20 CO_2 offset	73.7 Tonnes	74.3 Tonnes	75.1 Tonnes	46.7 Tonnes

Table 49: Kirby Misperton Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.11. Kirkbymoorside Squash Club

4.11.1. Overview

Kirkbymoorside Squash Club is located on the south-east side of Kirkbymoorside, a market town around 10.5km west of Pickering. The building was opened in 1980 and is constructed of brick, with a timber & fibreglass roof.

Figure 33: Kirkbymoorside Squash Club

Key Details	
Local Authority	Ryedale District Council
Designations	Visually important underdeveloped area; North York Moors National Park
Usage	~ 35 hours/week
Footprint	~230 m²
Existing Solar PV installation?	No
Heating system	Gas and Electric

Table 50: Kirkbymoorside Squash Club overview

The building has gas central heating, as well as infrared radiators that hear the squash court. The site's energy is managed by the Kirkbymoorside Town Council.

4.11.2. Energy demand

The heat and electricity demand of Kirkbymoorside Squash Club is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	17.5 p/kWh
Annual electricity cost	£420
Annual electricity demand	1810 kWh
Annual electricity emissions	0.41 Tonnes CO_2
Heat unit price	4.3 p/kWh
Annual heating cost	£1,220
Annual heat demand	28125 kWh
Annual heat emissions	5.74 Tonnes CO_2

Table 51: Kirkbymoorside Squash Club energy demand

4.11.3. Energy opportunities

Electricity generation

The building has a north-facing roof which is not typically suitable for a PV installation; however, the installation of frames upon which a south-facing array could be mounted would drastically reduce the quantity of PV modules that could be installed. Given the utilisation of the building though, the additional cost of such a mounting system would not be justified.

A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Kirkbymoorside Squash Club is presented below.

Component	Value
Roof material	Timber & fibreglass
Orientation	345°
Roof slope	10°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~220 m²

Table 52: Kirkbymoorside Squash Club system inputs

The key outputs for a PV & battery system are presented below, based on a single option for an array of the maximum size allowed under a g98 application for a building with a single-phase electricity supply, and 320Wp panels. The costs presented are inclusive of battery and PV installation as well as planning fees.

Component	Option 1
Array size	3.84 kWp
Array area	20 m²
Battery capacity	5.8 kWh
installation cost	£6,610
Annual generation	2747 kWh
Annual emissions offset	0.6 Tonnes CO_2

Table 53: Kirkbymoorside Squash Club solar PV & battery system outputs

The figure below demonstrates the payback periods for this system, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Kirkbymoorside squash club, the maximum possible usage by the hall of electricity generated onsite would be around 66%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly.

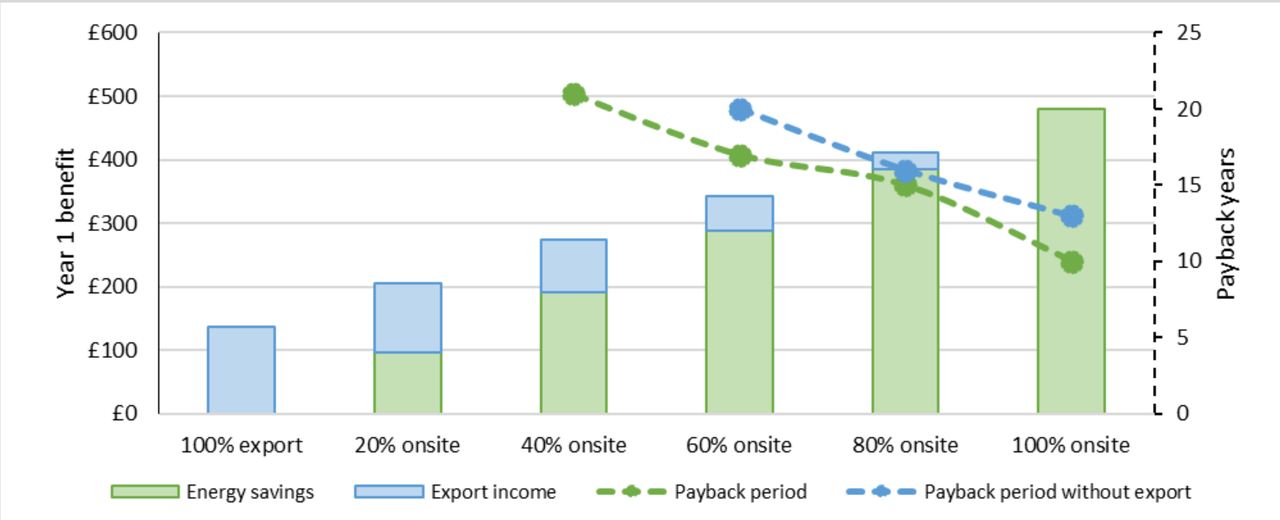

Figure 34: Kirkbymoorside squash club - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Kirkbymoorside squash club is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	GSHP	Electric
Capacity	18 kW			
Capex	£13,500	£6,300	£22,500	£7,200
Running costs	£1,266	£1,197	£1,107	£4,430
Savings vs now	-£46	£23	£113	-£3,210
Simple payback	-	-	-	-
Y1 CO_2 offset	3.9 Tonnes	4 Tonnes	4.2 Tonnes	-0.6 Tonnes
Y20 CO_2 offset	93.8 Tonnes	94.9 Tonnes	96.4 Tonnes	41.3 Tonnes

With 30% of heat demand offset by PV generation:				
Running costs	£886	£838	£775	£3,101
Savings vs now	£334	£382	£445	-£1,881
Simple payback	-	16 years	-	-
Y1 CO_2 offset	4.5 Tonnes	4.5 Tonnes	4.6 Tonnes	1.3 Tonnes
Y20 CO_2 offset	100.1 Tonnes	100.9 Tonnes	101.9 Tonnes	63.4 Tonnes

Table 54: Kirkbymoorside squash club renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand below is illustrative only).

4.12. Lastingham and Spaunton Village Hall

4.12.1. Overview

Originally built as a school in 1885, the Lastingham and Spaunton Village Hall (also known as Darley Memorial Hall) is located in Lastingham, approximately 19km north of Malton in the south of the North York Moors National Park. The building is of stone construction, with high ceilings and large single glazed windows. The roof is pan tiled ridged and was semi-recently refurbished in 1996.

Figure 35: Darley Memorial Hall - Lastingham and Spaunton

Key Details	
Local Authority	Ryedale District Council
Designations	North York Moors National Park & Conservation Area
Usage	~5-10 hours/week
Footprint	~100 m²
Existing Solar PV installation?	No
Heating system	Electricity

Table 55: Lastingham and Spaunton Village Hall overview

The regular weekly occupancy of the building extends to Keep Fit classes, with further ad-hoc events.

Heating is electrically-driven, through electric wall heaters and convectors in the main hall, with storage heaters in the kitchen and accessible toilet. It is noted that in the summer months, heating is not required; however, in winter, the heating is turned on manually 15 minutes before classes to warm up the hall. Heating is not required during events with high occupancies.

4.12.2. Energy demand

The heat and electricity demand of Lastingham and Spaunton Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	16.2 p/kWh
Annual electricity cost	£480
Annual electricity demand	2764 kWh
Annual electricity emissions	0.62 Tonnes CO_2

Table 56: Lastingham and Spaunton Village Hall energy demand

4.12.3. Energy opportunities

Electricity generation

The building has a small south-facing roof to the rear that is most suitable for a PV installation. Additionally, an installation in this location would minimise the visual impacts to the main road. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Lastingham and Spaunton Village Hall is presented below.

Component	Value
Roof material	Tiles
Orientation	140°
Roof slope	60°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~85 m²

Table 57: Lastingham and Spaunton Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on two options and 320Wp PV modules. The first option is an array sized for a G98 grid application and the second is for the practical maximum array size. The costs presented are inclusive of battery and PV installation, planning fees, and (for Option 2) grid application fees.

Component	Option 1	Option 2
Array size	11.52 kWp	14.4 kWp
Array area	61 m²	77 m²
Battery capacity	5.8 kWh	5.8 kWh
Installation cost	£13,330	£14,050
Annual generation	9720 kWh	12150 kWh
Annual emissions offset	2.2 Tonnes CO_2	2.7 Tonnes CO_2

Table 58: Lastingham and Spaunton Village Hall solar PV & battery system outputs

The figures below demonstrate the payback periods for these options, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Lastingham and Spaunton Village Hall, the maximum possible usage by the hall of electricity generated onsite under Option 1 could be as high as 28%. For Option 2, this would be around 23%.

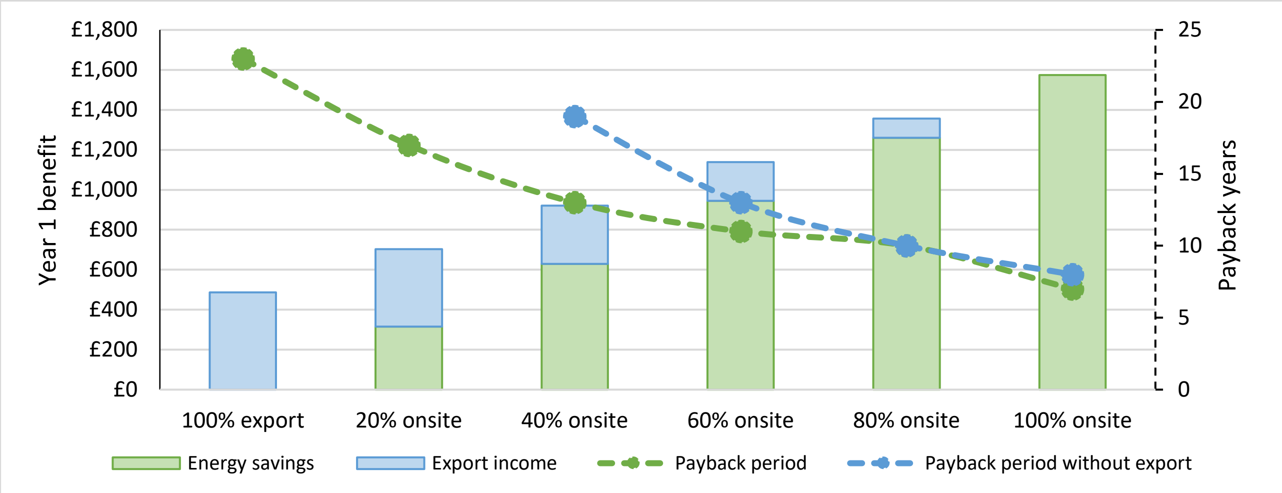

Figure 36: Lastingham and Spaunton Village Hall - Option 1 benefit & payback

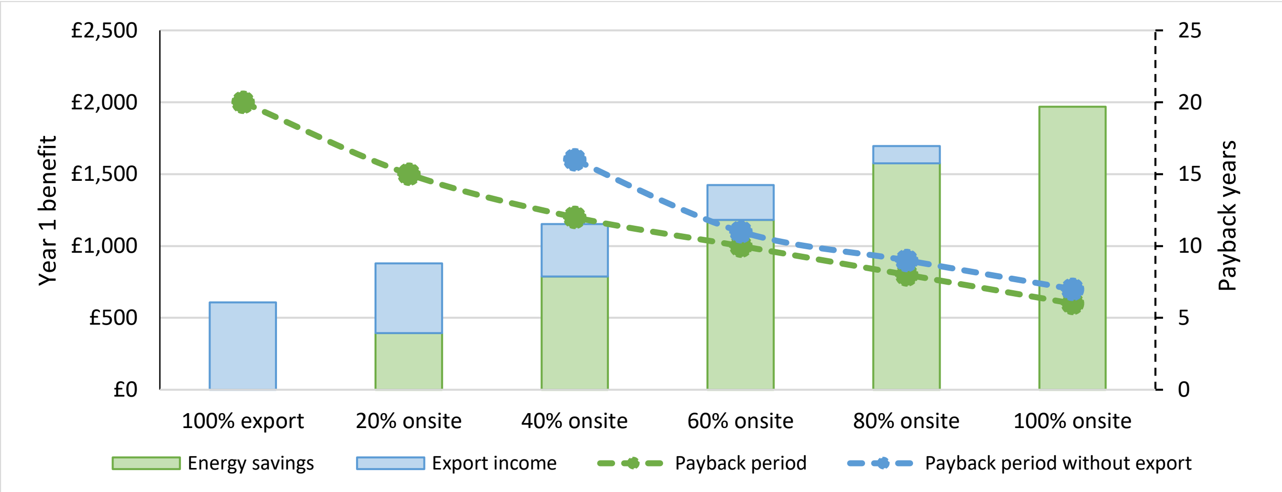

Figure 37: Lastingham and Spaunton Village Hall - Option 2 benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Lastingham and Spaunton Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP
Capacity	8 kW	
Capex	£6,000	£2,800
Running costs	£90	£85
Savings vs now	£246	£251
Simple payback	24 years	11 years
Y1 CO_2 offset	0.3 Tonnes	0.3 Tonnes
Y20 CO_2 offset	7.3 Tonnes	7.4 Tonnes

With 30% of heat demand offset by PV generation:		
Running costs	£63	£59
Savings vs now	£273	£277
Simple payback	22 years	10 years
Y1 CO_2 offset	0.3 Tonnes	0.4 Tonnes
Y20 CO_2 offset	7.7 Tonnes	7.8 Tonnes

Table 59: Lastingham and Spaunton Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.13. Middleton and Aislaby Village Hall

4.13.1. Overview

Middleton and Aislaby Village Hall, located at the eastern end of Middleton, approximately 13km north of Malton, consists of two separate but adjacent buildings, which are both single storey and of stone construction. The Main Hall was previously the Village School until 1955 and the small hall, known as the Sunday School Room, was a reading room gifted to the village in 1832, so built prior to that date. The roofs on both buildings are tiled and the roof on the main hall was replaced approximately eight years ago. Insulation is present within roof spaces and windows in both halls are double glazed.

Figure 38: Middleton and Aislaby Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	Conservation Area
Combined usage	~ 25 hours/week
Hall 1 Footprint	~150m^2
Hall 2 Footprint	~60m^2
Existing Solar PV installation?	No
Heating system	Gas

Table 60: Middleton and Aislaby Village Hall overview

Heating in both halls is through gas fired central heating, with a domestic sized boiler system in each building supplying standard radiators.

