RENEWABLE ENERGY SPECIALISTS

Loco2gen

Towards Carbon Neutral Churches in Craven Feasibility Study

Phase 2 Report

For the Towards Carbon Neutral Churches in Craven group

Document Information		
Document title:	7157-FEAS-REP-0002-Craven Phase 2	
Date of issue:	15/10/2021	
Status:	~~Draft in preparation; Draft Complete; Checked in revision; Checked complete;~~ Approved	
Prepared by:	*Charlotte Mitchell*	Date:
Checked by:	*Leila Tavendale*	*14/10/2021*
Approved by:	*Leila Tavendale*	*14/10/2021*

Version	**Date**	**Purpose of amendment**
01	15/10/2021	Draft document
02	30/11/2021	Amended following client review
03	06/12/2021	Final amendments
04	09/12/2021	Minor correction

Executive Summary

The 'Towards Carbon Neutral Churches in Craven' project is a feasibility study funded under Stage 1 of the North East, Yorkshire & Humber branch of the Rural Community Energy Fund. Locogen were appointed to undertake this project on behalf of a consortium of rural churches throughout Craven. The project has been executed in two phases, with the first comprising a high-level appraisal of solar PV and renewable heating options for the 5 participating churches. This report, presented in the Stage 1 RCEF format, summaries the work completed in the second phase of the project.

Following a brief introduction, the locations of each site are analysed in section 2, in terms of the designations and constraints that influence renewable energy development. This highlights that all of the churches (excluding St. Augustine's in Draughton) are Listed buildings. In addition, all are located in various conservation areas. This section also clarifies that each site has a suitable solar resource, grid connection and operating structure to accommodate a solar PV installation.

In section 3, an overview of solar PV, heat pump and battery technology is presented, as well as the ancillary electrical equipment required for safety and controls. Based on Locogen's expertise as a commercial installer of renewables, solar PV modules with 330Wp generation capacity are recommended. Supplementary electric heating is also discussed, as given the physical size of some of the larger buildings within the study, the efficiency of "heating the people" rather than the building volume, should be carefully considered. The physical properties, operational lifetime, and (minimal) maintenance requirements for each technology are also outlined in this section.

Planning and permitting requirements are discussed in section 4. It is established that, in accordance with local and national planning policies, the majority of proposed solar PV and heat pump installations will require planning permission (except for rooftop PV at St Augustine's). Furthermore, fees for planning applications and advice are presented in this section.

Subsequently, grid connection options are explained, these being G98 and G99 connections. The former is a free application for up to 3.68kW of generation per phase (so 3.68kW for a building with a single-phase electricity supply or 11.04kW for a three-phase supply – based on the inverter size, rather than the total PV capacity). For installations exceeding G98 limits, a G99 application is required. This involves a new electricity connection agreement, which carries significant costs. Owning to the high costs of G99 connections, these are not recommended for any of the churches. Grid connection options for battery storage are also discussed.

In section 5, the financial considerations for renewable energy installations are discussed. This includes an overview of individually owned options and other routes. In the first case, the churches could, separately or in tandem, apply for grant funding and appoint a contractor to install solar PV, batteries and heat pumps (where applicable). In terms of other routes, the churches could form their own energy co-op, but this is not advised due to the huge administrative burden associated, or they could appoint an existing co-op to install renewable energy systems their buildings. In this case, the system would be owned and maintained by the co-op, and the churches would benefit from offset electricity and heat costs (but not make income from exports to the grid). Also in this section, development, capital and operational costs are explained, as are income mechanisms, namely the Smart Export Guarantee (SEG). Lastly, the financial modelling process conducted for each church is explained, as are the underlying assumptions.

In Section 6, an overview of the proposed solar PV array is presented for each church, including the recommended array size, location and annual generation, calculated from 3D models (accounting for shading, pitch and orientation) in PVSyst software. A discussion around the appropriate low-carbon heat technology recommended for installation is set out where applicable. The development, capital and lifetime costs for each array and an optimally-sized battery and heat pump are then presented. The insights from each church's energy flow models are summarised, as per the example in the following figure which shows the monthly energy demand, generation, storage and export for a typical building. Each energy flow model is based on half-hourly solar PV generation from PVsyst, the church's annual electricity demand, a half-hourly heat demand profile and a half-hourly demand profile based on the occupancy and load information provided.

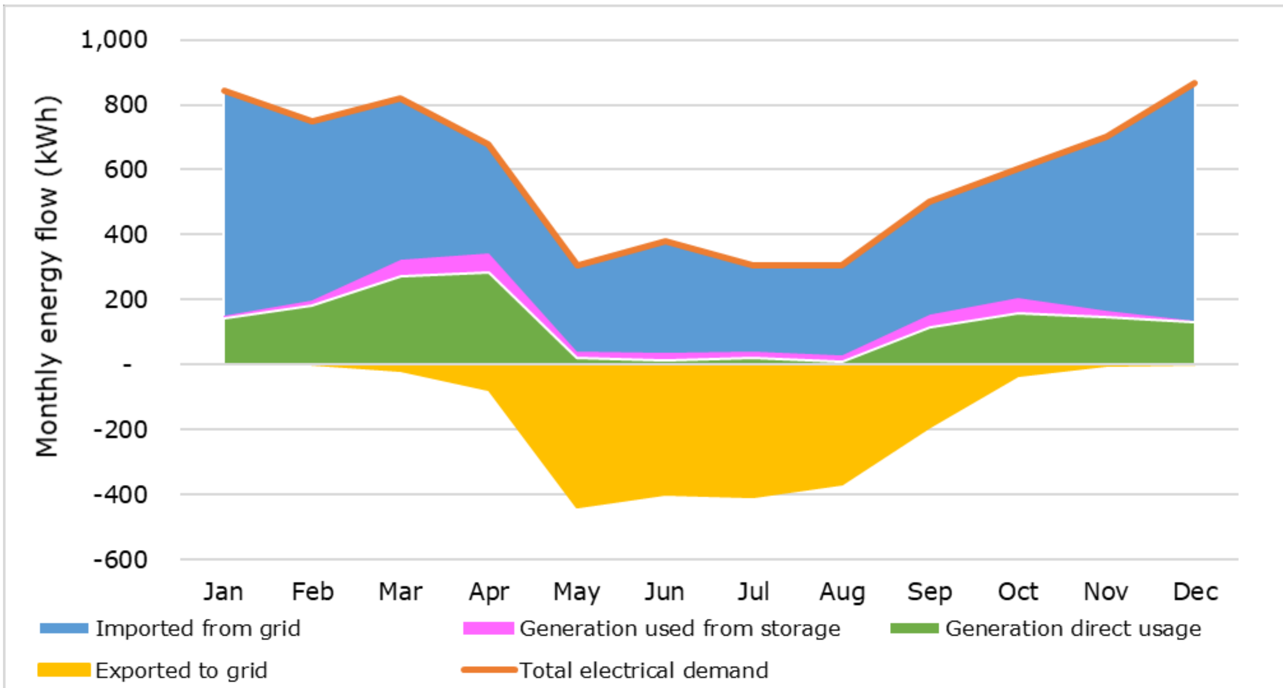

Figure 1: Example church - monthly energy flows

The outputs of each energy flow model are used to inform a cost and emissions analysis. For each church, financial returns and carbon offsets are tabulated for the cases with and without a battery, grant funding and a heat pump system (where applicable). In each case, the solar PV arrays are shown to bring impressive carbon benefits in terms of emissions reductions. The financial paybacks vary significantly across the churches, but are greatly enhanced by grant-funding, as expected. The high capital cost of batteries means that the addition of these assets provides higher annual financial benefits to each church but does slow the returns in almost every situation. As such, batteries are generally not recommended at this time.

The heat demands for the churches contained within this study are high, largely due to the age of the buildings and limited scope for building fabric improvements (due to listed status or the churches' locations within Conservation Areas). As such, large heat pump systems would be required to replace existing fossil fuel heating systems, which incur significant capital cost. Due to the lack of support currently in place for low carbon heating, alongside the low cost of gas and oil in comparison to electricity, the cost analysis largely appears quite negative with regards to heat pump installation.

Several shorter sections form the remaining body of this report. Firstly, section 7 looks at the feasibility of installing electric vehicle chargepoints alongside the proposed renewable energy systems, to ensure that the maximum amount of solar PV generated electricity is used on site, while generating further financial opportunities for the churches. The community impacts of the recommended renewables systems are discussed in section 8. These include demonstrating replicable systems to local communities; contributions to local and national decarbonisation targets; and facilitating reduced overheads and modest income streams to each church. In section 9, operation and governance issues are summarised, and this section reiterates that the administration and maintenance burdens associated with owning and operating a solar PV-battery-heat pump system are minimal. Section 10 provides a roadmap which explains the steps towards implementing an individually owned installation (as opposed to an installation owned by a co-op). Lastly, the conclusions section summarises the findings of the report and establishes that the next step for each church is to decide which system they want to move forward to design and installation with, and whether the individually-owned or co-op owned option is preferred.

In the appendices to the report, a list of proposed grant funding options is provided, as is a list of local MCS-accredited installers. Draft specification documents for solar PV have also been provided to assist with procurement. A risk register is included, which demonstrates the likely risks facing the development and operation of the installations and the recommended measures to mitigate their impacts, and a short feasibility analysis is also included for two additional churches which did not form part of the initial assessment. Lastly, additional financial analysis is presented to capture the impacts of applying alternative discount rates.

A draft version of this report was discussed in November 2021 at an online workshop held to discuss the findings and further funding opportunities. A number of updates have been included within this report following the workshop in order to capture these discussions.

Table of contents

List of Abbreviations

A2A	Air-to-air
A2W	Air-to-water
AC	Alternating current
AONB	Area of Outstanding Natural Beauty
ASHP	Air Source Heat Pump
BEIS	Department for Business, Energy and Industrial Strategy
CHG	Clean Heat Grant
CO_2	Carbon dioxide
COP	Co-efficient of Performance
DC	Direct current
DNO	District Network Operator
EA	Environment Agency
EV	Electric vehicle
FiT	Feed-in Tariff
GIS	Geographic Information System
GMPV	Ground-mounted photovoltaic
GSHP	Ground Source Heat Pump
HE	Historic England
IRR	Internal Rate of Return
kg	kilograms
km	kilometres
kW	kilowatt
kWh	kilowatt-hour
kWp	kilowatt-peak
LED	Light Emitting Diode
LEP	Local Enterprise Partnership
LPA	Local Planning Authority
m	metres
m/s	metres per second
m^2	square metres
MCS	Microgeneration Certification Scheme
MOD	Ministry of Defence
MW	megawatt
MWp	megawatt-peak
NATS	National Air Traffic Services
NE	Natural England
NPG	Northern Powergrid

NPPF	National Planning Policy Framework
NPV	Net Present Value
p	pence
PV	Photovoltaic
RCEF	Rural Community Energy Fund
RHI	Renewable Heat Incentive
RMPV	Roof-mounted photovoltaic
RO	Renewable Obligation
SEG	Smart Export Guarantee
SSSI	Site of Special Scientific Interest
WSHP	Water source heat pump
Y1	Year 1
Y20	Year 20

1. Introduction

1.1. Project background

Led by the Parochial Church of St Mary the Virgin, Embsay, a group of five churches in the District of Craven are working together under the 'Towards Carbon Neutral Churches in Craven' project. The TCNCC group are looking to explore options to decarbonise the energy systems of their churches, driven by the Church of England's aim to reach net-zero carbon emissions by 2030. This project is supported by the BEIS funded Rural Community Energy Fund (RCEF) which is managed by North East, Yorkshire and Humber Energy Hub and administered by the Tees Valley Mayor and Combined Authority.