4.13.2. Energy demand

The heat and electricity demand of Middleton and Aislaby Village Hall is summarised below, based on information provided to Locogen and supplementary estimates. Hereafter, the larger of the halls is referred to as 'Hall 1', and the smaller as 'Hall 2'.

Component	Value
Electricity price	15.1 p/kWh
Annual electricity cost	£610
Annual electricity demand	2772 kWh
Annual electricity emissions	0.63 Tonnes CO_2
Heat unit price	4.5 p/kWh
Annual heating cost	£820
Annual heat demand	18125 kWh
Annual heat emissions	3.7 Tonnes CO_2

Table 61: Middleton and Aislaby energy demand – Hall 1

Component	Value
Electricity price	21.7 p/kWh
Annual electricity cost	£350
Annual electricity demand	635 kWh
Annual electricity emissions	0.14 Tonnes CO_2
Heat unit price	5.2 p/kWh
Annual heating cost	£390
Annual heat demand	7500 kWh
Annual heat emissions	1.53 Tonnes CO_2

Table 62: Middleton and Aislaby energy demand – Hall 2

4.13.3. Energy opportunities

Electricity generation

Both buildings have south-west facing roofs that would be suitable for separate PV installations. Another option (not explored in this report) could be to install a single system on the roof of one of the halls that provides a portion of its generation to the other.

A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Middleton and Aislaby Village Hall is presented below.

Component	Value
Roof material	clay tiles
Orientation	215°
Roof slope	25°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~75 m²

Table 63: Middleton and Aislaby system inputs– Hall 1

Component	Value
Roof material	clay tiles
Orientation	215°
Roof slope	35°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~35 m²

Table 64: Middleton and Aislaby system inputs– Hall 2

The key outputs for a PV & battery system are presented below, based on two options and 320Wp PV modules. Both of these options maximise the roof area whilst avoiding the grid connection costs associated with exceeding g98 limits. The costs presented are inclusive of battery and PV installation, planning fees, and grid application fees.

Component	Option 1 – Hall 1	Option 2 – Hall 2
Array size	11.52 kWp	6.08 kWp
Array area	61 m²	32 m²
Battery capacity	5.8 kWh	5.8 kWh
installation cost	£13,330	£6,685
Annual generation	10420 kWh	5580 kWh
Annual emissions offset	2.4 Tonnes CO_2	1.3 Tonnes CO_2

Table 65: Middleton and Aislaby solar PV & battery system outputs

The figures below demonstrate the payback periods for these options, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Middleton and Aislaby Village Hall, the maximum possible usage by the hall of electricity generated onsite would be around 27% for Option 1. For Option 2, this would be around 11%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly in each case.

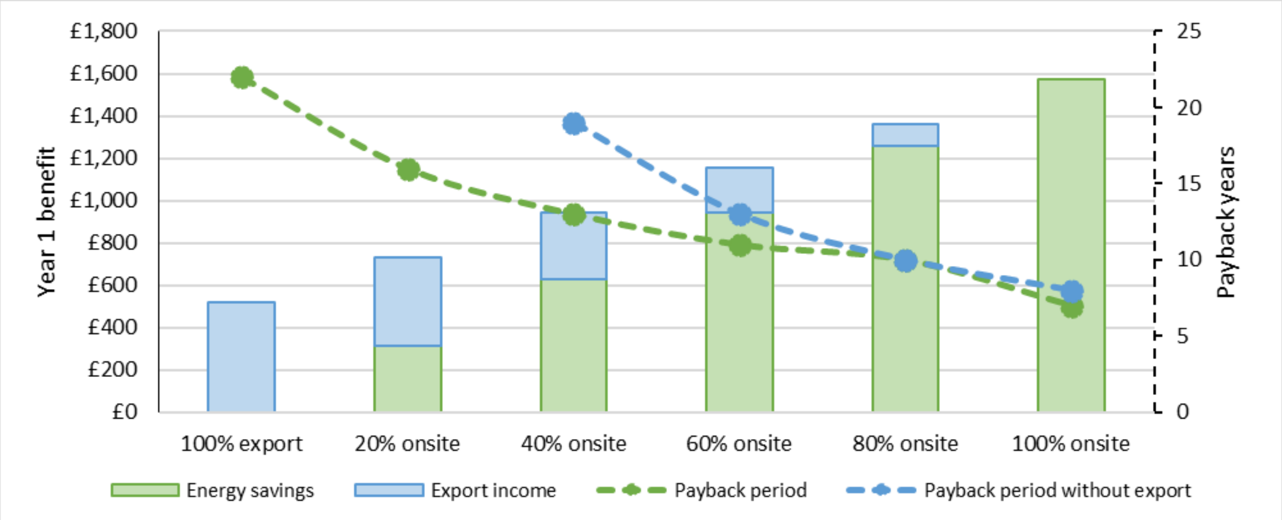

Figure 39: Middleton and Aislaby Village Hall - Option 1

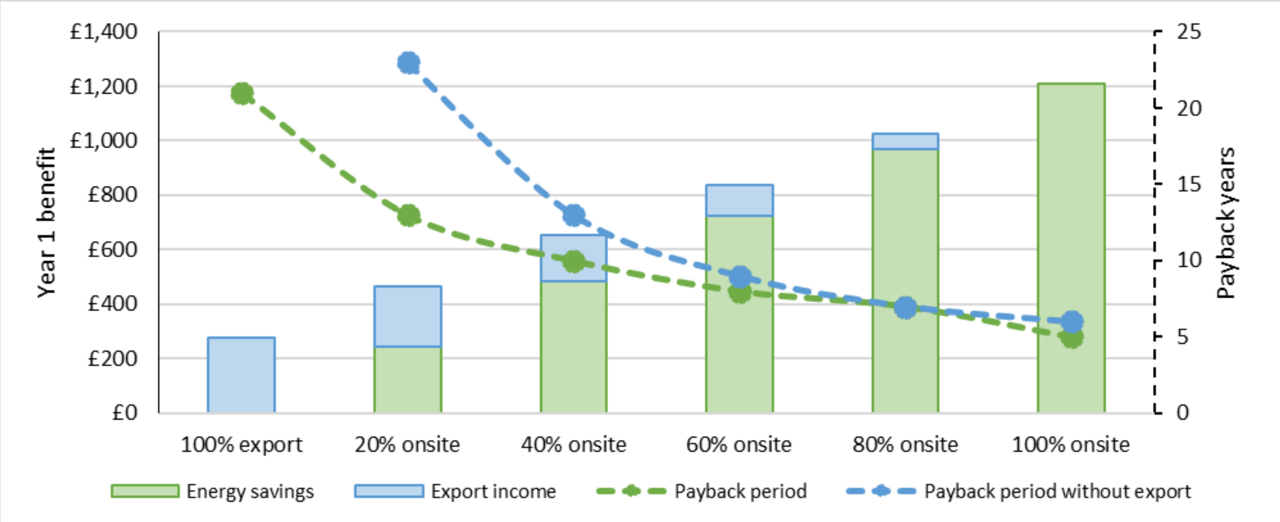

Figure 40: Middleton and Aislaby Village Hall – Option 2

Renewable heat generation

A summary of the renewable heating system options identified for Middleton and Aislaby Village Hall is presented in the tables below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

As with PV, these are presented for both halls individually (based on estimated heat demands). Of course, a joint system could be installed if this was preferable.

Factor	A2W HP	A2A HP	Electric
Capacity	12 kW		
Capex	£8,700	£4,060	£4,640
Running costs	£704	£666	£2,463
Savings vs now	£116	£154	-£1,643
Simple payback	-	-	-
Y1 CO_2 offset	2.5 Tonnes	2.6 Tonnes	-0.4 Tonnes
Y20 CO_2 offset	60.4 Tonnes	61.2 Tonnes	26.6 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£493	£466	£1,724
Savings vs now	£327	£354	-£904
Simple payback	-	11 years	-
Y1 CO_2 offset	2.9 Tonnes	2.9 Tonnes	0.8 Tonnes
Y20 CO_2 offset	64.5 Tonnes	65 Tonnes	40.8 Tonnes

Table 66: Middleton and Aislaby renewable heating system outputs – Hall 1

Factor	A2W HP	A2A HP	Electric
Capacity	5 kW		
Capex	£3,600	£1,680	£1,920
Running costs	£419	£396	£1,465
Savings vs now	-£29	-£6	-£1,075
Simple payback	-	-	-
Y1 CO_2 offset	1 Tonnes	1.1 Tonnes	-0.2 Tonnes
Y20 CO_2 offset	25 Tonnes	25.3 Tonnes	11 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£293	£277	£1,025
Savings vs now	£97	£113	-£635
Simple payback	-	15 years	-
Y1 CO_2 offset	1.2 Tonnes	1.2 Tonnes	0.3 Tonnes
Y20 CO_2 offset	26.7 Tonnes	26.9 Tonnes	16.9 Tonnes

Table 67: Middleton and Aislaby renewable heating system outputs – Hall 2

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.14. Milton Rooms

4.14.1. Overview

Malton, a market town and civil parish in the Ryedale district of North Yorkshire, is on the border of the Howardian Hills AONB, 27km north-east of the city of York. It is home to the Milton Rooms, a large arts and community centre owned by the Fitzwilliam Estate which was built in 1931 on the former site of the original theatre. The Milton Rooms are constructed from brick-work with a standard tile roof.

Figure 41: The Milton Rooms

Key Details	
Local Authority	Ryedale District Council
Designations	Malton Conservation Area, Grade 2 listed
Usage	~ 30 hours/week
Footprint	~ 550m^2
Existing Solar PV installation?	No
Heating system	Electricity

Table 68: Milton Rooms overview

The building is heated using electric storage heaters. One main event is held weekly at the Milton Rooms, alongside usage by local community groups including brass band practice, dance schools, yoga, and food markets. It is anticipated that usage will increase in future now that a new group of trustees are in place.

4.14.2. Energy demand

The heat and electricity demand of Milton Rooms is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	18.6 p/kWh
Annual electricity cost	£3,800
Annual electricity demand	19866 kWh
Annual electricity emissions	4.48 Tonnes CO_2

Table 69: Milton Rooms energy demand

4.14.3. Energy opportunities

Electricity generation

The building has a small south-facing roof over the Subscription Rooms; however, the roof face is heavily overshaded by surrounding buildings and would be unsuitable for a PV installation. As such, we have proposed to install a PV array on the west-facing roof face. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for the Milton Rooms is presented below.

Component	Value
Roof material	Tiles
Orientation	255°
Roof slope	30°
Shading	Mild
Annual irradiation	947 kWh/m²
Suitable roof area	~140 m²

Table 70: Milton Rooms system inputs

The key outputs for a PV & battery system are presented below, based on two options and 320Wp PV modules. The first option is an array sized for a G98 grid application and the second is for the practical maximum array size. The costs presented are inclusive of battery and PV installation, planning fees, and (for Option 2) grid application fees.

Component	Option 1	Option 2
Array size	11.52 kWp	23.68 kWp
Array area	61 m²	126 m²
Battery capacity	40.6 kWh	40.6 kWh
Installation cost	£25,330	£33,195
Annual generation	9370 kWh	19250 kWh
Annual emissions offset	2.1 Tonnes CO_2	4.3 Tonnes CO_2

Table 71: Milton Rooms solar PV & battery system outputs

The figures below demonstrate the payback periods for these options, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Milton Rooms, the maximum possible usage by the hall of electricity generated onsite would be around 100% for Option 1. For Option 2, this would also be around 100%.

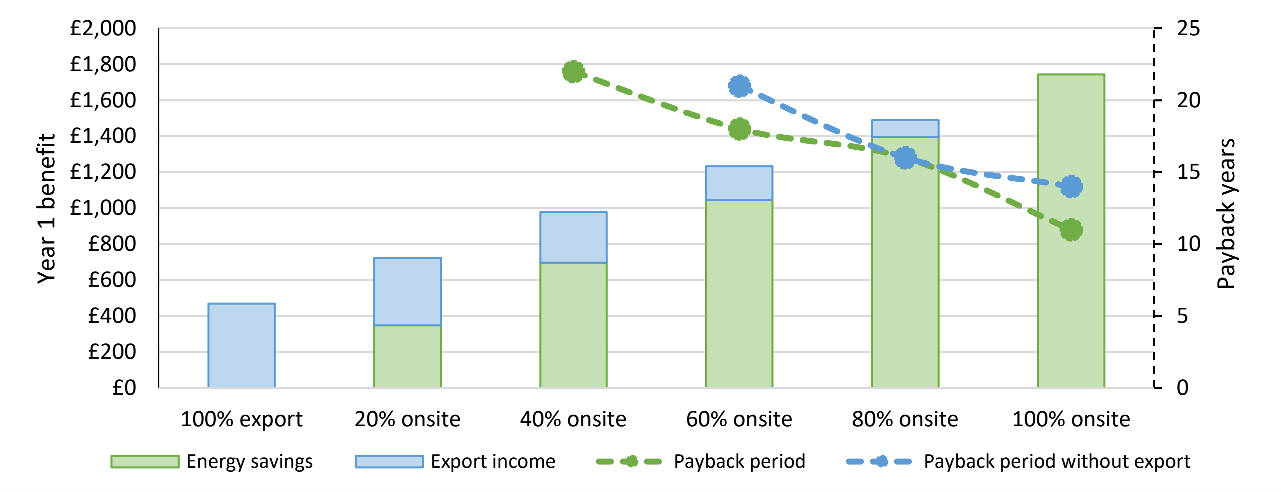

Figure 42: Milton Rooms - Option 1 benefit & payback

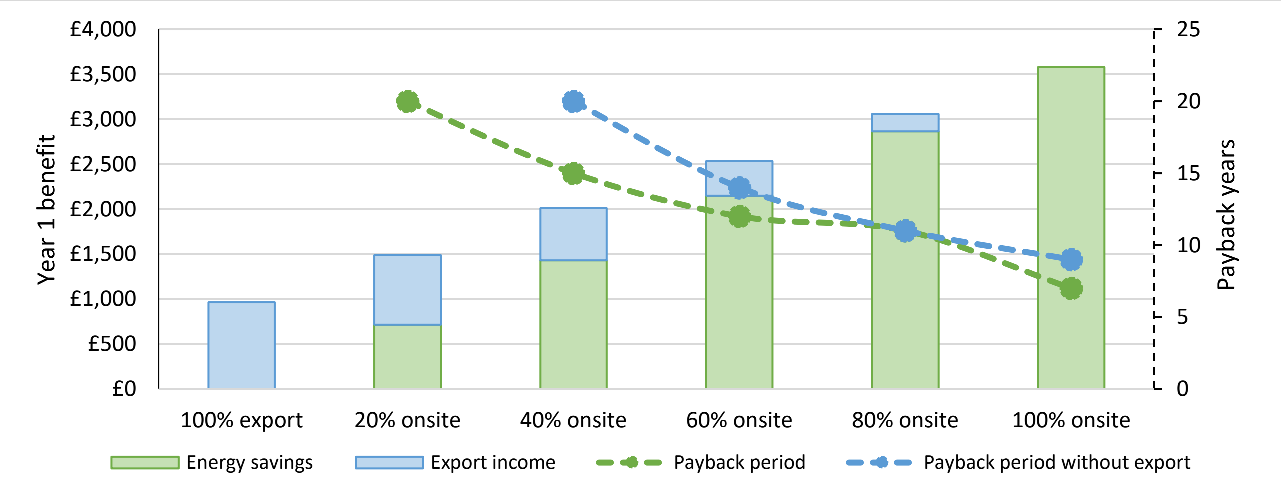

Figure 43: Milton Rooms - Option 2 benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for the Milton Rooms is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	GSHP
Capacity		44 kW	
Capex	£33,000	£15,400	£55,000
Running costs	£739	£699	£647
Savings vs now	£1,921	£1,961	£2,013
Simple payback	17 years	8 years	-
Y1 CO_2 offset	2.2 Tonnes	2.3 Tonnes	2.4 Tonnes
Y20 CO_2 offset	52.4 Tonnes	52.9 Tonnes	53.7 Tonnes

With 30% of heat demand offset by PV generation:			
Running costs	£517	£489	£453
Savings vs now	£2,143	£2,171	£2,207
Simple payback	15 years	7 years	25 years
Y1 CO_2 offset	2.5 Tonnes	2.5 Tonnes	2.6 Tonnes
Y20 CO_2 offset	55.5 Tonnes	55.9 Tonnes	56.4 Tonnes

Table 72: Milton Rooms renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand below is illustrative only).