This document represents the work conducted under the second of two project phases and is the second report issued to the client. Phase 1 of the project was conducted earlier in 2021 and considered the high-level technical and financial feasibility of renewable energy opportunities for each of the participating churches. Initially, renewable heating systems and roof-mounted solar PV were considered. Following issue of the Phase 1 report, a virtual workshop was held with representatives from each church, in which Locogen presented the report's findings and facilitated a Q&A session. Following the workshop, the five churches were confirmed for participation in Phase 2, as listed below:

- The Church of St Mary the Virgin, Embsay with Eastby
- Holy Trinity Church, Skipton
- St. Augustine's Church, Draughton
- St. Mary's Church, Carleton
- All Saints Parish Church, Burton in Lonsdale

1.2. Phase 2 outline

The aim of Phase 2 of the feasibility study is to consider in greater detail the renewable energy generation and low-carbon heat opportunities for the 5 churches. To help facilitate this, a site visit was undertaken in August 2021, which reviewed each building's current heating system, building fabric and energy efficiency measures already implemented, as well as surveyed suitable roof spaces and external grounds for the installation of solar PV and ground source heat pump technology.

Following this site visit, detailed energy modelling has been undertaken utilising information collected for each building, evidence provided by the group and several modelling tools. These include PVSyst, a programme for designing solar PV arrays that generates half-hourly generation profiles, and Locogen's energy flow model which takes electricity demand and generation as inputs to determine the annual electrical energy flows within each system in half-hourly discretisation. This energy flow model has also been used as the basis for energy storage (battery) sizing and financial modelling in Phase 2. Practical and regulatory considerations have also been explored, including the planning process and various options for funding the PV, low carbon heat and battery projects.

This report is also required to follow the Stage 1 RCEF report requirements outlined by BEIS. As such, the remaining body takes the following structure:

- Site;
- Technology;
- Planning & permitting;
- Financial considerations;
- Financial projections;
- Community benefits;
- Community engagement;
- Operation and Governance;
- Scheduling; and

- Conclusions.

There are also four appendices to the report. The first is a list of potential sources of grant funding; followed by an overview of all assumptions made within the financial and carbon modelling; then a list of local MCS-accredited installers; and the finally a risk register which documents the risks associated with the proposed installations and steps to mitigate them.

2. Site

A map showing the location of each of the five churches participating in the project is presented below in Figure 2. The majority of the churches are located within small, rural settlements and all but All Saints Church are located within 7km from each other in southeast Craven. All Saints is located in Burton in Lonsdale, around 40km northwest of the other sites.

Two churches (St Mary's, Embsay and St Mary's, Carleton) are Grade 2 Listed; one (All Saints, Burton in Lonsdale) is Grade 2* Listed and one (Holy Trinity, Skipton) is Grade 1 listed. All of them are located in conservation areas, and St Mary's, Embsay lies just within the boundary of the Yorkshire Dales National Park. These designations introduce development restrictions which would not usually be encountered for solar arrays and renewable heat installations of the scales considered in this project. Associated planning requirements are discussed in Section 4 of this report.

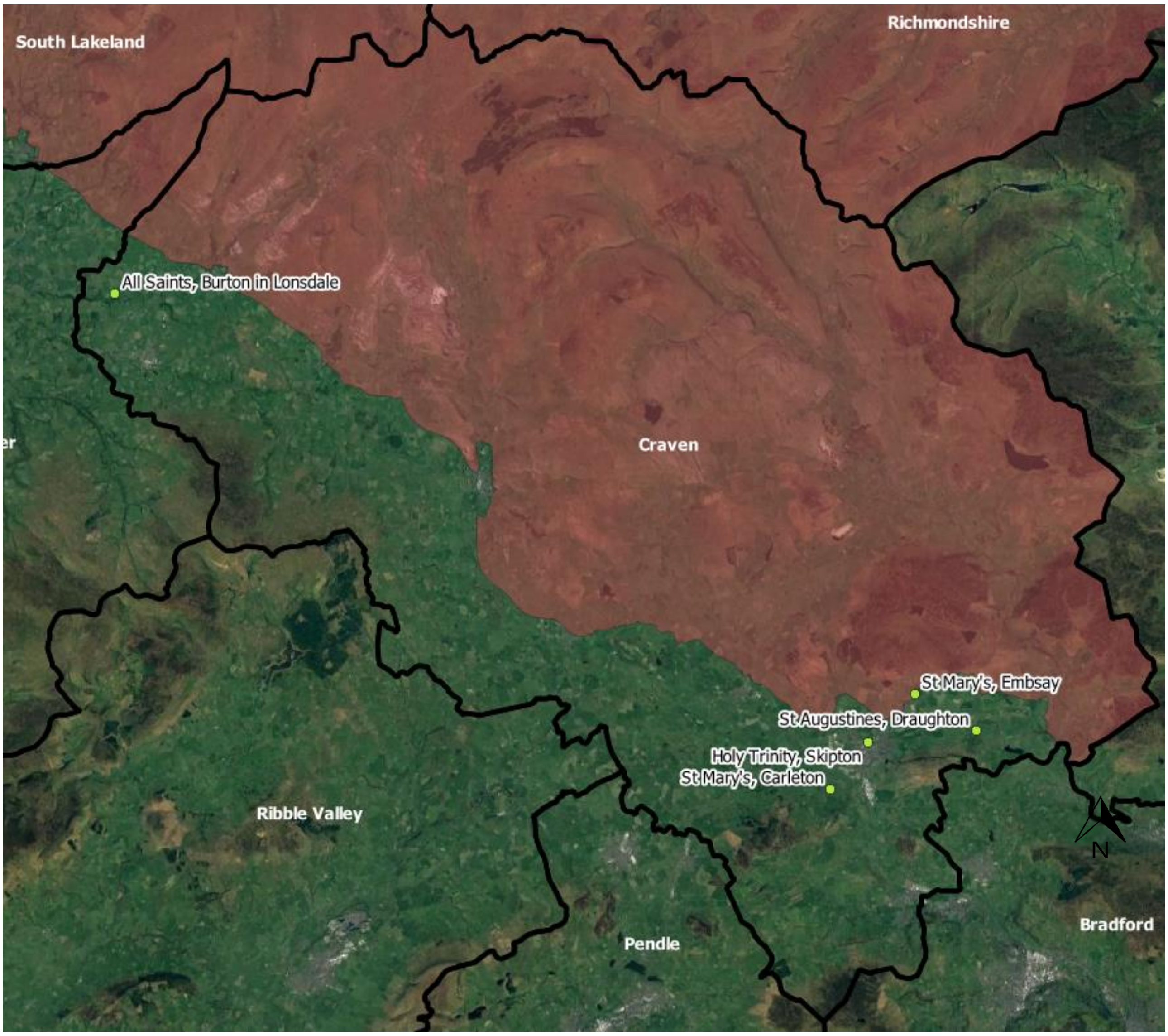

Figure 2: Site locations (Districts outlined in black, National Park shaded red)

There are no day-to-day tasks associated with management of the proposed installations, therefore each church's caretakers are anticipated to be able to take on the management of their own renewable energy installations.

The churches are all suitable for low-carbon heat installations, namely air source heat pumps. They are also suitable for solar PV installations, as they all have an electricity connection to the

National Grid and are sited in locations that receive 900-950kWh/m2 of solar energy annually. However, the buildings are of a range of sizes and orientations and are impacted by shading to different degrees. These aspects have been taken into consideration for the solar yield modelling performed for each building. The condition and age of the roof also impacts cost of installation and this has been accounted for in the financial modelling performed for each church. As such, the feasibility of installing PV at each location is reflected in the financial projections presented in section 5.

3. Technology

3.1. Overview

3.1.1. Energy efficiency

Lighting

An 'easy win' to reduce the electricity demand of an existing building is to replace existing incandescent and halogen light fixtures with LEDs. This does not require specialist design, fees or equipment but can cut lighting bills by over half. Installing occupancy sensors in communal areas is also encouraged, such that lighting can always be switched off when these spaces are not in use.

Insulation

Ideally, any building would be insulated as much as possible prior to the installation of a new heating system in order to reduce the peak heating demand of the building by minimising heat loss to the atmosphere via its walls, roof, windows and doors. Old buildings such as churches tend to be constructed of very poorly insulated elements such as stone walls and single-glazing. However, given that they are often listed buildings (as in the case of all TCNCC churches except St Augustine's, Draughton), this task becomes difficult as it is very unlikely that energy efficiency measures which have visual impacts externally will be permitted. Some churches will also have internal elements included in their listings, which makes other measures challenging.

Given that all the TCNCC churches have vaulted ceilings, roof insulation, where technically feasible, is a very complex and expensive process and is therefore recommended only if it can be done in conjunction with reroofing works. The vast majority of windows in the TCNCC churches are stained glass set in stone surrounds. Any alterations to these, such as secondary glazing, are likely to be prevented due to their impact on the buildings listings. However, it is recommended that standard single-glazed windows in kitchens and other rooms are replaced with double glazing, where possible.

Similar to insulation, draught proofing can also reduce the heat demand of each church, as well as enhance the comfort of its users by eliminating cold air ingress. It is recommended that a draught-proofing audit be conducted at each church, to identify opportunities to fill in cracks or other gaps in walls; improve seals around doors and windows; repair window openings and repair any slipped stained glass that have led to permanent air gaps.

Energy storage

Almost all domestic and small-scale batteries available in the UK are lithium-ion based devices and can be wall mounted. They tend to require less than 1m^2 of wall area, and depth will vary from model to model but single units will take up around 0.2-0.5m plus access space. A well ventilated cupboard or utility room would be a suitable location for a battery, and although some models (such as the Tesla Powerwall) can be installed outdoors, this is not recommended to due to the potential of the development's local climate to affect performance.

Warranties for high quality batteries now extend up to 10 years, indicating that their lifetimes are likely to extend a few years beyond this period. As they have no moving parts, there are no maintenance requirements for batteries, and provided that the battery is interfaced with an appropriate PV diverter, no regular operational requirements either. However, depending on the balance between generation and demand over the winter, batteries may be required to be manually switched to 'winter mode' to safeguard their performance if they are not likely to be used for longer periods. This function would not be required if the battery was programmed (by the smart diverter) to store off-peak electricity from a variable tariff.

The impact that a battery system can have on a building's energy flows is primarily dictated by its capacity. Grid connection limitations (as explained in section 4.3) limit the battery capacity that can be installed without significant grid connection costs. As such, batteries considered within this study are in the region of 10kWh storage capacity. (For context, this represents enough energy to boil a kettle around 75 times). For a 12kW solar PV array (which is the size typically considered in this study), this would store c. 1h of electricity generation in the summer and c. 3h in the winter. If this energy was consumed by a c. 30kW heat pump (appropriate for a church of the scales considered in this study), operating at a third of its capacity, the battery would be discharged after just one hour. Therefore, it is important to understand that batteries certainty can serve a useful purpose but only to a limited extent.

At present, batteries are very expensive and do not always provide financial benefits as envisioned, therefore their impact on the energy flows of any building needs to be carefully assessed. In addition, the lithium required for most battery models is a scarce material and most often comes from mining, which requires significant volumes of water and energy, such that batteries tend to carry a high embodied carbon footprint. It is anticipated that in the future, lithium recycling from existing batteries and other, more sustainable, extraction methods will become more commonplace, which may reduce these adverse impacts. It is also possible that the costs of batteries will decrease in the future too, and it would be possible to install batteries at a later stage than other energy system upgrades, once they present a more cost-effective option.

3.1.2. Solar PV

PV modules and mounting

The key element of a solar PV installation is the PV modules themselves. For modelling purposes, Locogen works with a 330Wp unit of standard size (1x1.7m) which weighs approximately 20kg each. The 330Wp output represents the upper end of performance for standard sized, widely available panels. Warranties for PV modules are now upwards of 25 years.

Locogen recommend that modules are secured to pitched roofs via non-penetrative mounting systems, to avoid the risks of penetrative systems, namely leakages. This can arise from drilling through the roof and using sealant which wears over time, or from structural movement, for example due to high winds moving the panels, and damaging the external roof material. For tiled and slate roofs, flash fixings can be used to ensure that the tiles or slates do not bear any of the load as they fix directly onto the roof’s rafters. For lead roofs, non-penetrative mounting is generally only possible for lead roofs where they have ridged seams onto which clamps can be fixed. Otherwise, hanger bolts (a common penetrative fixing) are likely to be required.

For roofs which contain asbestos, we would advise against installing solar PV directly onto the roof, unless an asbestos surveyor identifies a solution. Instead, the roof may need to be replaced or overclad, which in either case would allow for enhanced insulation of the building. This cost has not been factored into the anticipated project costs for any churches expected to have asbestos due to the variability associated with pricing such projects.

If a church is due to be reroofed, or if planning permission is required, another option is an in-roof system, as shown in Figure 3. These systems have a lower visual impact but are roughly twice as expensive has on-roof systems, so are not recommended in the first instance.

Ground mounted solar is generally installed on a metal frame, the design of which would be confirmed by the Contractor specifying the system in line with wind loading calculations and ground type. Ballasted bucket type systems are available, but these are generally used where the ground already has a small pitch, or the ground make-up is such that drilling supports for framework would be cost prohibitive.

Figure 3: In-roof PV example from Viridian Solar

Ancillaries

The ancillary equipment required for a roof-mounted solar array tends to be small and can be wall-mounted within storage cupboards or plant rooms. Necessary equipment is as follows:

- Inverters – The solar panels are connected in strings, which are then connected to inverters which convert the DC electricity generated to AC electricity, which is required for UK appliances and grid connections. For G98 systems, an export limitation device will also be required to ensure that the system complies with its grid connection arrangement. This functionally can be incorporated into inverters.
- Isolations – There will be two isolators, one on the DC side and one on the AC side of the inverter. These are ultimately safety features to ensure that electrical faults do not spread between equipment.
- Grid connection & metering equipment – Electricity will then pass through a generation meter (which tracks how much electricity is generated) before supplying the consumer unit.
- Diverter – This is a small control unit that allows onsite usage of PV to be maximised by directing surplus generation to a battery, heat sink, or other loads such as electric vehicle chargepoints.

3.1.3. Heat

Air source heat pumps

Air source heat pumps (ASHPs) are generally made up of an external and an internal component, and tend to have a useful lifetime of 20 years. The external unit should ideally be located on an outside wall which sees good levels of sunlight and is not constrained by other walls or shrubbery which can block the intake air flow. The impact of sunlight will raise the temperature of the external air, which will marginally improve the system's efficiency. Visual and noise impacts should also be considered when it comes to locating external units.

The external unit uses heat within the external air to generate heat for use internally. This is then circulated around the building in one of two ways:

Air-to-air

Once the external unit has generated heat, this is transferred to a refrigerant fluid (or water) which is then circulated around the building via narrow pipework connections to "air blowers". This heat is used to heat up recirculated air from within the space, or to supplement a ventilation system by pre-heating the air before it is blown into a room. Air-to-air systems are typically one of the cheapest low-carbon heating systems to install and can be installed as a split-system (one outdoor unit linked to one indoor unit) or a multi-split system (one outdoor unit to multiple indoor units). Thermostatic controls can be used to control the unit, or more simply, the indoor unit is controlled through a remote control which can turn the unit on and off, or turn the temperature up and down as required.

For large spaces, air heating provides many benefits – the primary one coming from the phenomenon known as 'alliesthesia', whereby while a room may be cold, but if a warm breeze is being blown across the occupants, they will feel comfortable. However, air-based heating can invite unwanted noise into a space, due to the fans within the units, which was noted to be a common comment during the site visits to churches with fan-assisted radiators.

It is also important to highlight that air-to-air heat pumps cannot generate hot water for use within kitchens and bathrooms and as such, point of use electric water heaters should also be considered for installation.

Air-to-water

Once the external unit has generated heat, this is transferred to water which is then circulated around the building in a conventional radiator circuit. This system can be controlled in the same way as any conventional gas- or oil-fired radiator system, with thermostats installed on radiators or within key rooms. Air-to-water heat pumps are typically slightly more expensive to install than air-to-air systems, but the difference is marginal.

As highlighted earlier, one of the key considerations with regards to air-to-water heat pumps is that the temperature of the hot water generated (or more technically, the difference in temperature between the flow and return temperatures within the circuit) is lower/smaller than would be achieved by a gas-fired boiler and as such, radiators are required to be much bigger in order to give off the same amount of heat to meet the room's heat demand. In the older churches considered within this report, where large, cast iron radiators are currently in use, air-to-water heat pumps may represent a suitable solution without any additional upgrades; however, where small, slimline radiators are present, these radiators would have to be replaced with larger ones in order to meet the heat demands. This would then introduce additional costs to the installation.

Supplementary electric heating

A document published in January 2020 by the Church of England stated that '*heating guidance needs to focus not primarily on boilers or heaters, but instead on people, and their activities. It is people who feel comfort or discomfort and people who are the focus of the mission of the church. A warm and welcoming building is ideal, but realistically many churches struggle to achieve this; space heating to 18°C is often aimed for, but is expensive, doesn't always make people comfortable, and can be environmentally unsustainable. What is more, inappropriate heating can cause significant damage to the historic building fabric and artefacts, which can result in further considerable costs […] to repair or conserve*'.

Their recommendations relating to heating the people suggested that '*heating is installed near to where the people sit, which may include under pew, portable, and/or overhead far-infra-red radiant heating panels*'.

Modern infrared heating panels no longer look like glowing red tubes installed on a wall, which are less than desirable within the beautifully preserved spaces, but instead can look like flat panels, which are available in various colours, as shown in Figure 4 below. These panels heat up quickly and work by heating the people, not the space and can be integrated into the existing buildings with minimal disturbance or visual impact. Typically, they have a range of c. 10m and are light-weight, meaning that they can be installed on walls, columns and ceilings (although not underneath seating).

An indicative figure for the cost of supplementary heating has been included within the financial assessments to allow for the purchase and installation of infrared heating panels within the main body of each building to be budgeted. These values are based on the size of each church, and the number required would depend on the preferred style of panels (which is primarily an aesthetic consideration).

Figure 4: Ceiling mounted infrared heating panel

Hybrid heating systems

As an addition or alternative to supplementary electric heating systems, the existing gas/oil boilers could be retained for the remainder of their useful lifetimes. Although this would significantly impede progress towards carbon neutrality, it would allow for the installation of heat pump capacity to be staged over a longer time period.

As heat pumps operate best closest to their maximum output, it is generally recommended to install multiple smaller units to meet a total capacity, rather than a single unit. For example, installing 3x30kW heat pumps rather than 1x90kW unit would allow for one or two heat pumps to operate at higher efficiencies during periods of low demand, rather than to have a single unit operate at a poor efficiency (as heat pumps operate best closest to their maximum output). Therefore, it would be possible for part of the total heat pump capacity to be installed initially, with the remaining portion added once the existing system has reached its end of life. This approach would allow for the capital costs associated with installing renewable heating capacity to be portioned out over a longer timeframe, thus reducing the initial investment required. However, it would lead to separate grid applications being required for each tranche of heat pump capacity installed, which would likely lead to greater grid connection costs and disruption than would be expected with a single application for the full capacity required.

3.2. Project assessments

In order to assess each church's suitability for solar PV and heat pump installations, GIS mapping software was used to identify constraints and measure dimensions. These desktop based assumptions were confirmed during site surveys. Most notably, the nature of the buildings' electricity connection being single- or three-phase, as this dictates the maximum PV and battery capacity allowable under G98 grid connections.

Locogen have also sought indicative grid connection costs from NPG for large arrays, but as per section 4.3, these are very expensive and therefore systems have been sized to avoid these (by complying with G98 requirements) unless the demand: generation relationship makes this financially viable. Rooftop PV installations are also designed to comply with the permitted development conditions – which require, amongst other factors, a 1m clearance between the PV system and a roof's external edges.

To quantify the electricity generation of each proposed installation, a model was created for each church using PVSyst software. In PVSyst, a 3D model of each church was used to estimate the annual generation of a solar PV array on a half-hourly basis, relative to the size, position, orientation and pitch and accounting for shading impacts of trees, chimneys and nearby buildings. The outputs of this exercise were interfaced with energy flow models in order to estimate the financial returns of each array, as reported in section 5.1.2.