4.15. Old Malton Village Hall

4.15.1. Overview

The Old Malton War Memorial Hall is located in Old Malton, approximately 1.5km north-east of Malton in North Yorkshire. The hall is brick-built, with a pitched, pantile roof which was replaced and likely insulated two years ago. The windows to the front and the side of the hall are double glazed, but all other windows are single glazed.

Figure 44: Old Malton Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	Conservation area
Usage	~10 hours/week
Footprint	~250 m²
Existing Solar PV installation?	No
Heating system	Electric

Table 73: Old Malton Village Hall overview

The heat demands at Old Malton Village Hall are met by night storage heaters and supplemented by electric wall mounted heaters, whereby users of the hall can pay £1 for 15-20 minutes of heating.

4.15.2. Energy demand

The heat and electricity demand of Old Malton Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Daytime electricity price	15.8 p/kWh
Annual electricity cost	£2,690
Annual electricity demand	16500 kWh
Annual electricity emissions	3.72 Tonnes CO_2

Table 74: Old Malton Village Hall energy demand

4.15.3. Energy opportunities

Electricity generation

The building has a small south-facing roof to the rear that is most suitable for a PV installation. Additionally, an installation in this location would minimise the visual impacts to the main road. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Old Malton Village Hall is presented below.

Component	Value
Roof material	Pantiles
Orientation	190°
Roof slope	45°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~50 m²

Table 75: Old Malton Village Hall overview

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation as well as planning fees.

Component	Option 1
Array size	9.28 kWp
Array area	49 m²
Battery capacity	17.4 kWh
Installation cost	£15,315
Annual generation	8730 kWh
Annual emissions offset	2 Tonnes CO_2

Table 76: Old Malton Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Old Malton Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 90%.

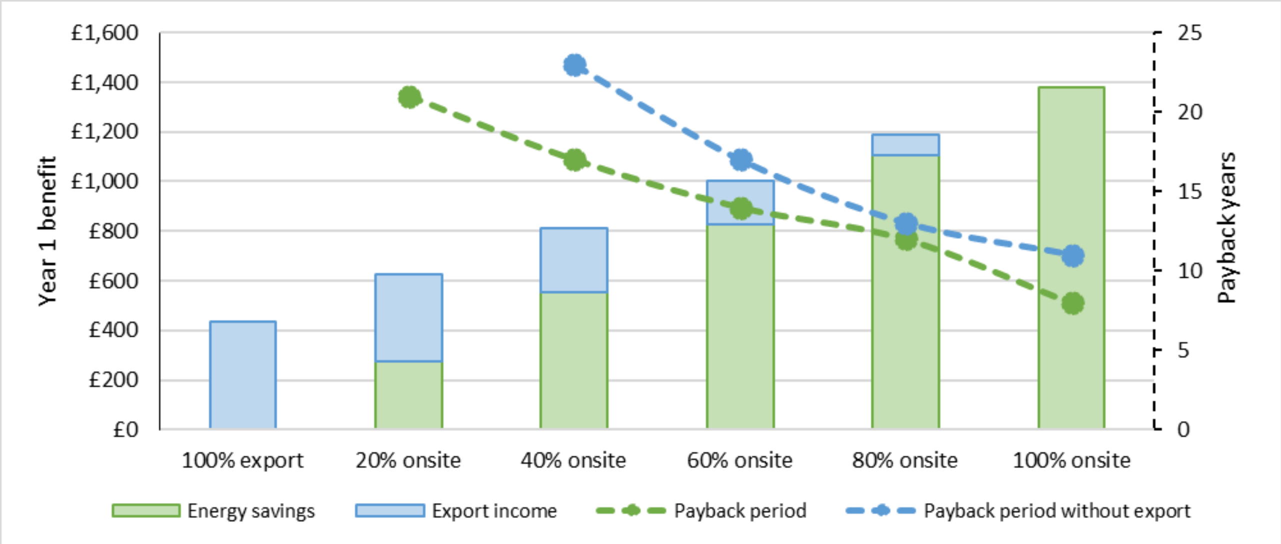

Figure 45: Old Malton Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Old Malton Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP
Capacity	20 kW	
Capex	£15,000	£7,000
Running costs	£521	£493
Savings vs now	£1,362	£1,390
Simple payback	11 years	5 years
Y1 CO_2 offset	1.9 Tonnes	1.9 Tonnes
Y20 CO_2 offset	43.5 Tonnes	44 Tonnes
With 30% of heat demand offset by PV generation:		
Running costs	£365	£345
Savings vs now	£1,518	£1,538
Simple payback	10 years	5 years
Y1 CO_2 offset	2.1 Tonnes	2.1 Tonnes
Y20 CO_2 offset	46.1 Tonnes	46.4 Tonnes

Table 77: Old Malton Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand below is illustrative only).

4.16. Oswaldkirk Village Hall

4.16.1. Overview

Built in 1988, Oswaldkirk Village Hall is located approximately 18km north-west of Malton in the Howardian Hills AONB. The hall is constructed of block walls with an air gap between skins. The front of the Hall (north facing) is faced with stone, the other walls are all rendered. The roof is constructed of pantiles on timber. A new storeroom and toilet were added to the east end of the building in 2019, which are insulated according to current building regulations. All windows are double glazed; those on the south wall of the Hall were put in during the recent refurbishment undertaken alongside the extension.

Figure 46: Oswaldkirk Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	Howardian Hills AONB, Oswaldkirk Conservation Area
Usage	~ 15 hours/week
Footprint	~100 m²
Existing Solar PV installation?	No
Heating system	Oil

Table 78: Oswaldkirk Village Hall overview

Usage of Oswaldkirk Village Hall is generally throughout weekdays in afternoons and early evenings for a variety of sports classes. It is noted that in summer, when PV generation would be at its peak, usage of the hall reduces significantly.

4.16.2. Energy demand

The heat and electricity demand of Oswaldkirk Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	16.7 p/kWh
Annual electricity cost	£320
Annual electricity demand	1402 kWh
Annual electricity emissions	0.32 Tonnes CO_2
Heat unit price	5.1 p/kWh
Annual heating cost	£640
Annual heat demand	12500 kWh
Annual heat emissions	2.82 Tonnes CO_2

Table 79: Oswaldkirk Village Hall energy demand

4.16.3. Energy opportunities

Electricity generation

The building has a south-facing roof to the rear that is most suitable for a PV installation, noting however that rooflights may restrict how many solar PV modules could be installed. Additionally, an installation in this location would minimise the visual impacts to the main road. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Oswaldkirk Village Hall is presented below.

Component	Value
Roof material	Tiles
Orientation	175°
Roof slope	30°
Shading	Mild
Annual irradiation	977 kWh/m²
Suitable roof area	~40 m²

Table 80: Oswaldkirk Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	6.72 kWp
Array area	36 m²
Battery capacity	5.8 kWh
Installation cost	£9,010
Annual generation	6470 kWh
Annual emissions offset	1.5 Tonnes CO_2

Table 81: Oswaldkirk Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Oswaldkirk Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 22%.

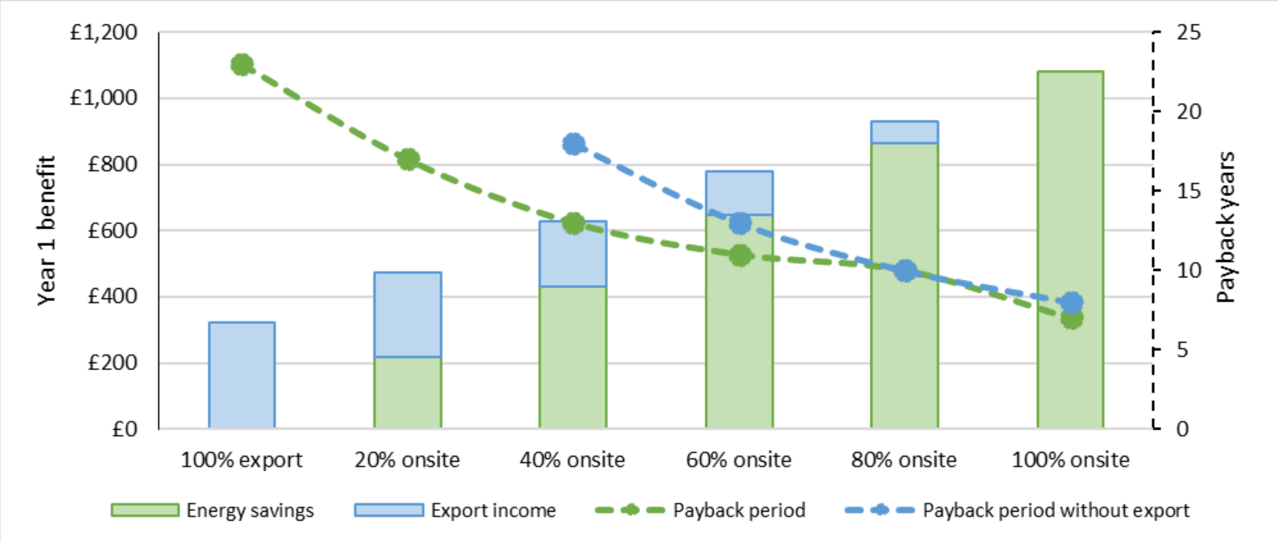

Figure 47: Oswaldkirk Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Oswaldkirk Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs. GSHPs have been excluded given the limited amount of external space available at the hall.

Factor	A2W HP	A2A HP	Electric
Capacity	8 kW		
Capex	£6,000	£2,800	£3,200
Running costs	£447	£423	£1,566
Savings vs now	£193	£217	-£926
Simple payback	-	13 years	-
Y1 CO_2 offset	3.3 Tonnes	3.3 Tonnes	1.3 Tonnes
Y20 CO_2 offset	72.4 Tonnes	72.9 Tonnes	49.1 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£313	£296	£1,096
Savings vs now	£327	£344	-£456
Simple payback	18 years	8 years	-
Y1 CO_2 offset	3.5 Tonnes	3.6 Tonnes	2.1 Tonnes
Y20 CO_2 offset	75.2 Tonnes	75.6 Tonnes	58.9 Tonnes

Table 82: Oswaldkirk Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.17. Pickering Memorial Hall

4.17.1. Overview

Pickering Memorial Hall was built in 1867 and used originally as a corn mill. Located in the centre of Pickering, overlooking Pickering Beck, the hall is approximately 12km north of Malton at the edge of the North York Moors National Park. The building is Grade 2 listed, of brick construction and is four storeys high, with a double height main hall and four large east-facing windows. The hall was fully refurbished in 2000 and at this time, a new slate roof was added to the building.

Figure 48: Pickering Memorial Hall

Key Details	
Local Authority	Ryedale District Council
Designations	Conservation Area; Grade 2 listing
Usage	~40 hours/week
Footprint	~800 m²
Existing Solar PV installation?	No
Heating system	Gas

Table 83: Pickering Memorial Hall overview

The building is served by a three-phase electrical supply and heating throughout is gas-fired.

4.17.2. Energy demand

The heat and electricity demand of Pickering Memorial Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	14.8 p/kWh
Annual electricity cost	£3,300
Annual electricity demand	21378 kWh
Annual electricity emissions	4.82 Tonnes CO_2
Heat unit price	4.1 p/kWh
Annual heating cost	£4,090
Annual heat demand	100000 kWh
Annual heat emissions	20.4 Tonnes CO_2

Table 84: Pickering Memorial Hall energy demand

4.17.3. Energy opportunities

Electricity generation

Pickering Memorial Hall does have a south-facing roof, but this is noted to be heavily shaded by a tall neighbouring building. Therefore, the east facing pitched roof in the centre of the building is proposed as the most suitable location for PV installation. This roof stands as tall as the surrounding building but unlike the adjacent west facing roof, it is not visible from the front of the building. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Pickering Memorial Hall is presented below.

Component	Value
Roof material	Slate
Orientation	95°
Roof slope	35°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~80 m²

Table 85: Pickering Memorial Hall system inputs

The key outputs for a PV & battery system are presented below, based on two options and 320Wp PV modules. The first option is an array sized for a G98 grid application and the second is for the practical maximum array size for the east-facing roof. The costs presented are inclusive of battery and PV installation, planning fees, and (for Option 2) grid application fees.