4. Planning and Permitting

4.1. Permitted Development rights

Rooftop solar PV

For solar PV installations of up to 50kWp capacity, planning permission is not required, as per Schedule 2, Part 14 of the Town and Country Planning (General Permitted Development) (England) Order 2015[1].

The Permitted Development order stipulates that solar PV can be installed on the roof of a non-domestic building, subject to the condition that an installation is sited *"so as to minimise its effect on the external appearance of the building and the amenity of the area"* and the following exclusions:

> *"(a)the solar PV equipment or solar thermal equipment would be installed on a pitched roof and would protrude more than 0.2 metres beyond the plane of the roof slope when measured from the perpendicular with the external surface of the roof slope;*
>
> *(b)the solar PV equipment or solar thermal equipment would be installed on a flat roof, where the highest part of the solar PV equipment would be higher than 1 metre above the highest part of the roof (excluding any chimney);*
>
> *(c)the solar PV equipment or solar thermal equipment would be installed on a roof and within 1 metre of the external edge of that roof;*
>
> *(d)in the case of a building on article 2(3) land, the solar PV equipment or solar thermal equipment would be installed on a roof slope which fronts a highway;*
>
> *(e)the solar PV equipment or solar thermal equipment would be installed on a site designated as a scheduled monument; or*
>
> *(f)the solar PV equipment or solar thermal equipment would be installed on a listed building or on a building within the curtilage of a listed building."*

All proposed arrays for this project have been sized and located such that the first three exclusions would not apply, and none of the churches or their surroundings are noted to be scheduled monuments.

Exclusion (f) applies to Holy Trinity, St Mary's (both Embsay and Carleton), and All Saints, as these are Listed buildings and therefore would need planning permission for rooftop solar PV.

In relation to exclusion (d), 'article 2(3) land' is protected land and includes Conservation Areas, whilst highways include roads and public rights of way. As such, all of the churches fall into this category. However, for St Augustine's, the proposal would not front a highway and therefore would constitute a permitted development. These considerations are summarised in Table 1.

Ground-mounted PV

There are also cases in which ground-mounted solar PV is a permitted development. However, the size of the permitted array is limited to a maximum of 9m^2, which is much smaller than any

---

[1] https://www.legislation.gov.uk/uksi/2015/596/schedule/2/part/14

of the systems proposed in this study. Therefore, any of the proposed GMPV systems would require planning permission.

Other technologies

At present, there are no permitted development rights for non-domestic ASHPs, therefore planning permission will be required for all proposed ASHP installations. Small-scale, indoor energy storage batteries to do not require planning permission.

Usually, EV chargepoints are permitted developments and would not require planning permission. However, they are not a permitted development if located within the curtilage of a listed building, meaning that planning permission would be required for most of the TCNCC churches.

Church	Designation	Permission required?
The Church of St Mary the Virgin, Embsay	Listed building; Conservation area	**Yes**
Holy Trinity Church, Skipton	Listed building; Conservation area	**Yes**
St. Augustine's Church, Draughton	Conservation area	No
St. Mary's Church, Carleton	Listed building; Conservation area	**Yes**
All Saints Parish Church, Burton in Lonsdale	Listed building; Conservation area	**Yes**

Table 1: Permitted Development considerations for Rooftop PV and EV chargers

4.2. Planning permission

4.2.1. Local Policy

Within Craven, renewable energy planning applications would be considered against Policy ENV9 of the Craven District Local Plan[2]. The Policy states the following conditions for acceptable renewable energy proposals:

Renewable and low carbon energy development will help to reduce carbon emissions and support sustainable development. This will be achieved by;

- *a) Supporting projects and infrastructure proposals that offer a good balance of economic, environmental and social benefits, and are not outweighed on balance by one or more negative impacts.*
- *b) Ensuring that there are no significant adverse impacts on natural, built and historic assets, and developments harmonise with the local environment and respect the character of the immediate setting and wider landscape.*
- *c) Avoiding developments that may detract from the landscape and scenic beauty of the Forest of Bowland Area of Outstanding Natural Beauty or its setting and the setting of the Yorkshire Dales National Park.*
- *d) Safeguarding the amenity of local residents and communities, and ensuring that satisfactory mitigation can be achieved to minimise impacts such as noise, smell or other pollutants.*

[2] https://www.cravendc.gov.uk/planning/craven-local-plan/

e) Developers engaging with the community at the earliest stages of the planning process and seeking to achieve community benefits wherever possible.
f) Ensuring there are no unacceptable impacts on civil, military aviation, radar and telecommunications installations.
g) Supporting proposals which demonstrate that the natural environment including designated sites will not be adversely affected without satisfactory mitigation. Enhancements should be achieved wherever possible.
h) Supporting proposals where the potential cumulative impacts are not found to be significantly adverse.
i) Ensuring operational requirements can be met including accessibility and suitability of the local road network, ability to connect to the grid and where relevant, proximity of feedstock.
j) Grid connections being provided underground, wherever feasible without adversely impacting upon historical or archaeological assets.
k) *Ensuring measures are in place to secure the removal of infrastructure should it become redundant or no longer operational and that satisfactory site restoration can be achieved*.

Based on our experience, it is likely that planning applications for the systems in this study would be scrutinised most heavily against conditions b) and d), and in the case of St Mary' s, Embsay, condition c) too. In order to maximise the chances of permission being granted, Locogen would strongly recommend that preapplication advice is sought from the Council's planning department.

4.2.2. Planning application fees

There are various fees for submitting planning applications and advice requests to any local authority. Relevant fees for this project are provided Table 2 below.

Application	Fee
Listed building consent	£0
Full planning permission	£234 (per 0.1 hectares)
Preapplication advice	£289 (temporarily suspended in Craven)

Table 2: Relevant planning application fees

4.3. Grid notification requirements

Solar PV and battery installations involve 'new generation' connections to the National Grid. These are managed by the local electricity Distribution Network Operator (DNO), which, for most of the project's locations, is Northern PowerGrid (NPG). For All Saints, Burton-in-Lonsdale, the DNO is Electricity Northwest. Depending on the capacity of generation to be connected, there are two different options.

Small solar PV connections (G98)

For connections up to 3.68kW per phase, a 'G98 - Single premises notification' would be required. This is a simple 'connect and notify' process with no fees and can be done quickly online via NPG's Micro-generator Notification form. The installer has 28 days to fill out this form from the date of commissioning.

Large solar PV connections (G99)

For larger connections (over 3.68 per phase) an application to the DNO is required, as NPG needs to determine what impact the new generation will have on its network, and make local upgrades accordingly. This would typically be a 'Low voltage generation (G99) connection application and would cost a minimum of £650 but are often 10 times this value. The cost of connection would be determined from the online application form and is guaranteed to be established by NPG within 45 days.

Connection costs vary greatly depending on the location and type of building and are often more expensive for rural locations, where the network consists at least partially of overhead rather than underground cable systems – this classification applies to all the churches within this project. The median cost of this kind of connection is £14,000 (according to NPG's current guide-prices[3]) meaning that the connection cost for rooftop solar can outweigh the cost of installing the array itself. The connection itself is completed by the DNO roughly 5-10 weeks after payment.

Given limited time and financial resources of community organisations, Locogen often recommend against pursuing G99 applications, in order to keep the grid connection process simple and to avoid uncertainty in the timescales and cost of the project, as this can negatively impact grant-funding applications. Lastly, expensive grid connections create a step-change in the capital costs of a solar PV project, as illustrated in Figure 5. This step-change, at the scales applicable to this study, rarely leads to an improved financial outlook for the installation versus a maximised G98 system.

Of the churches considered in this report, none are deemed suitable for G99 PV applications. Instead, all but St Augustine's are advised to apply for additional import capacity to accommodate their proposed heating systems. This is likely to increase their import connection from a single-phase to a three-phase supply. The impact of this increase is to in turn increase the allowable electricity export capacity (i.e., the G98 capacity of each building) which further justifies the avoidance of G99 costs. In short, increasing the size of your incoming electricity supply will allow more solar panels to be installed under the G98 limits.

Battery connections

In the UK electricity network, batteries are treated as generators, so have a similar connections process to solar PV installations. NPG recently introduced a 'Fast track electricity storage applications (G99)' process, which is a free application for connections of battery capacity that meets G98 limits (3.68kW per phase) for a building which has a proposed or existing G98-compliant solar PV array. A G100-compliant export limiting device is required so that the combined system can be guaranteed never to deliver more than 3.68kW per phase of electricity to the national grid. Also, the systems must be prevented from operating in island mode, meaning they could not be used during a power cut. Lastly, the proposed system must be commissioned within 10 days to 3 months of the application.

If these conditions are met, the fast-track application is likely to be approved and the battery can then be installed without grid connection costs. If the fast-track application was rejected, a G99 application would be required instead. In this case, Locogen would recommend disregarding battery storage as the cost of a G99 application is extremely unlikely to be recuperated from a battery that was suitably sized to store energy from a G98-compliant PV array.

[3] https://www.northernpowergrid.com/guide-prices-and-timescales/generation-connection

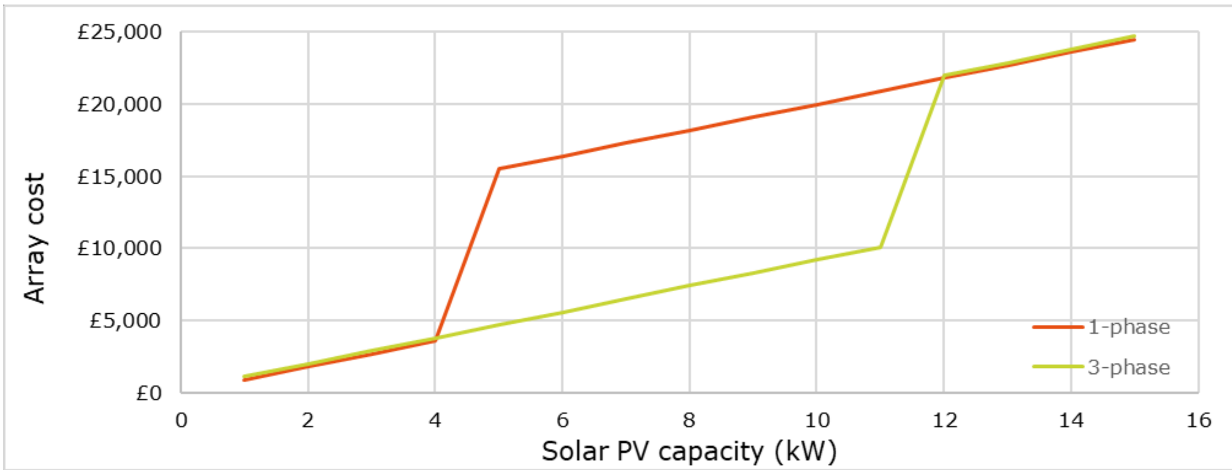

Figure 5: Illustrative impact of grid costs on PV array installation

5. Financial Considerations

Arguably the most important and challenging aspect of the proposed renewable energy solutions is how they are financed, which is directly related to how they are owned. Two key routes are explored below.