Component	Option 1	Option 2
Array size	11.52 kWp	13.44 kWp
Array area	61 m²	71 m²
Battery capacity	17.4 kWh	17.4 kWh
installation cost	£17,330	£19,060
Annual generation	8490 kWh	9900 kWh
Annual emissions offset	1.9 Tonnes CO_2	2.2 Tonnes CO_2

Table 86: Pickering Memorial Hall solar PV & battery system outputs

The figures below demonstrate the payback periods for these options, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Pickering Memorial Hall, the maximum possible usage by the hall of electricity generated onsite approach 100% for either option, provided that appropriately sized battery storage was included.

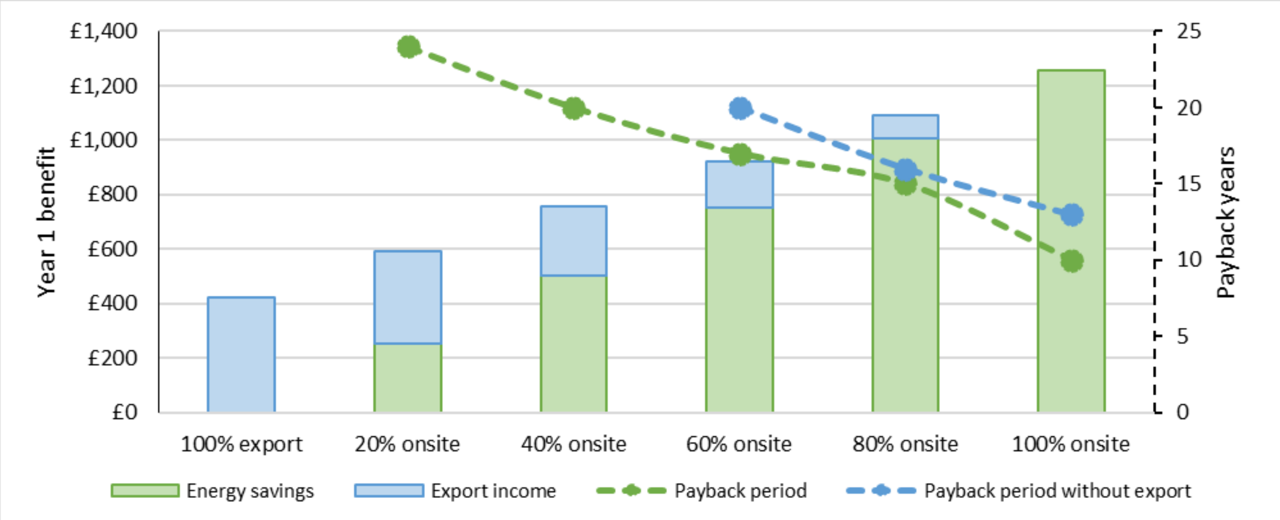

Figure 49: Pickering Memorial Hall - Option 1 benefit & payback

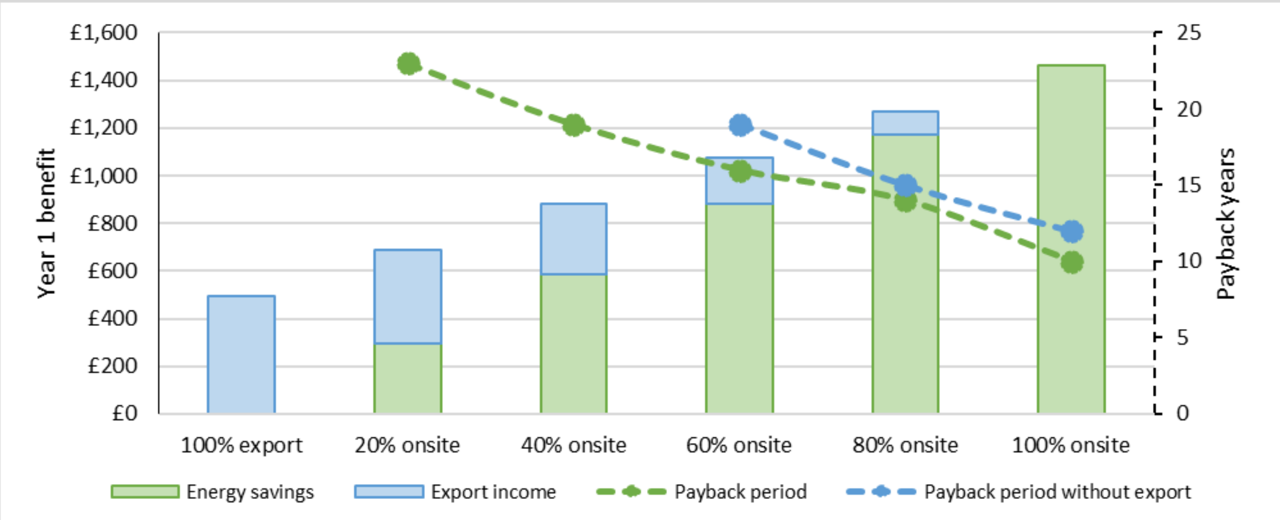

Figure 50: Pickering Memorial Hall - Option 2 benefit & payback

The very high predicted utilisation of these systems does indicate that adding PV to further roofs on the building may be of value. This has not been presented though, given that the next most suitable roof is likely the west-facing pitched roof that overlooks the front of the building. PV in this location would likely face more scrutiny from the planning department, as it would affect the front aspect of a listed building in a conservation area.

Renewable heat generation

A summary of the renewable heating system options identified for Pickering Memorial Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	GSHP	Electric
Capacity	64 kW			
Capex	£48,000	£22,400	£80,000	£25,600
Running costs	£3,806	£3,600	£3,330	£13,320
Savings vs now	£284	£490	£760	-£9,230
Simple payback	-	-	-	-
Y1 CO_2 offset	14 Tonnes	14.3 Tonnes	14.8 Tonnes	-2.2 Tonnes
Y20 CO_2 offset	333.4 Tonnes	337.5 Tonnes	342.8 Tonnes	147 Tonnes
With 30% of heat demand offset by PV generation:				
Running costs	£2,664	£2,520	£2,331	£9,324
Savings vs now	£1,426	£1,570	£1,759	-£5,234
Simple payback	-	14 years	-	-
Y1 CO_2 offset	15.9 Tonnes	16.1 Tonnes	16.5 Tonnes	4.6 Tonnes
Y20 CO_2 offset	355.8 Tonnes	358.6 Tonnes	362.3 Tonnes	225.3 Tonnes

Table 87: Pickering Memorial Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.18. Romanby WI Village Hall

4.18.1. Overview

The Romanby Women's Institute Hall was completed in the summer of 1939. Located in the centre of Romanby, approximately 1km south-west of Northallerton, the hall is of timber construction with poor insulation. The hall has new double glazing which was installed in August 2019. The roof is original and tiled, with insulation.

Figure 51: Romanby WI Village Hall

Key Details	
Local Authority	Hambleton District Council
Designations	None identified
Usage	~ 15 hours/week
Footprint	~ 180 m²
Existing Solar PV installation?	No
Heating system	Gas

Table 88: Romanby WI Village Hall overview

The hall is used regularly throughout the week and also throughout the day, with groups and classes held first thing in the morning, around lunchtime and again in the late afternoon/early evening.

Heating throughout is via a gas-fired boiler which was installed in August 2019 to replace an oil-fired system. New radiators with thermostats were installed alongside the new gas-fired boiler.

4.18.2. Energy demand

The heat and electricity demand of Romanby WI Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	22.1 p/kWh
Annual electricity cost	£760
Annual electricity demand	3008 kWh
Annual electricity emissions	0.68 Tonnes CO_2
Heat unit price	5.4 p/kWh
Annual heating cost	£2,100
Annual heat demand	38715 kWh
Annual heat emissions	7.9 Tonnes CO_2

Table 89: Romanby WI Village Hall energy demand

4.18.3. Energy opportunities

Electricity generation

A summary of the key considerations affecting the technical and financial feasibility of a solar PV system at Romanby WI Village Hall is presented below.

Component	Value
Roof material	Tiles
Orientation	265°
Roof slope	45°
Shading	Mild
Annual irradiation	998 kWh/m²
Suitable roof area	~155 m²

Table 90: Romanby WI Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	11.52 kWp
Array area	61 m²
Battery capacity	5.8 kWh
Installation cost	£12,370
Annual generation	8850 kWh
Annual emissions offset	2 Tonnes CO_2

Table 91: Romanby WI Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system. Based on the current electricity demand of Romanby WI Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 34%.

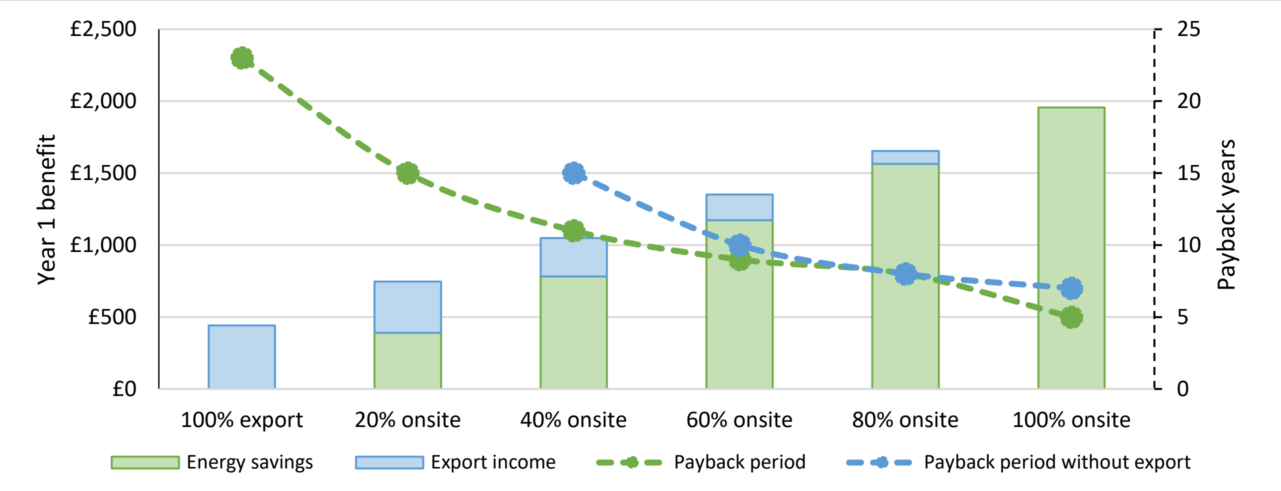

Figure 52: Romanby WI Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Romanby WI Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	Electric
Capacity		14 kW	
Capex	£10,500	£4,900	£5,600
Running costs	£2,200	£2,081	£7,700
Savings vs now	-£100	£19	-£5,600
Simple payback	-	-	-
Y1 CO_2 offset	5.4 Tonnes	5.5 Tonnes	-0.8 Tonnes
Y20 CO_2 offset	129.1 Tonnes	130.6 Tonnes	56.9 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£1,540	£1,457	£5,390
Savings vs now	£560	£643	-£3,290
Simple payback	19 years	8 years	-
Y1 CO_2 offset	6.2 Tonnes	6.2 Tonnes	1.8 Tonnes
Y20 CO_2 offset	137.7 Tonnes	138.8 Tonnes	87.2 Tonnes

Table 92: Romanby WI Village Hall renewable heating system outputs

Most of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.19. Sand Hutton and Claxton Village Hall

4.19.1. Overview

The Sand Hutton and Claxton Village Hall, located in Sand Hutton, approximately 11km north-east of York, was constructed in the late 19th century. The original building is brick, with a pitched slate roof, which was strengthened with additional internal timbers in 2019. A flat-roof extension was added to the front of the building in the 1960's.

Figure 53: Sand Hutton and Claxton Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	Conservation Area
Usage	20-45 hours/week
Footprint	~140m^2
Existing Solar PV installation?	No
Heating system	Oil

Table 93: Sand Hutton and Claxton Village Hall overview

The hall is heated throughout by an oil boiler. The village hall trustees have already identified that the existing oil boiler is aged and should be replaced within the next two to three years.

4.19.2. Energy demand

The heat and electricity demand of Sand Hutton and Claxton Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Daytime electricity price	16.1 p/kWh
Annual electricity cost	£570
Annual electricity demand	2602 kWh
Annual electricity emissions	0.59 Tonnes CO_2
Heat unit price	5.1 p/kWh
Annual heating cost	£610
Annual heat demand	12020 kWh
Annual heat emissions	3.27 Tonnes CO_2

Table 94: Sand Hutton and Claxton Village Hall energy demand

4.19.3. Energy opportunities

Electricity generation

The building has a large pitched south-southwest facing pitched roof which appears highly suitable for a PV installation. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Sand Hutton and Claxton Village Hall is presented below.

Component	Value
Roof material	Slates
Orientation	190°
Roof slope	30°
Shading	Moderate
Annual irradiation	995 kWh/m²
Suitable roof area	~65 m²

Table 95: Sand Hutton and Claxton Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation as well as planning fees.

Component	Option 1
Array size	10.88 kWp
Array area	58 m²
Battery capacity	5.8 kWh
Installation cost	£12,755
Annual generation	10730 kWh
Annual emissions offset	2.4 Tonnes CO_2

Table 96: Sand Hutton and Claxton Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Sand Hutton and Claxton Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 24%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly.

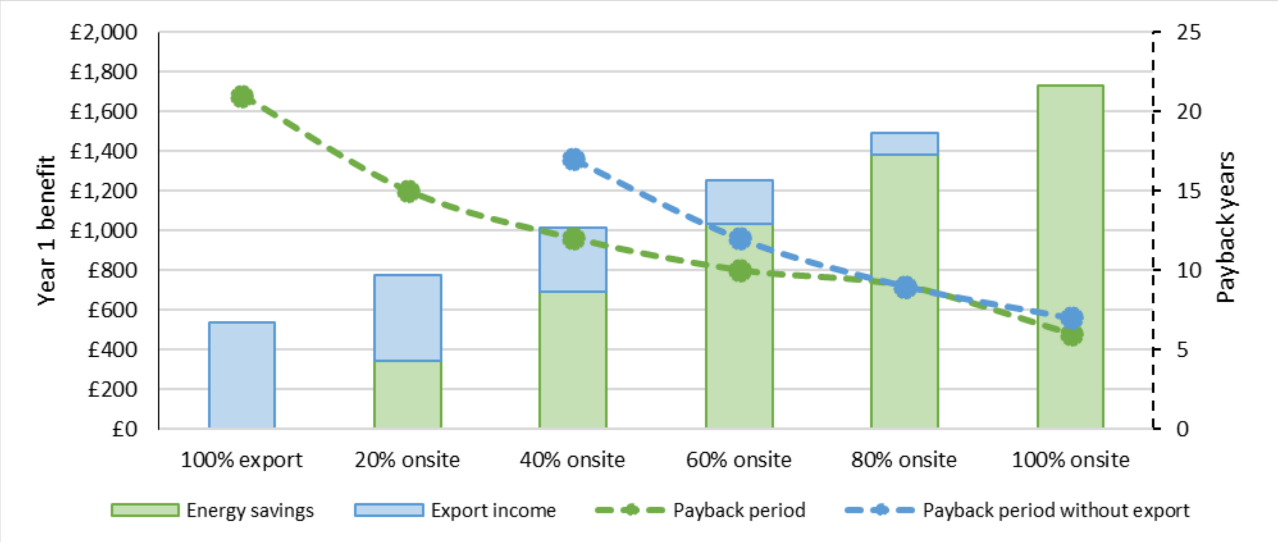

Figure 54: Sand Hutton and Claxton Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Sand Hutton and Claxton Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	GSHP	Electric
Capacity	11 kW			
Capex	£8,400	£3,920	£14,000	£4,480
Running costs	£415	£392	£363	£1,451
Savings vs now	£195	£218	£247	-£841
Simple payback	-	18 years	-	-
Y1 CO_2 offset	3.2 Tonnes	3.2 Tonnes	3.3 Tonnes	1.2 Tonnes
Y20 CO_2 offset	69.6 Tonnes	70.1 Tonnes	70.8 Tonnes	47.2 Tonnes
With 30% of heat demand offset by PV generation:				
Running costs	£290	£275	£254	£1,016
Savings vs now	£320	£335	£356	-£406
Simple payback	-	12 years	-	-
Y1 CO_2 offset	3.4 Tonnes	3.4 Tonnes	3.5 Tonnes	2 Tonnes
Y20 CO_2 offset	72.3 Tonnes	72.7 Tonnes	73.1 Tonnes	56.6 Tonnes

Table 97: Sand Hutton and Claxton Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.20. Settrington Village Hall

4.20.1. Overview

Built in 1964, Settrington Village Hall is located towards the north of Settrington, approximately 5km south-east of Malton, North Yorkshire. The hall is of timber clad construction and it is believed that there is little to no insulation within the external walls. A new roof was added to the building in 2004, which was fully insulated in line with Building Regulations at the time. The hall is single glazed throughout.

Figure 55: Settrington Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	None identified
Usage	~ 15 hours/week
Footprint	~ 240 m²
Existing Solar PV installation?	No
Heating system	Electricity

Table 98: Settrington Village Hall overview

Settrington School uses the hall for indoor sports two to three times a week, particularly in wet or cold weather; once a week for after school clubs and on an ad-hoc basis for exams and assemblies. The local Scout group uses the hall once a week, as does Seedlings pre-nursery group. West Heslerton Junior Football team uses the kitchen and toilets on Saturdays during football season, while the local cricket team use the changing rooms, toilets and kitchen during cricket season.

The main hall and committee room are heated through electric wall-mounted fan heaters, with an additional free-standing electric heater in the committee room. It is understood that the rest of the building is also heated electrically, although details of this have not been provided.

4.20.2. Energy demand

The heat and electricity demand of Settrington Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	24.5 p/kWh
Annual electricity cost	£1,810
Annual electricity demand	7035 kWh
Annual electricity emissions	1.59 Tonnes CO_2

Table 99: Settrington Village Hall energy demand

4.20.3. Energy opportunities

Electricity generation

The building has a north-facing roof which is not typically suitable for a PV installation; however, the installation of frames upon which a south-facing array could be mounted would drastically reduce the quantity of PV modules that could be installed and may not provide any significant generation opportunities above that of the north-facing array proposed. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Settrington Village Hall is presented below.

Component	Value
Roof material	Metal
Orientation	10°
Roof slope	3°
Shading	Mild
Annual irradiation	947 kWh/m²
Suitable roof area	~230 m²

Table 100: Settrington Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	11.52 kWp
Array area	61 m²
Battery capacity	5.8 kWh
Installation cost	£12,370
Annual generation	9320 kWh
Annual emissions offset	2.1 Tonnes CO_2

Table 101: Settrington Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Settrington Village Hall, the maximum possible usage by the hall of electricity generated onsite would be around 75%.

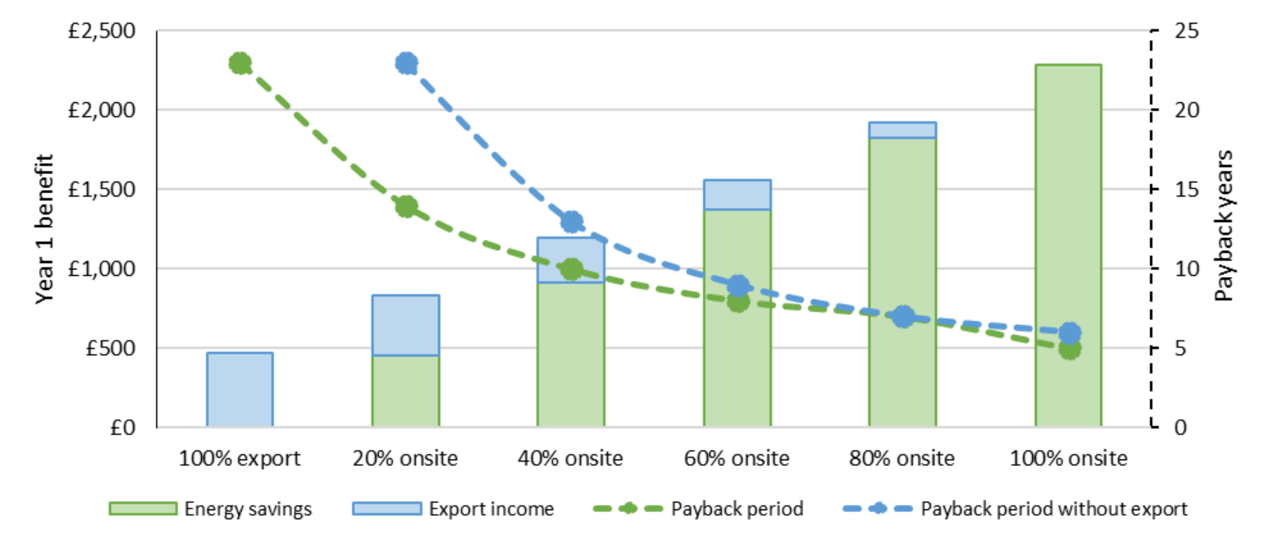

Figure 56: Settrington Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Settrington Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP
Capacity	19 kW	
Capex	£14,100	£6,580
Running costs	£345	£326
Savings vs now	£922	£941
Simple payback	15 years	7 years
Y1 CO_2 offset	0.8 Tonnes	0.8 Tonnes
Y20 CO_2 offset	18.5 Tonnes	18.7 Tonnes
With 30% of heat demand offset by PV generation:		
Running costs	£241	£228
Savings vs now	£1,026	£1,039
Simple payback	14 years	6 years
Y1 CO_2 offset	0.9 Tonnes	0.9 Tonnes
Y20 CO_2 offset	19.6 Tonnes	19.8 Tonnes

Table 102: Settrington Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.21. Terrington Village Hall

4.21.1. Overview

Terrington Village Hall is a single storey building constructed in 1994. The village of Terrington is located in the centre of the Howardian Hills Area of Outstanding Natural Beauty and is positioned 20km north-east of the city of York. The building is of brick construction with cavity wall insulation and a tiled roof. Windows on the west of the building are double glazed.

Figure 57: Terrington Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	Howardian Hills AONB
Usage	~5 hours/week
Footprint	~500m^2
Existing Solar PV installation?	No
Heating system	Oil and gas

Table 103: Terrington Village Hall overview

The heating system is a combination of oil and gas, whereby an oil boiler supplies some radiators and delivers hot water within the kitchen, gas heaters are installed in the main hall and hot water for bathrooms is generated via an electric immersion heater.

4.21.2. Energy demand

The heat and electricity demand of Terrington Village Hall is summarised below, based on information provided to Locogen and supplementary estimates. The values presented for heat represent the combined figures from the oil and gas systems.

Component	Value
Daytime electricity price	15.5 p/kWh
Annual electricity cost	£870
Annual electricity demand	5122 kWh
Annual heating cost	£980
Annual heat demand	18700 kWh
Annual heat emissions	5.09 Tonnes CO_2

Table 104: Terrington Village Hall energy demand

4.21.3. Energy opportunities

Electricity generation

The building has a large south-west facing roof to the rear which appears to be highly suited to a solar installation. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Terrington Village Hall is presented below.

Component	Value
Roof material	Tiles
Orientation	245°
Roof slope	30°
Shading	Minimal
Annual irradiation	977 kWh/m²
Suitable roof area	~270 m²

Table 105: Terrington Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on two options and 320Wp PV modules. The first option is an array sized for a G98 grid application and the second is for the practical maximum array size. The costs presented are inclusive of battery and PV installation, planning fees, and (for Option 2) grid application fees.

Component	Option 1	Option 2
Array size	11.52 kWp	45.76 kWp
Array area	61 m²	243 m²
Battery capacity	5.8 kWh	5.8 kWh
installation cost	£12,370	£37,240
Annual generation	9860 kWh	39180 kWh
Annual emissions offset	2.2 Tonnes CO_2	8.8 Tonnes CO_2

Table 106: Terrington Village Hall solar PV & battery system outputs

The figures below demonstrate the payback periods for these options, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Terrington Village Hall, the maximum possible usage by the hall of electricity generated onsite through Option 1 could be as high as 52%. For Option 2, this would be around 13%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly in each case.

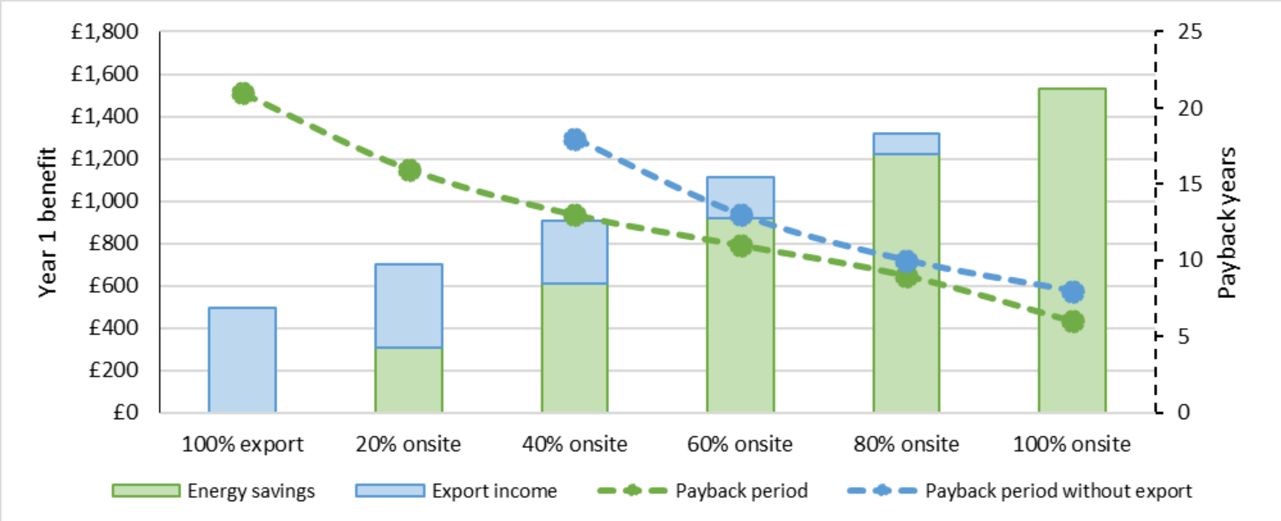

Figure 58: Terrington Village Hall - Option 1 benefit & payback

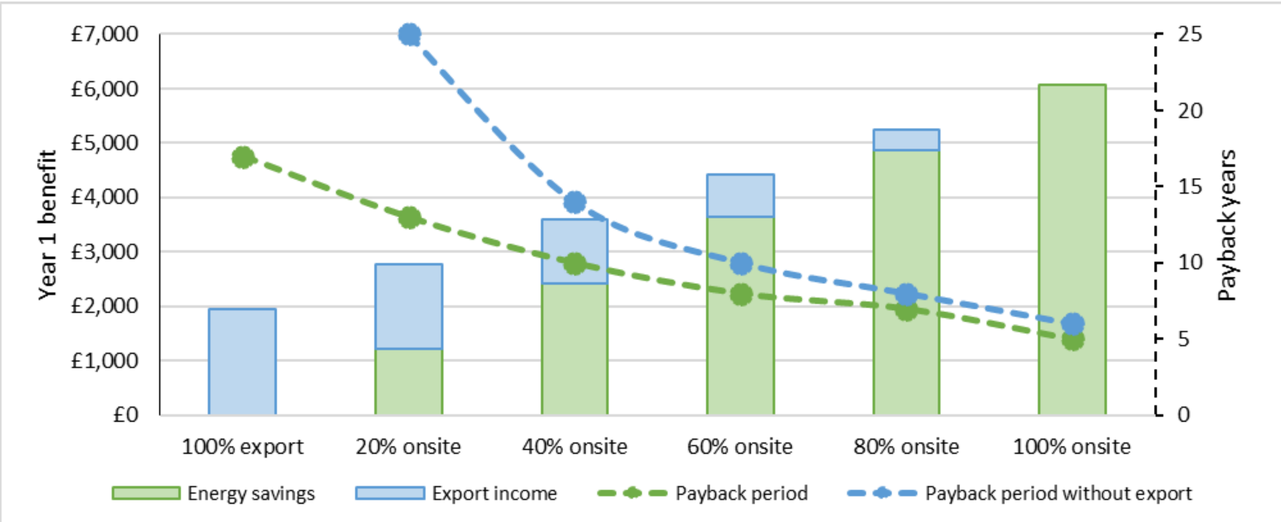

Figure 59: Terrington Village Hall - Option 2 benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Terrington Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	Electric
Capacity	40 kW		
Capex	£30,000	£14,000	£16,000
Running costs	£745	£705	£2,609
Savings vs now	£235	£275	-£1,629
Simple payback	-	-	-
Y1 CO_2 offset	3.9 Tonnes	3.9 Tonnes	0.9 Tonnes
Y20 CO_2 offset	87.8 Tonnes	88.5 Tonnes	52.9 Tonnes

With 30% of heat demand offset by PV generation:			
Running costs	£522	£494	£1,826
Savings vs now	£458	£486	-£846
Simple payback	-	-	-
Y1 CO_2 offset	4.2 Tonnes	4.3 Tonnes	2.1 Tonnes
Y20 CO_2 offset	92 Tonnes	92.5 Tonnes	67.6 Tonnes

Table 107: Terrington Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.22. Thixendale Village Hall

4.22.1. Overview

A former school built in 1872, Thixendale Village Hall is located adjacent to the Old School House in Thixendale, 12km south-east of Malton, North Yorkshire. The Village Hall is a Grade 2 listed building and was extended and developed around 15 years ago with a National Lottery Grant.