Individually owned systems

Under this conventional option, each church would own their PV installations. They would be required to raise cash or seek grants to fund their own their own arrays. It would be possible to apply for grant funding individually or as part of a group, which will allow access to larger funding pots. Acting as a group would also allow for joint procurement exercise which may lead to capital savings of up to 10% per project. This would also reduce the administrative burden for most groups, although a lead would need to be appointed to coordinate funding and/or procurement activities. Potential funding sources for each church are listed in Appendix A.

In owning their PV & battery system, each church would benefit from reduced electricity bills and from the income from selling to surplus electricity to the grid. This would be subject to securing a Smart Export Guarantee (SEG) tariff from a licensed energy supplier. SEG contracts tend to be renewed annually or biannually, and this would be the main administrative task associated with the system. To be eligible to receive the SEG, a PV array must have a Microgeneration Certification Scheme (MCS) or equivalent certificate. A list of local MCS-certified installers is given in Appendix C.

The operational costs of these systems would be minimal. Most buildings insurance policies accommodate solar PV installations at no extra charge, but this is always worth checking. Therefore, the main operation cost will be for cleaning, although this can be done by a window-cleaner on an ad-hoc basis, and arrays on roofs with a pitch of at least 15^{o} to be classed as self-cleaning. Other ad-hoc costs over a system's lifetime include the replacement cost for the inverter and battery, both of which should last for around 10 years.

Alternative options

Instead of and funding their own systems, it may be possible for the churches to partner with a renewable energy co-operative. Co-ops tend to be funded by grants and also by individuals and organisations who buy shares in the co-op for a small, long-term return on their investment. Relevant examples include the Big Solar Co-op and Energy4All which operate across the UK. If and when they have the resources to do so, a co-op would develop, install and own the system and manage its maintenance and export contract. Each church would benefit from reduced electricity bills from solar and heat generation used directly, but would not receive any income from exported solar electricity unless it invested in the co-op.

The upside of this option is that it allows a hands-off approach from the churches, as well as significantly reduced, or indeed zero capital costs. Conversely, systems are not guaranteed to be allowed to include batteries, and the co-op may have limited capacity for new systems which may result in a long-waiting list or competitive application process. At present, the Big Solar Co-op is actively looking for candidate rooftops[4].

A further option is for the churches to form their own co-op. This is not recommended given the extensive administrative requirements before any success is guaranteed, especially not before the above options have been exhausted. Furthermore, the combined capacity of the church PV

[4] https://bigsolar.coop/submit-a-site/

projects is not sufficient to allow for meaningful benefits in terms of buying power or in securing competitive rates for Power Purchase Agreements (PPAs) – which are an alternative to the SEG used by most large-scale renewables projects. However, if this option was of interest, organisations such as Co-operatives UK exist to support communities to create co-ops and offer development grants as well as match funding for community shares raised[5].

5.1.1. Cost elements

Development costs

Locogen would recommend that a structural survey is carried out at an early stage to ensure that a given roof is capable of hosting new or additional PV capacity without reinforcement. Generally, truss roofs are suitable for PV, especially when relatively new. These surveys typically cost £250-500 and should be carried out by a licensed professional. For roofs known or suspected to contain asbestos, a more thorough survey would be required, costing £550-800. Where required, planning applications would cost £234, with fees for addition planning advice as indicated in section 4.2.

Installation costs

Rooftop Solar PV installations can broadly be expected to cost £900-1,200 per kWp installed, depending on the size of the installation, the condition of the roof and access requirements. Ground-mount systems tend to be cheaper at ~ £800 per kWp installed, as they do not require scaffolding or work at heights. These figures are inclusive of invertors and other ancillaries listed in section 3.1.2. For each proposed array, Locogen have provided estimates based on our experience as a commercial installer of solar PV systems.

Batteries are still a very expensive technology and cost in the region of £300-400 per kWh to install, as they have shorter lifetimes than PV, replacement costs will also need to be factored into financial plans. Lastly, the costs of control equipment, namely solar generation divertors need to be considered. These cost in the region of £300-500, depending on how many loads they are connected to.

Air source heat pumps cost in the region of £750 per kW installed, and costs stated within this report allow for the purchase and installation of the ancillary equipment associated with the installation, such as hot water cylinders for air-to-water type air source heat pumps.

A budget cost has been provided for supplementary electric heating where recommended, recognising that this is only recommended for use in the main body of the churches.

Operational costs and income

As established above, the maintenance burden for solar is minimal. If a given array is not found to be self-cleaning, semi-annual maintenance is recommended, costing £50-£100 depending on the size of the array. An annual service is also recommended to ensure that the system is operating as intended, and should cost around £100. Battery and inverters will both need to be replaced at least once over the lifetime of a solar PV array. Given that they both have a 10+ year lifetime, the replacement costs are likely to be lower than their upfront capital costs.

Operational income from a solar PV array depends on the SEG tariff secured and how much of the generation is directly used on site and stored. Generally, it is always better to utilise as much electricity on site as possible. At present, high SEG rates range from 5-5.6p/kWh.

---

[5] https://www.uk.coop/start-new-co-op/support/community-shares/booster-programme

Air source heat pumps also have a small maintenance burden. Specifically, it is recommended that an annual service be carried out by a heating engineer, who should visually inspect all elements and drain the wet system (for air to water heat pumps). This should cost around £250 per heating system.

5.1.2. Private wire systems

A Private Wire system is one through which electricity is transferred from a 'generator' (in this context a solar PV array) to a neighbouring 'offtaker' under different ownership. In the UK, such arrangements can only be established between non-domestic parties. Contractually, the generator is usually required to supply all of its spare electricity to the offtaker, before exporting surplus to the grid. Similarly, the offtaker will be required to offtake all the power available from the generator that it is able to use at a given time. The key benefit of a Private Wire system is that electricity can be traded at a more favourable rate for both parties than if it was imported from or exported to the national grid. Based on current electricity and SEG prices, a reasonable estimate for a private wire rate would be ~12p/kWh, although this would be subject to tax on the generator's side. Private wire systems also have a capital cost, as they require a physical (usually trenched) connection between the two locations. The cost of this changes relative to the current rate for cabling, but tends to be in the region of £150-200/m.

The electricity demand of the offtaker is therefore an important factor (the higher the better), as the capital cost of the connection must be justified by the additional income generated by it though electricity sales. Given the scale of the solar PV systems herein, in our experience, it is highly unlikely that the financial case for a local private wire system would stack-up. The success of a private wire agreement will also hinge on a number of other factors, the scope of which exceed this feasibility study, including:

- The agreed wholesale purchase cost of electricity by the generator;
- The contract value of electricity sold to an offtaker;
- The legal feasibility of installing a wayleave to an offtaker across private land;
- The willingness of the generator to either manage or appoint someone to manage the agreement between themselves and the offtaker; and
- The willingness of an offtaker to enter into a contractual agreement that will be required to be in place for a fixed period which will exceed contracts normally offered by typical electricity suppliers (i.e., a 10 year contract as opposed to a two year contract).

If the client wishes to explore this opportunity further, we recommend consulting a legal entity who specialises in private wire arrangements to discuss their options in more detail.

5.1.3. Project financial models

For each church, an annual energy flow model has been utilised in order to determine the impact financial and carbon impacts of the proposed solar PV, battery systems (where these would be beneficial and represent a positive financial return) and renewable heating systems. A 'typical' weather year's half-hourly energy yields from solar PV systems have been incorporated into the model from the PVSyst simulations. The electricity demands, renewable generation and electricity exports and imports represent the energy flows in each model.

The energy flow models consider a 20-year horizon, accounting for PV and battery performance degradation over this period and for replacement costs of inverters and batteries after 10 years, due to their shorter guaranteed lifetimes.

The financial model illustrates the impact of the PV, battery systems and renewable heat generation through net annual benefits; payback periods; Net Present Value (NPV); and Internal Rates of Return (IRR). Carbon impacts are also demonstrated, in terms of annual emissions savings (for the first year of operation – assumed to be 2022) and cumulative emissions savings after 20 years, based on the predicted rate of decarbonisation of the UK electricity grid.

The outputs of the financial model are presented for each church in Section 6.

6.4. St. Mary's Church, Carleton

6.4.1. Proposed solution

Solar PV

The extent of the proposed PV array for St Mary's, Carleton is shown in the figure below.

As established during the site visit, one of two ground mounted options is preferred over a roof-mounted PV system at this location. The proposed location is shown in the figure below, for an array size of 11.9kWp, consisting of two rows of 18x 330Wp modules, and is anticipated to produce 12830 kWh of solar energy annually if orientated along the length of the church wall at a pitch of 30°. The 3D energy yield modelling completed indicated that compared to an equivalent array sited outside of the church grounds to the north of the boundary wall, this location would encounter significantly lower shading losses. Siting the array here will also avoid legal arrangements and long-term land rental contracts with the neighbouring landowner.

The client has noted interest in utilising solar PV from the local school, via a private wire connection. However, private wire connections are not recommended for reasons explained in section 5.1.2. Additionally, the cost of connecting the two buildings via a physical wire would be in the region of £9,000-£12,000, which is equivalent (if not more than) the cost of a dedicated ground mounted array within the grounds of the church. Unlike a dedicated array however, the church would only benefit from surplus generation not utilised by the school, making financial paybacks significantly slower and much less predictable.

To ensure that as much PV is utilised by the building as possible, the option of a 5-15kWh battery has been considered, but is not recommended.

Figure 15: St Mary's, Carleton PV proposal

Heat

As the church has an existing traditional wet heating system, an air-to-water type air source heat pump would represent the best low-carbon heating option; as the existing distribution system can likely be reused, although further radiators may need to be installed depending on the specification of the heat pump. It is recommended that the heat pump be installed in the location of the current oil boiler. As well as providing heat during occupied hours, this solution will also be able to provide background heating to facilitate building fabric protection over the winter.

As the building currently has a single-phase electricity supply, it is likely that installing a heat pump will require additional electricity supply from the national grid. The cost of implementing this has been estimated from Northern Powergrid's online estimator tool. The new connection is noted to be very expensive as the local network appears to be heavily constrained.

Costs

The anticipated development, installation and operational costs for the system as described above for St Mary's, Carleton are presented in the table below. Note that development costs have been excluded for subsequent financial modelling as it is assumed that these can be covered by Stage 2 RCEF funding.

Item	Cost
New grid connection	£27,000
Planning permission	£234
11.9 kWp Solar PV installation & ancillaries	£9,500
75 kW_{th} ASHP installation & ancillaries	£54,750
Supplementary electric heating (budget cost)	£3,000
Annual maintenance budget (ASHP)	£250
Annual maintenance budget (PV)	£100
Invertor replacement after ~10 years	£1,500

Table 16: St Mary's, Carleton - anticipated project costs

6.4.2. Energy flow and financial model results

In the following figure, the monthly energy flows for the church are demonstrated, based on the results of the energy flow modelling for the optimum scale of solar PV. Without a battery, 31% of the church's annual electricity demand is met, and 55% of PV generation is exported. With a battery, 34% of demand is met and 51% of generation is exported. Therefore, a battery would increase the portion of demand met from PV electricity by 3%. Owning to this near-negligible increase (and based on our previous experience), we advise against battery storage at St Mary's, Carleton as the financial and carbon impacts would not justify its costs. This is demonstrated in the second anticipated project returns table below, based on a 5kWh battery costing £2,000 to install.

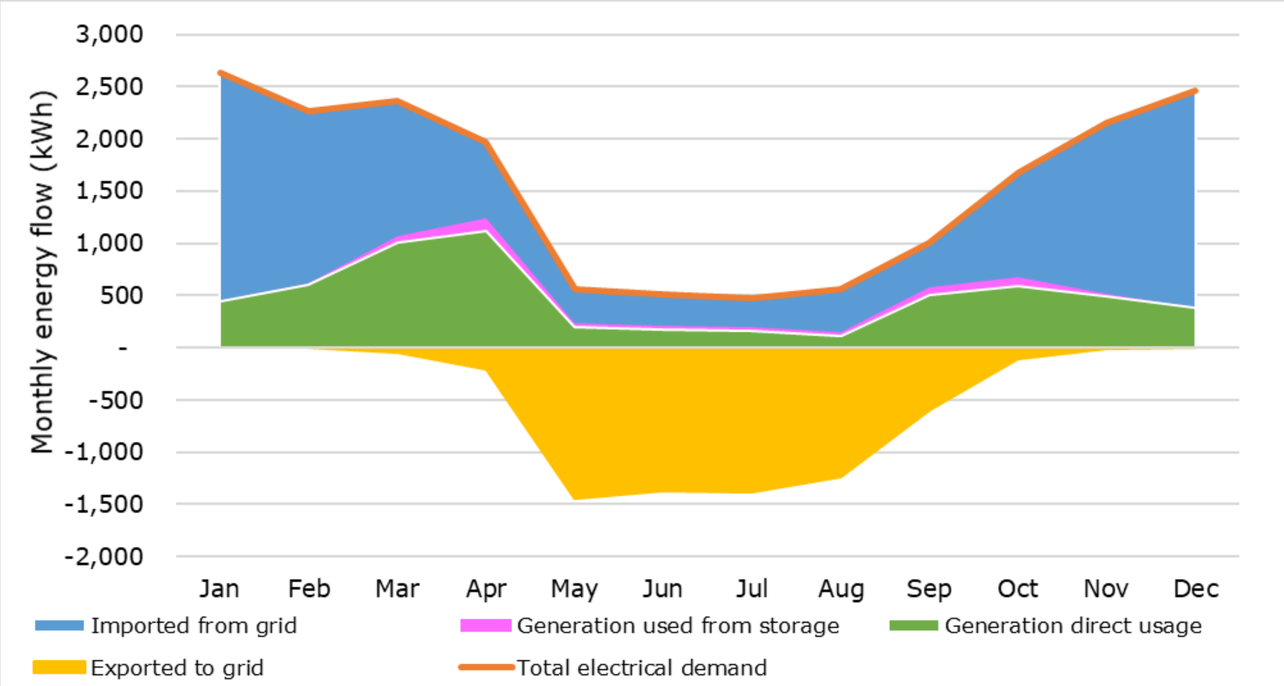

Figure 9: St Mary's, Carleton monthly energy flows – with ASHP, PV, battery

The table below demonstrates the anticipated financial returns of the proposed system for two funding scenarios and for cases with only the ASHP, with additional PV and with a battery. If the project was fully grant funded, only the net annual benefit would be relevant. If the project was financed by a co-op, only the net annual savings would be relevant.

Indicator	**No grant**	**50% grant funding**	**No grant**	**50% grant funding**
Variant	ASHP only		PV only	
Whole system capex	£54,750	£27,375	£9,500	£4,750
Heat savings	£1,017		£0	
Elec savings	£0		£206	
Export income	£0		£574	
Net annual benefit	£1,017		£681	
Y20 NPV	-£37,694	-£10,663	-£324	£4,626
Y20 IRR	-7%	-1%	3%	13%
Payback years	n/a	24.0	15.5	6.9
Cost of carbon avoided	£212 / T	£106 / T	£528 / T	£264 / T
Carbon emitted Y1	2.0 Tonnes		12.4 Tonnes	
Carbon emitted Y20	26.8 Tonnes		266.6 Tonnes	
Carbon offset Y1	11.8 Tonnes		1.3 Tonnes	
Carbon offset Y20	257.7 Tonnes		17.9 Tonnes	
2030 emissions	1.5 Tonnes		12.6 Tonnes	

Table 17: St Mary's, Carleton anticipated project returns – ASHP / PV only

Indicator	No grant	50% grant funding	No grant	50% grant funding
Variant	HP with PV		HP with PV, battery	
Whole system capex	£64,250	£32,125	£66,250	£33,125
Heat savings	£1,017		£1,017	
Elec savings	£886		£969	
Export income	£353		£321	
Net annual benefit	£2,156		£2,207	
Y20 NPV	-£31,170	£1,074	-£33,269	-£26
Y20 IRR	-3%	4%	-3%	3%
Payback years	27.1	14.7	27.8	15.3
Cost of carbon avoided	£233 / T	£116 / T	£240 / T	£120 / T
Carbon emitted Y1	0.6 Tonnes		0.6 Tonnes	
Carbon emitted Y20	8.9 Tonnes		8.1 Tonnes	
Carbon offset Y1	13.2 Tonnes		13.2 Tonnes	
Carbon offset Y20	276 Tonnes		276 Tonnes	
2030 emissions	0.5 Tonnes		0.5 Tonnes	

Table 18: St Mary's, Carleton anticipated project returns – ASHP, PV, battery

The tables above illustrate that a new ASHP would deliver vast carbon benefits compared to the existing oil system, and would even provide a payback with partial (50%) grant funding. This is due the high cost of oil, which justifies the high cost of the heat pump.

The solar PV system provides further, although comparably modest, carbon savings and would deliver a considerable annual benefit to the church by offsetting the electricity costs. This would improve the financial returns of the combined energy system significantly, allowing a financial payback to be achieved even without grant funding.

7. EV Chargepoint opportunities

7.1. Technology overview

Following Locogen's recommendation made in the Phase 1 report, several of the churches involved within the study are considering futureproofing their car parks by installing EV chargers. This is particularly important as the UK government has recently consulted on making these mandatory for new buildings in England. There are a number of companies within the UK specialising in EV charging installations, who could install and maintain the EV chargers with the appropriate metering capability. The churches would then be able to decide how to charge for electricity consumed and whether to make the chargers available to the public.

7.2. Equipment

EV chargers can be wall-mounted or standalone, with the latter being commonly used in the car parks. In order to cater for all types of plug-in electric cars, the chargers should have a universal socket – that is, one that is compatible with cars that need 'type 1' and 'type 2' plugs. This would require that users provided their own charging cable, which is considered reasonable given that these come as standard with EVs. A Pod Point stand-alone charger is shown in Figure 11 as an example of a suitable universal model.

Figure 11: Example stand-alone EV charger[6]

In terms of power output, there are three types of EV chargers:

- Slow (3-7kW) – able to charge a typical EV in 8-10 hours

[6] https://pod-point.com/business/case-studies/chester-zoo

- Fast (22kW) – able to charge a typical EV in 2-4 hours
- Rapid (50kW) – able to charge a typical EV in 30 minutes

For the churches, the slow chargers are the preferred option since the main users would be the members of the local community who could charge while they attend services or events at the space, as a 'top-up' to their charge points at home/work. Also, this option avoids the potentially high cost of additional grid electricity supply capacity required for fast or rapid charging (accommodating even 3-4 new fast chargers can often require a new substation, costing in the region of £50,000).

Depending on the layout of the car park, it could also be possible to mount the EV chargers to the external wall of the church. This would be desirable since they are smaller, cheaper and would have a lower visual impact, and because they do not require underground electrical wiring from the building. If this is not possible, Locogen would propose that the location of any EV chargers is as close to the building as possible, to reduce the cost of cabling and electrical losses.

7.3. Associated risks

It is considered that electric vehicle charge points carry risks around maintenance response times, available grid capacity and return on investment. Many EVCP manufacturers use internet-enabled chargepoints, either via Wi-Fi or 3G, which means that their in-house maintenance teams can troubleshoot any problems remotely. The churches will still have to make sure that the meters are working correctly and will have to contact local OLEV accredited electricians for any ad-hoc repairs that cannot be fixed remotely.

The available grid capacity can be another risk for the scheme, especially if a church decides to install faster EV chargers. In this case, it is possible to install a system that distributes the available power across each chargepoint, ensuring that the electricity capacity is never exceeded. This system enables up to three times more chargepoints to be installed using the same power availability, avoiding the need for costly grid upgrades. The chargepoints must be used sufficiently to deliver the expected return on investment. This is not considered a major risk, since the demand for electric vehicles and EV chargers is expanding rapidly over the last few years and, in 2020, the sale of electric vehicles across the UK has doubled from the year before. Furthermore, the UK Government plans to phase-out of new combustion engine vehicles by 2035.

7.4. Project costs

7.4.1. Development costs

In terms of planning requirements, the EV chargepoints are a permitted development under English Law. Therefore, they would not ordinarily require planning permission and so would not require equivalent permission from the Local Planning Authority. However, they are not permitted within the curtilage of listed buildings, therefore planning permission would be required prior to installation.

Installation of chargers should be a relatively simple and low-risk process. The chargers must be installed from the relevant church's electricity supply and should be installed by an electrician registered with OLEV, the UK Government's Office for Low Emission Vehicles. Locogen have noted that there are accredited installers operating across the UK. That said, not all of these installers will be able to lay cabling in the ground if this is required for a standalone (versus a wall-mounted) charger, so this option would add cost and complexity to the installation.