Figure 60: Thixendale Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	Listed (grade 2)
Usage	5-15 hours/week
Footprint	~100m^2
Existing Solar PV installation?	No
Heating system	Oil (with supplementary electric)

Table 108: Thixendale Village Hall overview

The village hall is heated by an oil boiler, which distributes heat throughout the hall via an underfloor heating system. Thixendale Village Hall have confirmed that the underfloor heating is inefficient and insufficient given the thickness of the floor, and that two forced convection radiators have been installed to supplement the heating. The oil-fired boiler also generates hot water for the building.

4.22.2. Energy demand

The heat and electricity demand of Thixendale Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Daytime electricity price	15.8 p/kWh
Annual electricity cost	£750
Annual electricity demand	4194 kWh
Annual electricity emissions	0.95 Tonnes CO_2
Heat unit price	5.1 p/kWh
Annual heating cost	£750
Annual heat demand	14706 kWh
Annual heat emissions	3.32 Tonnes CO_2

Table 109: Thixendale Village Hall energy demand

4.22.3. Energy opportunities

Electricity generation

The higher utilisation of the hall during the spring and summer indicates that solar PV could be a suitable opportunity to consider. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system is presented below.

Component	Value
Roof material	Rosemary (clay) tiles
Orientation	200°
Roof slope	60°
Shading	Minimal
Annual irradiation	977 kWh/m²
Suitable roof area	~70 m²

Table 110: Thixendale Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size allowed under the g98 grid connection and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	11.52 kWp
Array area	61 m²
Battery capacity	5.8 kWh
Installation cost	£12,370
Annual generation	10560 kWh
Annual emissions offset	2.4 Tonnes CO_2

Table 111: Thixendale Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Thixendale Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 39%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly in each case.

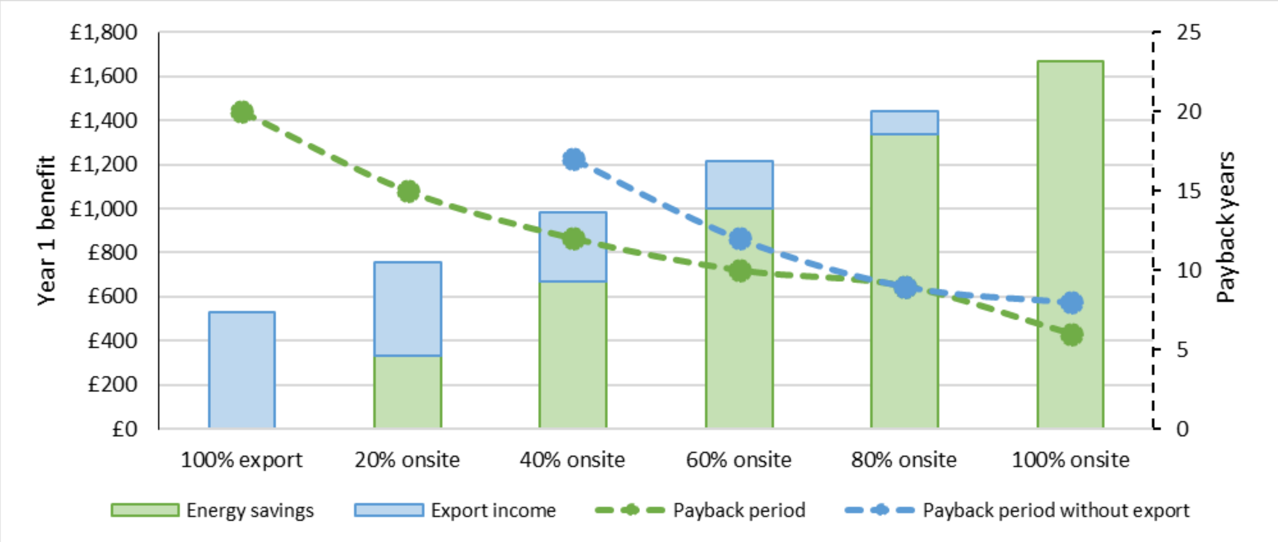

Figure 61: Thixendale Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Thixendale Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	Electric
Capacity	8 kW		
Capex	£6,000	£2,800	£3,200
Running costs	£498	£471	£1,743
Savings vs now	£252	£279	-£993
Simple payback	24 years	10 years	-
Y1 CO_2 offset	3.9 Tonnes	3.9 Tonnes	1.5 Tonnes
Y20 CO_2 offset	85.2 Tonnes	85.8 Tonnes	57.8 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£349	£330	£1,220
Savings vs now	£401	£420	-£470
Simple payback	15 years	7 years	-
Y1 CO_2 offset	4.1 Tonnes	4.2 Tonnes	2.5 Tonnes
Y20 CO_2 offset	88.5 Tonnes	88.9 Tonnes	69.3 Tonnes

Table 112: Thixendale Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand below is illustrative only).

4.23. Weaverthorpe Village Hall

4.23.1. Overview

Weaverthrope Village Hall is located at the western edge of Weaverthorpe, approximately 18km east of Malton, North Yorkshire. The building is timber framed and timber clad, with no insulation, and double glazed windows throughout. The roof was replaced two years ago and is self-insulated coated sheet steel.

Figure 62: Weaverthorpe Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	None identified
Usage	~6 hours/week
Footprint	~100 m²
Existing Solar PV installation?	No
Heating system	Electric

Table 113: Weaverthorpe Village Hall overview

Heat demands within Weaverthorpe Village Hall are met by electric panel heaters, with an electric immersion heater generating hot water for use within the building.

4.23.2. Energy demand

The heat and electricity demand of Weaverthorpe Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Electricity price	13.2 p/kWh
Annual electricity cost	£1,090
Annual electricity demand	6792 kWh
Annual electricity emissions	1.53 Tonnes CO_2

Table 114: Weaverthorpe Village Hall energy demand

4.23.3. Energy opportunities

Electricity generation

The small south-facing pitched roof to the rear of the building is deemed to be the most suitable location for a PV installation. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Weaverthorpe Village Hall is presented below.

Component	Value
Roof material	Coated steel
Orientation	155°
Roof slope	31°
Shading	Minimal
Annual irradiation	979 kWh/m²
Suitable roof area	~20 m²

Table 115: Weaverthorpe Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	3.52 kWp
Array area	19 m²
Battery capacity	5.8 kWh
Installation cost	£6,225
Annual generation	3320 kWh
Annual emissions offset	0.7 Tonnes CO_2

Table 116: Weaverthorpe Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Weaverthorpe Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 90%.

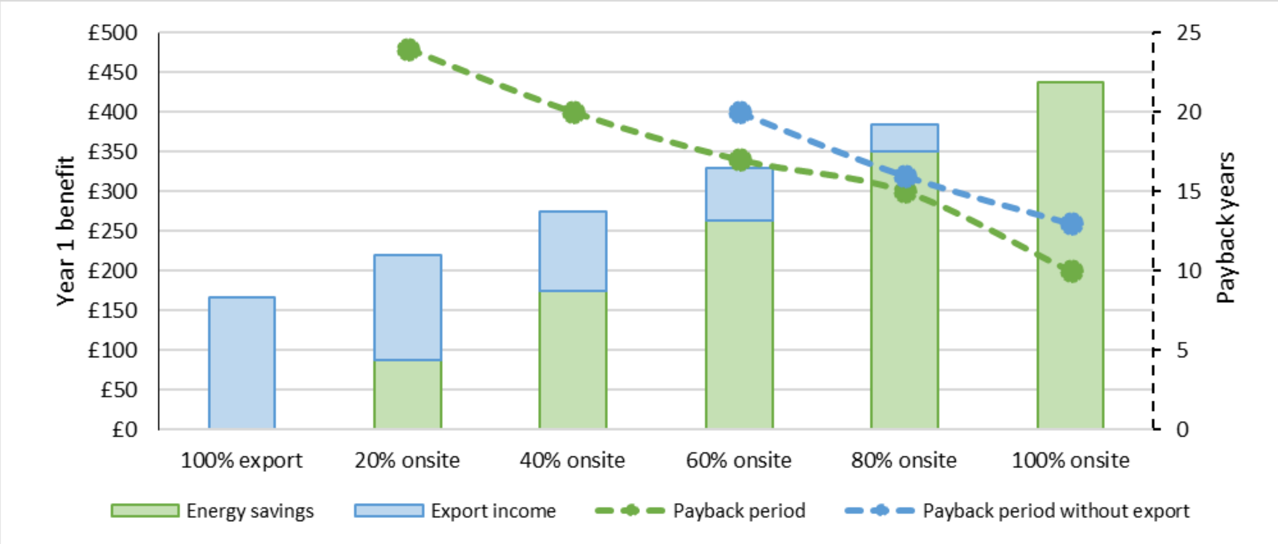

Figure 63: Weaverthorpe Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Weaverthorpe Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP
Capacity	8 kW	
Capex	£6,000	£2,800
Running costs	£179	£170
Savings vs now	£584	£593
Simple payback	10 years	5 years
Y1 CO_2 offset	0.8 Tonnes	0.8 Tonnes
Y20 CO_2 offset	17.9 Tonnes	18.1 Tonnes
With 30% of heat demand offset by PV generation:		
Running costs	£126	£119
Savings vs now	£637	£644
Simple payback	9 years	4 years
Y1 CO_2 offset	0.9 Tonnes	0.9 Tonnes
Y20 CO_2 offset	19 Tonnes	19.1 Tonnes

Table 117: Weaverthorpe Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.24. Welburn Village Hall

4.24.1. Overview

Welburn Village Hall, located in Welburn, a village and civil parish 21km north-east of York in the Ryedale district of North Yorkshire, was constructed in 2007. The hall comprises a single storey and is of a timber frame construction clad with horizontal larch cladding and a recycled aluminium roof.

Figure 64: Welburn Village Hall

Key Details	
Local Authority	Ryedale District Council
Designations	Howardian Hills AONB
Usage	15-30 hours/week
Footprint	~300m^2
Existing Solar PV installation?	No
Heating system	Oil (new)

Table 118: Welburn Village Hall overview

Information received indicated that the hall is used regularly throughout the week, with sports classes and art groups in the mornings, and local community groups in the evenings. The booking calendar provided suggests that the hall is more heavily used during the winter months (November – January) than in summer.

The village hall is heated by an oil boiler, which was installed 18 months ago to replace a ground source heat pump that did not meet the demands of the building. The building is also understood to have some electric heaters but not all of these are currently used.

4.24.2. Energy demand

The heat and electricity demand of Welburn Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Daytime electricity price	14.6 p/kWh
Annual electricity cost	£798
Annual electricity demand	4747 kWh
Annual electricity emissions	1.07 Tonnes CO_2
Heat unit price	4.2 p/kWh
Annual heating cost	£828
Annual heat demand	19,714 kWh
Annual heat emissions	4.45 Tonnes CO_2

Table 119: Welburn Village Hall energy demand

4.24.3. Energy opportunities

Electricity generation

With a large south facing roof area, Welburn Village Hall is well suited to a solar PV installation. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system is presented below.

Component	Value
Roof material	aluminium
Orientation	180°
Roof slope	30°
Shading	Moderate
Annual irradiation	977 kWh/m²
Suitable roof area	~250m²

Table 120: Welburn Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on two options and 320Wp PV modules. The first option is an array sized for a G98 grid application and the second is for the practical maximum array size. The costs presented are inclusive of battery and PV installation and (for Option 2) grid application fees.

Component	Option 1	Option 2
Array size	11.52 kWp	40.64 kWp
Array area	61 m²	216 m²
Battery capacity	11.6 kWh	11.6 kWh
installation cost	£14,370	£35,295
Annual generation	11640 kWh	41060 kWh
Annual emissions offset	2.6 Tonnes CO_2	9.3 Tonnes CO_2

Table 121: Welburn Village Hall solar PV & battery system outputs

The figures below demonstrate the payback periods for these options, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Welburn Village Hall, the maximum possible usage by the hall of electricity generated onsite through Option 1 would be around 41%. For Option 2, this would be around 12%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly in each case.