7.4.2. Capital costs

Whilst the cost of slow domestic chargers can vary depending on the model, manufacturer and installer and capabilities, an upper estimate for supply and installation would be in the range of £1,000 to £1,500 each. Fast chargers are likely to cost up to £500 more to install, plus the additional grid connection cost, which would be determined by the DNO. Currently, OLEV is offering grants of £350 per charger for up to 40 chargers to any business, charity or public authority.

7.4.3. Operation and Maintenance costs

The EV chargers tend to come with a warranty of 2-3 years. Given that they are simply an outlet for electricity with no moving parts, they should remain reliable throughout their lifetime and any performance issues will be self-revealing. However, given they are relatively new technology, expected operational lifetime is an unknown, although the UK government currently work with an estimate of 15-30 years[7]. The maintenance burden is not fully established, especially over the longer term, but annual inspections and ad-hoc repairs could be performed by local OLEV accredited electricians. For these reasons Locogen suggests that £100/year would be an appropriate value for maintenance costs for the chargepoints. Smart chargers are those which can be connected to a centralised management system, which tracks utilisation and allows various charging prices to be set. Rolec, whose chargers connect to the VendElectric platform, have advised that management and sim card fees are charged every three years, and cost £135 and £65 respectively, per socket.

7.5. Financial projections

The financial benefit of an EV charger is very dependent on how often it is used and the selling price of electricity, which would be set by the churches involved. The price could be changed as desired, whilst ensuring that the cost of charging remained competitive with any other local options. Using ZapMap, Locogen have identified that prices within the area vary from 15p-35p/kWh, although some subscription models are available that allow for free charging. As such, we have considered four charging prices from 20-30p/kW in our financial modelling. The O&M costs above have been applied, as has a £2,000 cost to supply and install a twin-socket, wall-mounted smart charger, along with a £350/socket OLEV grant. The key financial outcomes of the project are provided in Table 23 below, wherein the impacts of the four electricity selling prices are contrasted. It is very difficult to predict future utilisation of the chargers but Locogen has based calculations on the assumption that they will be used for 10 hours daily (between 9am and 7pm) with 10% utilisation in the first year, scaling up year on year to 60% utilisation by year 20. This is deemed to be a very conservative estimate.

Number of EV chargers	**2x slow chargers (7.2kW)**			
Capital cost with grant	£1,300			
Operation & Maintenance	£233			
Electricity price	15p/kWh			
Sale price of electricity	**20p/kWh**	**22.5p/kWh**	**25p/kWh**	**30p/kWh**
Net benefit Y1	£35	£166	£298	£560
Net benefit Y5	£339	£620	£901	£1,462
Y5 NPV	-£470	£415	£1,299	£3,068
Y5 IRR	-8.3%	12.4%	28.8%	56.4%
Payback years	5.9	3.9	2.9	1.9

Table 23: Financial model outcomes for two EV chargers

[7] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/818810/electric-vehicle-charging-in-residential-and-non-residential-buildings.pdf

Whilst there are several assumptions underpinning the values in Table 23, it demonstrates that it is likely that the chargers will represent a net income stream in the long term, and will likely pay back within 5 years if the charging price is set above 20p/kWh. Returns are also shown to improve as the selling price is raised, and would of course do so if utilisation was higher than assumed – for example, if the chargepoints were utilised overnight which may be possible given the central location of these churches within the villages they serve.

As inferred above, the selling price set also carries the potential to affect utilisation, as potential users may look for the most cost-effective charging opportunities locally. We recommend that the churches periodically investigate emerging local options, for example by consulting ZapMap or similar websites. Further down the line, as more homes are fitted with EV chargers, the churches may wish to lower the cost of charging over time to compete with domestic electricity prices.

In Table 23, it is assumed that no solar PV generation from the church's rooftop array is diverted towards the chargepoints. This could be implemented via a PV controller unit, in order to improve the returns further. In the table below, the impact of solar PV contribution to EV charging demand on the payback time is presented for the 4 charging prices considered.

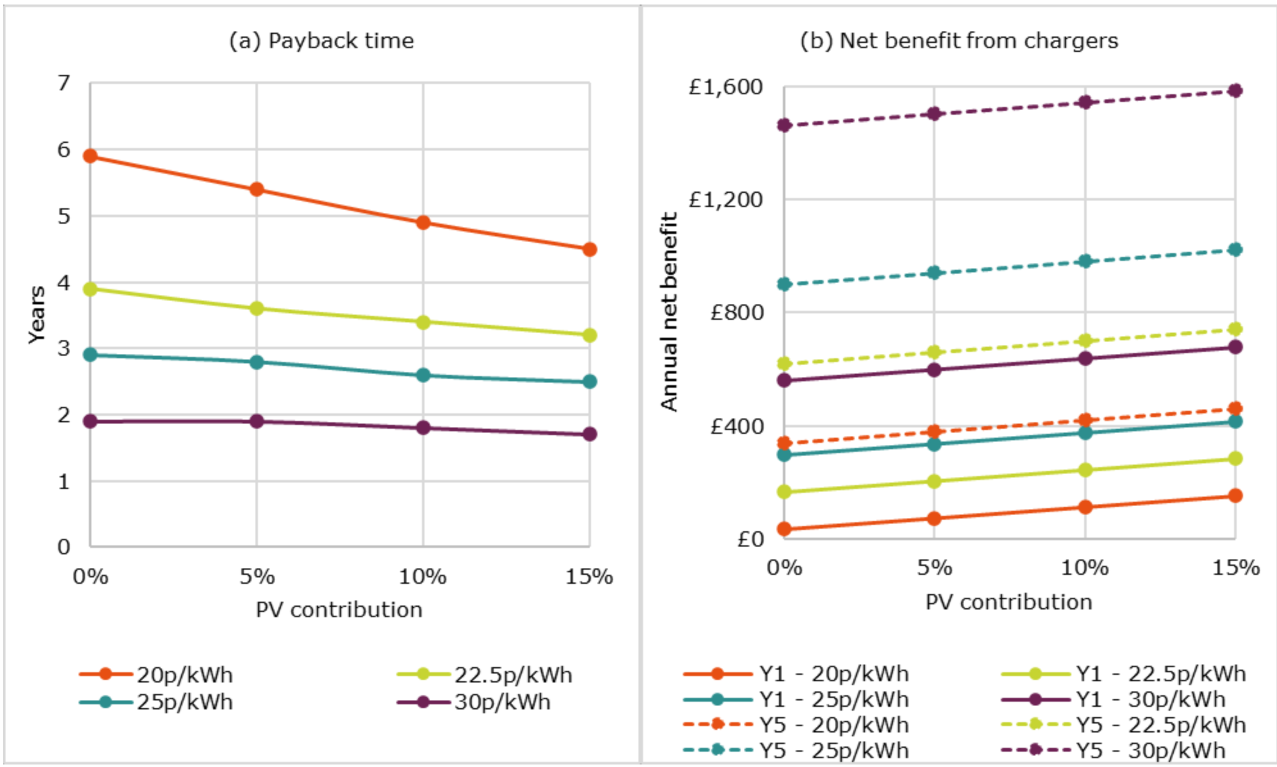

Figure 12: Impact of solar PV contribution on EV charger financials

The figure shows that at lower charging prices, PV generation has a more considerable impact on the chargers' payback time. Similarly, the more charging demand met from PV, the higher the net benefit (i.e., income after O&M costs). Therefore, we suggest that if an EVCP is installed alongside solar PV, a solar diverter unit is also installed, which will allow the rate of PV generation diverted to the EV chargers to be monitored and controlled. This will provide an indication of how 'renewable' the charging supply is and what charging price to set.

7.6. Summary and further considerations

The key benefit of installing chargepoints is that they will make the impending transition to EVs simpler and more convenient for the church users and community visitors. In line with this, the use of the chargepoints will also contribute to the reduction of carbon emissions associated with transport, especially if the electricity is produced from renewable energy.

It is envisaged that the EV chargers will provide a net income which will mean that they will pay for themselves over time and later on provide a small source of income to the church at which they are installed. The chargers will be operated by the individual churches with maintenance support provided by the charge point manufacturers, installers and local OLEV certified electricians.

To achieve the expected returns, the churches will have to make sure that the price of electricity is competitive with other local EV chargers. There is also a small risk in maintenance requirements given that this is a fairly new technology, so each church should set aside a small sum each year to account for any unexpected repairs/replacement parts that may be required.

7.7. Considerations specific to St Mary's, Embsay

St Mary's, Embsay have identified an EV chargepoint installation within their car park as a desired development. In order to confirm if the church's single-phase supply is sufficient to accommodate a chargepoint, an electrical survey would be required to determine the current supply's maximum import capacity and maximum demand. It is anticipated that the additional grid capacity required at the site for a heat pump would be sufficient to accommodate a single fast chargepoint or two slow chargepoints. However, if the heat pump was not installed, it is unlikely that more than a single slow charger could be accommodated without upgrading the supply.

Compared to preferred wall-mounted systems, this site would incur significant costs associated with routing a cable from the church building to the car park. This is a c. 25m distance, and would require the cable to be trenched under Kirk Lane. Routing a cable this distance is anticipated to cost in the region of £3,000-£5,000 (dependent on cable-costs which are highly variable). A road closure permit would also need to be acquired from Craven District Council for this installation. This additional cost associated with routing the cable to the car park would likely need to be recovered by selling electricity to chargepoint users at a premium rate, which would likely limit its popularity. Therefore, it is essential that the cabling costs of the installation are grant-funded, to ensure that a competitive/attractive EV chargepoint can be provided to the community.

7.8. Considerations specific to St Mary's, Carleton

St Mary's, Carleton have identified an EV chargepoint installation by the front wall of the church grounds by the entrance arch as a desired development. As this is outside of the land boundary of the church, they would likely require legal agreement with the landowner, who may wish the church to share any income generated from the installation. This is a key barrier to this development and should be investigated as a priority.

As with St Mary's, Embsay above, in order to confirm if the church's single-phase supply is sufficient to accommodate a chargepoint, an electrical survey would be required to determine the current supply's maximum import capacity and maximum demand. Again, it is anticipated that the additional grid capacity required at the site for a heat pump would be sufficient to accommodate a single fast chargepoint or two slow chargepoints. However, if the heat pump was not installed, it is unlikely that more than a single slow charger could be accommodated without upgrading the supply.