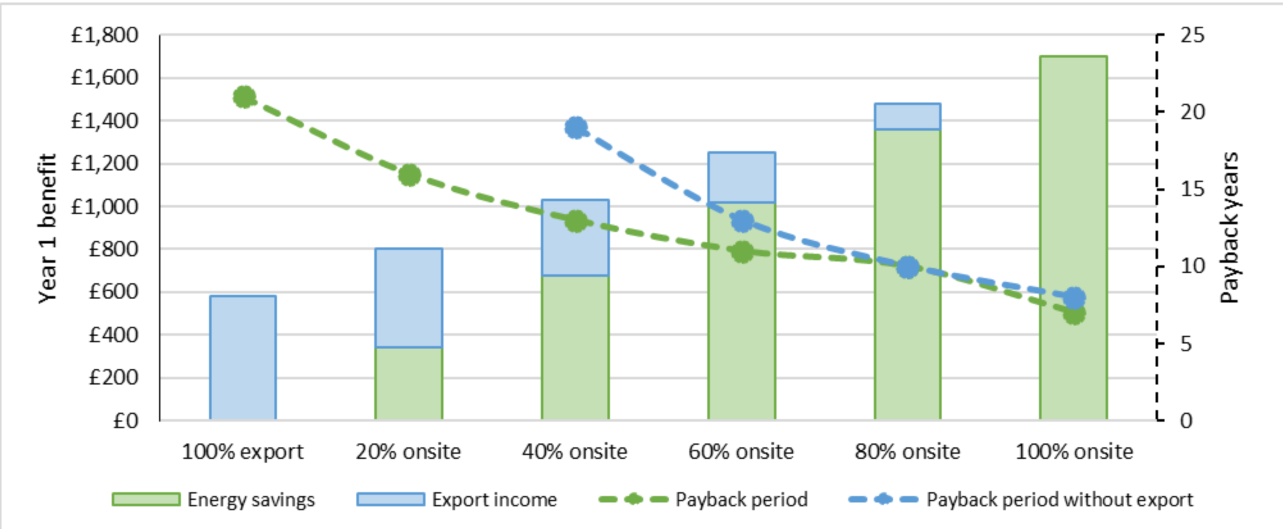

Figure 65: Welburn Village Hall - Option 1 benefit & payback

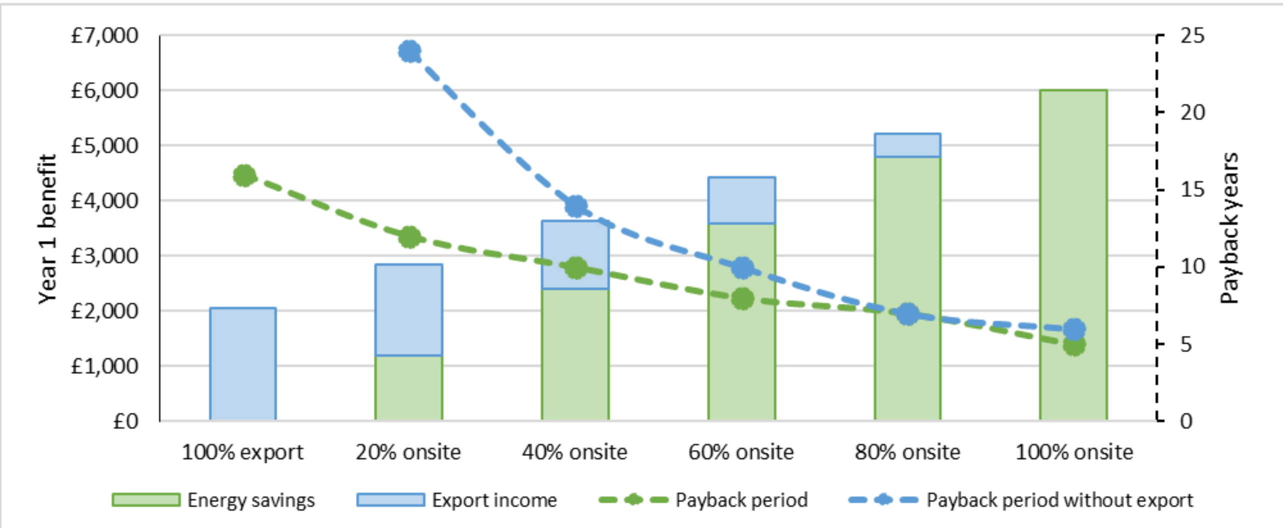

Figure 66: Welburn Village Hall - Option 2 benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Welburn Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs. Given that a GSHP was recently uninstalled, this option is assumed to be unfavourable in this case and has not been included. However, there are certainly heat pumps available that would be able to meet the flexibility and hot water demands of the hall.

Factor	A2W HP	A2A HP	Electric
Capacity	24 kW		
Capex	£17,850	£8,330	£9,520
Running costs	£740	£700	£2,590
Savings vs now	£90	£130	-£1,760
Simple payback	-	-	-
Y1 CO_2 offset	4.1 Tonnes	4.2 Tonnes	0.9 Tonnes
Y20 CO_2 offset	92.5 Tonnes	93.3 Tonnes	55.8 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£518	£490	£1,813
Savings vs now	£312	£340	-£983
Simple payback	-	25 years	-
Y1 CO_2 offset	4.5 Tonnes	4.5 Tonnes	2.2 Tonnes
Y20 CO_2 offset	97 Tonnes	97.5 Tonnes	71.2 Tonnes

Table 122: Welburn Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

4.25. Wintringham Village Hall

4.25.1. Overview

Wintringham Village Hall, located 36km north-east of York, was built in late 2015 and opened in January 2016. It is a single storey building, comprising a large hall able to seat in excess of 180 people, a meeting room, kitchen, toilets and a significant quantity of storage space. The building is brick built, with a tiled roof and double glazing throughout.

Figure 67: Wintringham Village Hall (east elevation)

Key Details	
Local Authority	Ryedale District Council
Designations	Howardian Hills AONB
Usage	5-15 hours/week; higher usage in the summer
Footprint	~400m^2
Existing Solar PV installation?	No
Heating system	ASHP (2no.)

Table 123: Wintringham Village Hall overview

Heating at Wintringham Village Hall is through two air source heat pumps, one of which serves the main hall and the other serves the kitchen, meeting room, entrance way and toilets, as well as providing hot water for sanitaryware.

4.25.2. Energy demand

The heat and electricity demand of Wintringham Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	Value
Daytime electricity price	15.4 p/kWh
Annual electricity cost	£1,460
Annual electricity demand	8775 kWh
Annual electricity emissions	1.98 Tonnes CO_2

Table 124: Wintringham Village Hall energy demand

4.25.3. Energy opportunities

Electricity generation

As Wintringham Village Hall already has two ASHPs, only electricity generation has been considered. The building has two pitched south-facing roofs (aside from a smaller one at the entrance) that are highly suitable for PV. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Wintringham Village Hall is presented below.

Component	Value
Roof material	Tiles
Orientation	160°
Roof slope	40°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~130 m²

Table 125: Wintringham Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on two options and 320Wp PV modules. The first option is an array sized for a G98 grid application and the second is for the practical maximum array size. The costs presented are inclusive of battery and PV installation, planning fees, and (for Option 2) grid application fees.

Component	Option 1	Option 2
Array size	11.52 kWp	22.08 kWp
Array area	61 m²	117 m²
Battery capacity	11.6 kWh	11.6 kWh
installation cost	£14,370	£21,005
Annual generation	11640 kWh	20560 kWh
Annual emissions offset	2.6 Tonnes CO_2	4.6 Tonnes CO_2

Table 126: Wintringham Village Hall solar PV & battery system outputs

The figures below demonstrate the payback periods for these options, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Wintringham Village Hall, the maximum possible usage by the hall of electricity generated onsite would be around 82% for Option 1. For Option 2, this would be around 43%.

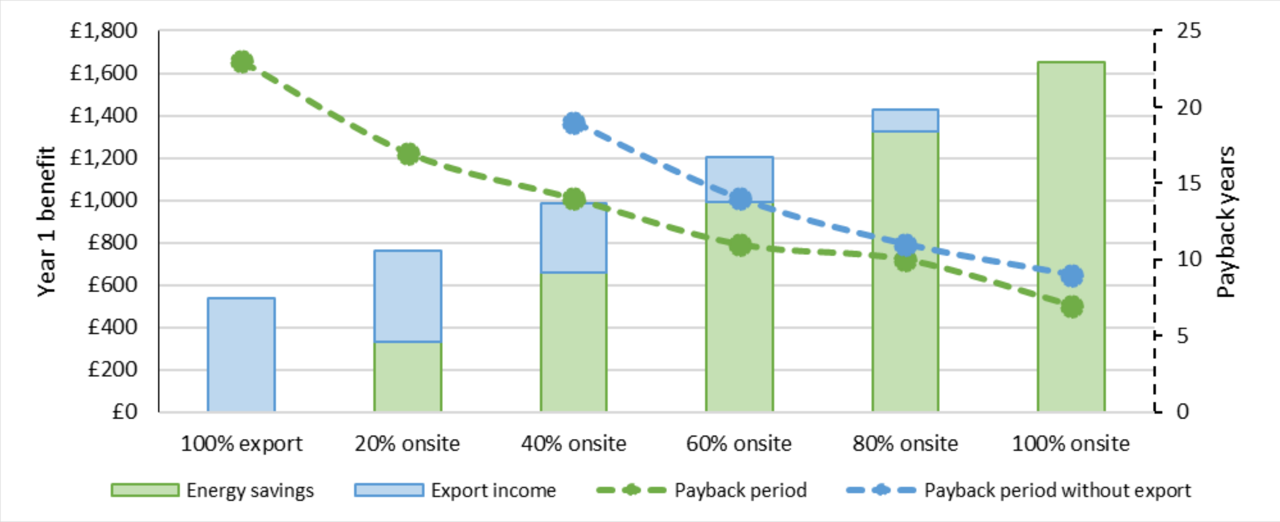

Figure 68: Wintringham Village Hall - Option 1 benefit & payback

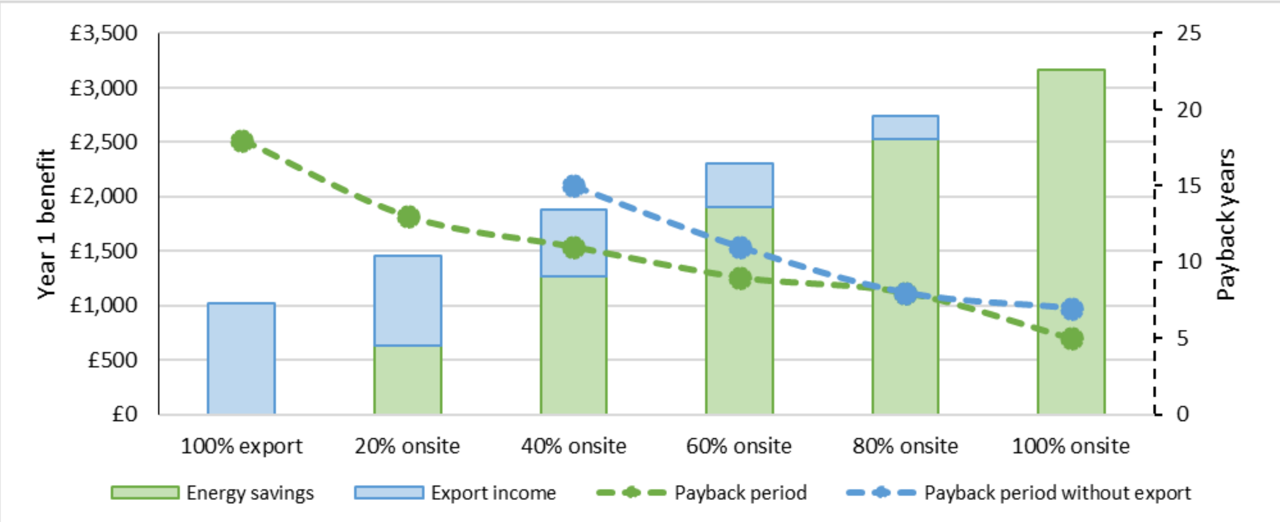

Figure 69: Wintringham Village Hall - Option 2 benefit & payback

4.26. Wrelton Village Hall

4.26.1. Overview

Wrelton Village Hall is located at the northern end of Wrelton, a small village 3km north-west of Pickering. The building comprises an original stone-built structure with a tiled roof, with a large extension to the rear, which has brick construction with a sheet metal roof.

Figure 70: Wrelton village hall

Key Details	
Local Authority	Ryedale District Council
Designations	None identified
Usage	~15 hours/week
Footprint	~160 m²
Existing Solar PV installation?	No
Heating system	Gas

Table 127: Wrelton Village Hall overview

The building is served by a 30kW combi boiler and is host to several weekly events, most of which take place during the daytime.

4.26.2. Energy demand

The heat and electricity demand of Wrelton Village Hall is summarised below, based on information provided to Locogen and supplementary estimates.

Component	**Value**
Daytime electricity price	17 p/kWh
Annual electricity cost	£340
Annual electricity demand	1356 kWh
Annual electricity emissions	0.31 Tonnes CO_2

Heat unit price	4.5 p/kWh
Annual heating cost	£760
Annual heat demand	16719 kWh
Annual heat emissions	3.41 Tonnes CO_2

Table 128: Wrelton Village Hall energy demand

4.26.3. Energy opportunities

Electricity generation

The building has an east-facing roof to the rear that appears most suitable for a PV installation. Additionally, an installation in this location would minimise the visual impacts to the main road. A summary of the key considerations affecting the technical and financial feasibility of a solar PV system for Wrelton Village Hall is presented below.

Component	Value
Roof material	Metal
Orientation	90°
Roof slope	35°
Shading	Minimal
Annual irradiation	947 kWh/m²
Suitable roof area	~55 m²

Table 129: Wrelton Village Hall system inputs

The key outputs for a PV & battery system are presented below, based on a single option for the practical maximum array size and 320Wp panels. The costs presented are inclusive of battery and PV installation.

Component	Option 1
Array size	9.28 kWp
Array area	49 m²
Battery capacity	5.8 kWh
Installation cost	£10,355
Annual generation	6870 kWh
Annual emissions offset	1.5 Tonnes CO_2

Table 130: Wrelton Village Hall solar PV & battery system outputs

The figure below demonstrates the payback periods for the installation, which is highly dependent on how much of the PV generation is used onsite. The benefit of batteries is that they increase onsite consumption, although they do of course add to the capital cost of the system.

Based on the current electricity demand of Wrelton Village Hall, the maximum possible usage by the hall of electricity generated onsite could be as high as 20%. If a heat pump or direct electric heating were to be implemented, this figure would rise significantly.

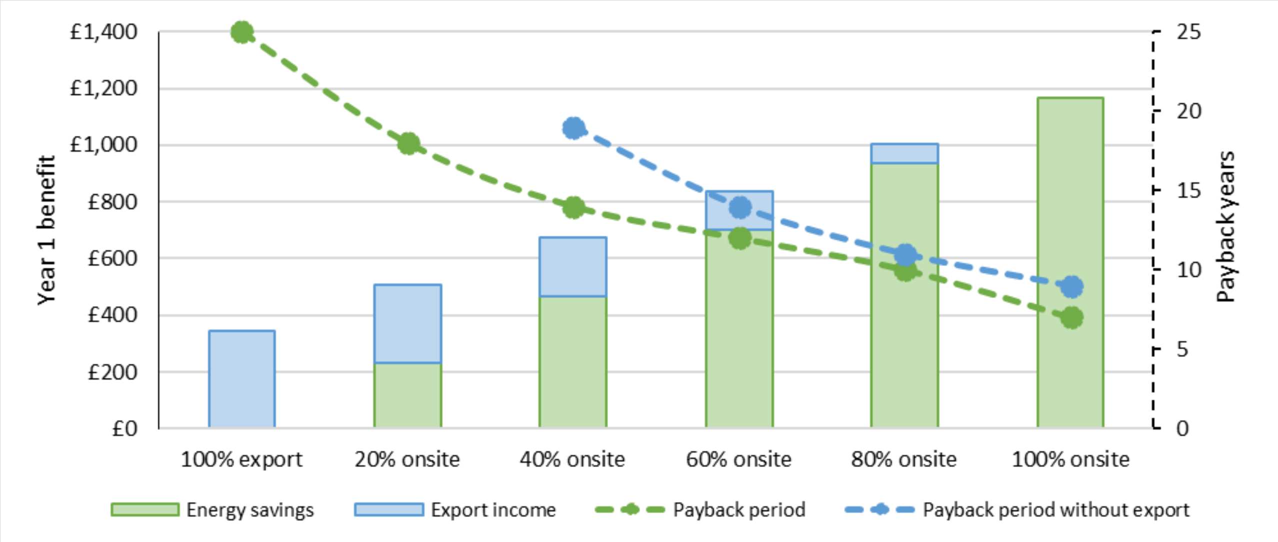

Figure 71: Wrelton Village Hall - PV & battery system benefit & payback

Renewable heat generation

A summary of the renewable heating system options identified for Wrelton Village Hall is presented in the table below. These numbers indicate the payback time (if less than 25 years) and potential operating cost- and carbon-savings that would arise from installing a new heating system, based on the current heating demand and fuel costs.

Factor	A2W HP	A2A HP	Electric
Capacity	12 kW		
Capex	£9,300	£4,340	£4,960
Running costs	£731	£691	£2,558
Savings vs now	£29	£69	-£1,798
Simple payback	-	-	-
Y1 CO_2 offset	2.3 Tonnes	2.4 Tonnes	-0.4 Tonnes
Y20 CO_2 offset	55.7 Tonnes	56.4 Tonnes	24.6 Tonnes
With 30% of heat demand offset by PV generation:			
Running costs	£512	£484	£1,791
Savings vs now	£248	£276	-£1,031
Simple payback	-	16 years	-
Y1 CO_2 offset	2.7 Tonnes	2.7 Tonnes	0.8 Tonnes
Y20 CO_2 offset	59.5 Tonnes	60 Tonnes	37.7 Tonnes

Table 131: Wrelton Village Hall renewable heating system outputs

All of these options offer meaningful emissions savings compared to the current system, which would be enhanced by PV generation (note that the 30% contribution of PV to heat demand above is illustrative only).

5. Other opportunities

A number of other schemes could be considered by the Consortium and this section sets out a range of additional options for further view. Due to the complexity of these options, additional energy modelling would form part of Phase 2 works, with flexibility in technologies used.

5.1. Energy efficiency measures

Within any new buildings, a 'fabric first' approach is always recommended as the first step in carbon and energy reductions. Fabric first typically involves creating a very efficient building envelope with appropriately sized and oriented windows, suitable levels of insulation and passive building systems (such as openable windows where appropriate, rather than mechanical ventilation). It is an approach to building design that looks at maximising the energy performance of the structure itself before renewable mechanical and electrical solutions are considered.

Where buildings are already constructed and operational, consideration should still be given to the benefits of additional insulation (particularly in roof spaces) and double glazing and the positive impacts that these changes could have on space heating demands.

In addition to this consideration can be given to lighting design (including day lighting), in order to minimise lighting requirements and to reduce ongoing running costs via the selection of energy efficient lighting equipment and controls. In existing buildings, the replacement of traditional halogen bulbs (where still operational) with LED bulbs can also save money and reduce electricity demand.

A-rated energy efficient fixed and moveable equipment are also worth of consideration, but it is recommended only to purchase or upgrade equipment when required, once existing equipment has reached its end-of-life. Water saving fittings should also be considered, which can reduce the amount of water a building requires and reduce the associated cost and carbon requirement.

5.2. Electric vehicles

Electric vehicle (EV) chargepoints are noted not to be of particular interest to the Ryedale Village Hall Consortium at this time, but Locogen would recommend considering this, particularly as the UK government has recently consulted on making these mandatory for new buildings. The procurement and installation cost for a slow or fast chargepoint (able to charge a typical EV in 8 and 4 hours, respectively) is in the region of £1,000-£1,500. Currently, the Government is offering a £350 grant against this cost via OLEV. As such, they are a relatively modest investment compared other low carbon technologies but also represent a modest opportunity for income through control of the cost of using the charger.

5.3. Electricity tariffs

The information collected for this study has highlighted that there is a broad range of electricity tariffs available to non-domestic costumers. The average daytime electricity tariff was found to be ~17p/kWh, within a range of 13-28p/kWh. This indicates that a large portion of the buildings considered could make meaningful savings on their electricity by switching to a lower fixed tariff.

Variable import tariffs

While variable electricity tariffs are not new to the market, real-time electricity tariffs are now appearing which compete with standard tariffs to offer potentially better rates to building owners/occupiers who have battery storage. These variable tariffs rise and fall with wholesale energy prices on a half-hourly basis, so the cost per unit of electricity can vary significantly depending on nationwide electricity demands. Such a tariff typically relies on the use of a smart meter in order for the electricity supplier to calculate electricity usage throughout the day and apply the wholesale price.

Typically, the unit price of electricity peaks between 6pm-9pm; however, if a building had battery storage, rather than taking electricity from the grid, the occupiers can switch to using their stored electricity and avoid the higher peak prices. This works particularly well where large appliances, such as dishwashers and washing machines, can be delayed to run at lower tariff times, or where electric car charging can be done when the tariff is more favourable.

The Economy 7, or differential tariff plans also work well with battery storage, where any batteries can be topped up to full capacity with electricity during the cheaper rates period at night and this stored electricity used to offset grid imports throughout the day.

Variable export tariffs

A handful of suppliers are now starting to offer variable 'agile' export tariffs, which don't give a guaranteed price per kWh for every unit exported back to the grid, but which vary this rate alongside half-hourly wholesale rates such that the rates received for exporting back to the grid are maximised. This works particularly well where batteries are installed, such that the energy generated can be reserved or 'held back' from the grid until the times where export payments are at their highest.

6. Conclusions and next steps

6.1. Phase 1 summary

This Phase 1 report comprises the results of an early stage, 'first pass' review of the following low and zero carbon electricity and heat generating technologies and associated storage options for installation in commercial buildings within the Ryedale and Hambleton localities:

- Solar PV
- Energy storage
- Air source heat pumps
- Ground source heat pumps

Due to technical, economic, and planning constraints, biomass developments were considered unsuitable for further analysis regarding installation within the local area.

Table 132 details the findings following the Phase 1 analysis and identifies which technologies have been deemed suitable for installation at this stage of feasibility, which technologies should be considered in more detail during Phase 2 of the works, and which technologies have been deemed unsuitable and will not be considered further.

Phase 1 findings	Suitable	To be considered further in Phase 2	Unsuitable
Symbol	✓	?	✗

Site	PV	Battery	ASHP	GSHP
Amotherby	✓	✓	?	✗
Allerston	✓	✓	✓	✗
Brawby	✓	✓	?	✗
Cropton	✓	✓	?	✗
East Thirsk Community	✓	✓	?	?
Farndale	✓	✓	✓	✗
Foston & Thornton le Clay	✓	✓	✓	✗
Ganton	✓	✓	?	✗
Kirkby Fleetham	✓	✓	?	?
Kirby Misperton	✓	✓	?	?
Kirkbymoorside Squash Club	✓	✓	✓	?
Lastingham and Spaunton	✓	✓	✓	✗
Middleton and Aislaby	✓	✓	?	✗

Site	PV	Battery	ASHP	GSHP
Milton Rooms	✓	✓	✓	?
Old Malton	✓	✓	✓	✗
Oswaldkirk	✓	✓	✓	✗
Pickering	✓	✓	?	?
Romanby WI	✓	✓	✓	✗
Sand Hutton and Claxton	✓	✓	?	?
Settrington	✓	✓	?	✗
Terrington	✓	✓	?	✗
Thixendale	✓	✓	✓	✗
Weaverthorpe	✓	✓	✓	✗
Welburn	✓	✓	?	✗
Wintringham	✓	✓	N/A	N/A
Wrelton	✓	✓	?	✗

Table 132: Phase 1 summary

All of the sites presented have potential for solar PV installations, although the returns of these systems vary depending on each building's geometry, aspect, energy demand and electricity tariff. High-level analysis has indicated the merits of each option presented on a cost and carbon basis. Its important to note here that potential grant funding opportunities have not yet been explored and their impact on the financial viability of these systems will be explored in phase 2.

Furthermore, opportunities for renewable heat generation have been identified. The RHI scheme is due to end in March 2021 for commercial properties and as such has not been included in the financial analysis of renewable heat opportunities in this study. Extensions to the deadlines as a result of the nationwide Covid-19 lockdown are under consideration by the Government but are not guaranteed. Further financial support is also likely to become available from the Government, but the form that this will take and the associated implementation timescales are as yet unknown.

Finally, it is important that Locogen and the Ryedale Village Hall Consortium make contact with Ryedale and Hambleton District Councils at the earliest opportunity to present the ideas set out within this report and determine what impact the position of the sites, specifically within the Conservation Areas and AONB, will have on the viability of low and zero carbon installations. It is necessary to understand which installations would trigger a planning application, the likely timescales and costs for determination of such planning applications and the potential obstructions to planning approval in order to better refine the solutions to be deployed and to mitigate any planning risks accordingly.

6.2. Next steps

Following issue of this report, workshops will be held with representatives from the village halls to the findings of this report. During this meeting, Locogen will be able to answer queries and explain the process and requirements of Phase 2. The anticipated sequence of events are as follows:

- Two workshop meetings to be held via video call. A representative from each building will be invited to attend one of these meetings. After this meeting, each building will be invited to confirm their interest in progressing to Phase 2. Up to twenty options will be able to proceed to Phase 2;
- As part of Phase 2 of the project, Locogen will:
  - Discuss the potential developments with external stakeholders. These will include: Ryedale and Hambleton District Councils planning departments, who will be able to comment on the acceptability of the proposed systems; and Northern Powergrid, who will be able to assess grid constraints and their cost implications.
  - Conduct site visits (in line with February's Covid-19 guidance) in order to collect further data, refine the underlying technical assumptions, and determine the best locations for plant, as well as any practical barriers for installations in each location.
  - Validate or revise the assumptions made in Phase 1 and carry out detailed energy and financial modelling. A half-hourly energy flow model will be used to determine optimum system sizes and the financial modelling will include the impacts of grant funding opportunities that are identified during this phase.
  - Develop a business case for the preferred energy systems and deliver this in the form of a report that meets the requirements of the RCEF Stage 1 fund guidelines. This report will provide a basis on which further development and capital funding may be sought, in order to bring the proposed systems to fruition.

Following a review meeting on the 9th December, this report was issued to the Consortium on the 18th December. We anticipate that two workshops with will be held in late January, after which Phase 2 will commence. The Phase 2 report will be submitted by the end March 2021.

Appendix A. Estimated carbon degression profile

Year	Carbon content of grid (kg/kWh)	Year	Carbon content of grid (kg/kWh)
2019	0.2560	2035	0.0411
2020	0.2283	2036	0.0399
2021	0.2037	2037	0.0387
2022	0.1817	2038	0.0376
2023	0.1621	2039	0.0364
2024	0.1446	2040	0.0354
2025	0.1289	2041	0.0343
2026	0.1150	2042	0.0333
2027	0.1026	2043	0.0323
2028	0.0915	2044	0.0313
2029	0.0816	2045	0.0304
2030	0.0728	2046	0.0295
2031	0.0649	2047	0.0286
2032	0.0579	2048	0.0278
2033	0.0517	2049	0.0270
2034	0.0461	2050	0.0262

Table 133: Carbon degression estimate, years indicated in blue are targets/estimations

- 2019 grid carbon content from BEIS: *Greenhouse Gas Reporting Conversion Factors 2019*
- 2035 estimated grid carbon content from BEIS: *Energy and Emissions Projections*
- 2050 UK Government grid target of 90% reduction by 2050.

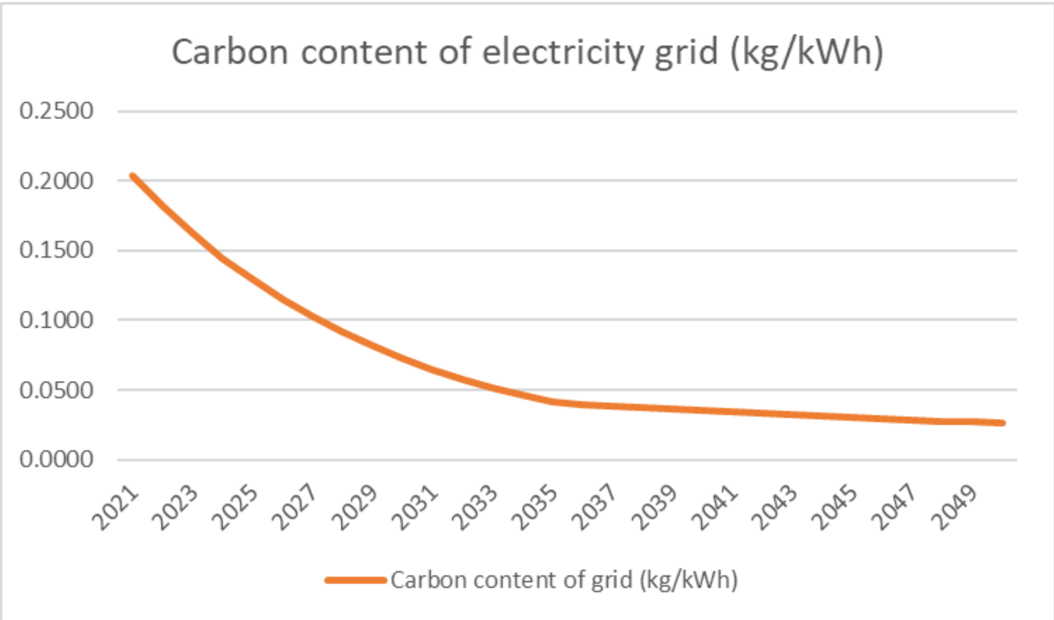

Figure 72: Carbon degression profile