This site would also incur significant costs associated with routing a cable from the church building to the chargepoint location. This is a c. 20m distance, and routing a cable this distance is anticipated to cost in the region of £2,500-£4,000 (again, dependent on cable-costs). This additional cost associated with routing the cable to the car park would likely need to be recovered by selling electricity to chargepoint users at a premium rate, which would likely limit its popularity. Therefore, it is essential that the cabling costs of the installation are grant-funded, to ensure that a competitive/attractive EV chargepoint can be provided to the community.

8. Community benefits and engagement

8.1. Benefits

There are numerous benefits to developing community renewables projects. Inherently, developing a renewable energy project at any scale should make a positive contribution to carbon reduction targets and ultimately the battle against climate change. Generating and using electricity at a local level is one of the key decarbonisation solutions identified by the UK Government. This ultimately minimises transmission losses and strain on the national electricity grid.

Beyond the positive impact on the environment, such projects empower communities. Renewable developments bring opportunity for education, resilience and economic income. By generating a sustainable income (or offsetting current electricity costs) funds can be used to further benefit the community on other projects. The installations can be exhibited to school and youth groups to aid education, or to raise awareness generally in the community and influencing the residents to be environmentally responsible. Furthermore, involvement in renewable projects strengthens the community's connections, making further projects easier as technology and markets advance, and further projects are sought. In addition, the projects will serve as exemplar renewable energy installations in their communities, and will allow local residents and small businesses to see how to procure and operate PV and battery storage systems. Similarly, and particularly if several projects are pursued, the local supply chain will be strengthened through the provision of short term contracts for installers and other contractors such as scaffolders and surveyors.

8.2. Engagement

Each of the five churches in the TCNCC project has informed and has the support of their congregation regarding this study. The project also has support from the Leeds Diocese of the Church of England.

The progress of the TCNCC project is being shared with the wider community has been shared in local news outlets[8] and on a dedicated section of the website of St Mary's, Embsay[9]. In addition, Locogen will assist the client in disseminating the findings of this RCEF study to the local community via an online seminar, to be held in early 2022.

[8] https://theembsayeastbypost.com/towards-carbon-neutral-churches-in-craven/

[9]https://www.stmaryembsay.org.uk/churches-in-craven-carbon-neutral/

9. Operation and Governance

9.1. Governance

Assuming the installations are self-owned (rather than owned by a co-op), each church will have to appoint a person or team to raise finance and manage the delivery of the project. Given the similarity and proximity of the proposed projects, there is scope to develop a consortium to manage joint funding applications and/or joint procurement exercises.

The main tasks in terms of delivery will be to appoint a structural surveyor, apply for planning permission (if necessary) and appoint a contractor to carry out the installation and manage its grid connection. Locogen recommend that three quotes are collected, and that a tender document is generated for each system to ensure that quotes can be compared on a like-for-like basis and that contractors meet the necessary safety and design standards.

9.2. Operation

Once commissioned, the PV and battery systems will be able to operate without interference. Therefore, the main burden is associated with the administration of SEG contracts to ensure that the project generates income from its surplus generation. This is a very similar process to managing electricity import contracts, therefore no specialist experience or training will be required.

Outwith the service requirements for any system, allowances should be made for component failure and replacement parts. Typically, it is recommended that a contingency fund be put aside to cover replacement parts over time. For solar PV and battery systems, an annual allowance of between 2-5% of the capital costs of the project would be a reasonable contingency fund.

Electrical connections – All non-domestic buildings with an electrical connection should have an Electrical Installation Condition Report (EICR) undertaken at least every 5 years (although this period can be less if deemed necessary). This would include all wiring up to any renewable installations. This could cost £100-300 per building.

Photovoltaic systems – There is no requirement to service a PV array to any extent further than the electrical testing regulations. However, it is recommended that the system be visually inspected each year, any filters on the inverters be cleaned, and the modules checked for dust or leaf build-up. In areas with dust, nesting birds or other contaminants the modules may require regular cleaning, but this can be gauged during the initial operational period. This can typically be done by a window cleaning service from the ground unless the array is too high/awkward to be accessed.

Battery storage – Batteries have no moving parts and do not have any servicing requirements. Faults are unlikely and will generally be communicated to the PV-battery control system.

Air source heat pumps - It is recommended that an annual service be carried out by a heating engineer, who should visually inspect all elements and drain the wet system (for air to water heat pumps). This should cost around £250 per heating system. All external units should be checked regularly to ensure that they are free from debris, such as crisp packets or leaves, but this is not required to be undertaken by a technician or engineer

10. Scheduling

An implementation pathway for a small (G98-compliant) solar PV and battery installation is presented in Figure 13 below. If the preferred option was to engage with an existing solar co-op, the only necessary step would be to approach the co-op. If the co-op had the resource to take on the project and deemed the site to be suitable, then they would handle the rest of the process.

Site Survey
- Commission a structural survey to confirm the size of array that the roof's structure can accomodate.
- This step should take 1 week to 1 month, depending on the availability of local surveyors.

↓

Pre-planning
- If planning permission is required, seek advice from the local authority. Depending on their feedback, the capacity of the array may need to reduced and other elements of the design may need to be adjusted.
- This step should take 1 week to 1 month

↓

Fundraising
- Submit application(s) to for funding single or group of installations, using estimated costs from feasibility study along with contingency or else, if available, seek indicative prices from local installers.
- Depending on the funding calls open at the time and their deadlines for applications and decisions, this step could take 1-6 months.

↓

Planning application
- If planning permission is required, submit a planning application to the local authority.
- This step may take up to 3 months, although the local authority may reach a decision earlier if there are no consultees or objections.

↓

Tendering
- Prepare a tender document and issue this to at least 3 contractors.
- Once tenders are recieved, appoint the preferred bidder.

↓

Installation
- The contractor will install the solar PV and battery along with controls and will then commission the system.
- They should also arrange the 'connect and notify' grid connection and provide a certificate of accredition.
- The installation itself should take less than one week.

↓

Operation
- Once the system has been commissioned, the church committee should register for a SEG tariff.
- Visual inspections should be undertaken periodically and cleaning should be arranged as needed.

Figure 13: Implementation pathway for self-owned solar PV & battery system

An implementation pathway for an air source heat pump system is presented in Figure 14 below.

Site Survey
- Commission a heating survey to finalise the size of heat pump that will be required.
- This step should take 1 week to 1 month, depending on the availability of local surveyors.

↓

Pre-planning
- As planning permission is required, seek advice from the local authority. Depending on their feedback, the position of the external heat pump may be required to be adjusted, or screening included in the proposal.
- This step should approximately 1 month.

↓

Fundraising
- Submit application(s) to for funding single or group of installations, using estimated costs from feasibility study along with contingency or else, if available, seek indicative prices from local installers.
- Depending on the funding calls open at the time and their deadlines for applications and decisions, this step could take 1-6 months.

↓

Planning application
- Sumbit a planning application to the local authority.
- This step may take up to 3 months, although the local authority may reach a decision earlier if there are no consultees or objections.

↓

Tendering
- Prepare a tender document and issue this to at least 3 contractors.
- Once tenders are recieved, appoint the preferred bidder.

↓

Installation
- The contractor will install the heat pump and emitters along with controls and will then commission the system.
- They should also arrange the 'connect and notify' grid connection and provide a certificate of accredition.
- The installation itself should take approximately two weeks, depending on the scale of the internal changes.

↓

Operation
- Visual inspections should be undertaken periodically and electrical testing should be completed annually.

Figure 14: Implementation pathway for self-owned ASHP system

11. Conclusions

In this Stage 1 RCEF study, Locogen has considered the feasibility of installing solar PV, battery systems and low carbon heating for 5 churches across Craven, with the goal of decarbonising each building's energy demand in order to progress towards the churches goal of reaching carbon neutrality by 2030. Renewable heating systems (specifically Air Source Heat Pumps) have been recommended as the baseline technology for each churches energy system as reaching carbon neutrality will not be possible without converting away from fossil fuel heating systems. All of the churches would also benefit from a solar PV array, although in each case, the cost of battery storage cannot be justified by is marginal impact on the operating costs and emissions of the churches. Where car parking is available, electric car charging points are also recommended for church users and the wider community – although these will not directly contribute to the churches' carbon neutrality goals.

In order to assess each site in detail, planning and grid restrictions were first examined. Due to the high costs associated with G99 grid applications, each church is recommended to install a G98-compliant system solar PV system, meaning that generation and storage capacity must each be limited to 3.68kW per phase. Due to the setting of all churches within conservation areas, and owing to their listed building status, planning permission will be required for all solar PV installations but St Augustine's, Draughton, and will be required for all heat pump installations. As such, each church is recommended to engage with the local planning authority (Craven District Council) at an early stage mitigate the risk of an unsuccessful planning application.

The above constraints informed the outline design of each proposed solar array, which was then modelled in PVSyst software in order to assess the anticipated annual generation, and compared to alternative options at the site. Heat pumps were sized using details pertaining to the existing heating system and verified using thermal modelling before half-hourly demand profiles were generated based on assumed usage profiles. This information was fed into an energy flow model, along with the current electricity demands and occupancy patterns of each church, in order to determine the likely financial impacts of each new system. The financial returns were presented for cases with no and partial grant funding and can be interpreted for cases with full grant funding.

The energy flow modelling also highlighted the environmental benefits of the proposed systems through reducing the carbon emissions of each building, and by contributing to the decarbonisation the national grid. Furthermore, the reduction in overheads for each church has the potential to benefit every member of the community that uses it, and the installations themselves will act as exemplar renewables projects for each local community and for further churches in Craven and the Leeds Diocese.

Provided that planning permission can be obtained, and sufficient capital funding can be raised, all the churches have a very high chance of successfully implementing renewable energy systems. If raising capital proves to be a difficult or undesirable process, an alternative option would be to partner with a solar, or energy co-op, who would design, procure, and manage a system. The churches would benefit from reduced electricity costs, and other financial benefits (from export sales) would be proportional to the degree of investment by the church into the co-op.

Stage 2 RCEF funding

In order to further develop and de-risk the proposed renewable energy measures, the TCNCC group are encouraged to apply for Stage 2 RCEF funding. This report may be used as evidence for a joint application for this funding, which could be procured to support development works to take projects further towards implementation. These can include the following activities:

- **conducting structural surveys:** to confirm the churches' roofs are able to accommodate the weight of the solar PV arrays proposed;

- **conducting electrical surveys:** to confirm the maximum import capacity of the churches' electricity supplies and whether any proposed new loads (i.e., heat pumps/ EVCPs) will require additional capacity / new connections;
- **surveying existing heat distribution systems:** to confirm requirements for and costs associated with the replacement/upgrade requirements for distribution components (i.e., pipework/radiators) and controls;
- **energy efficiency audits:** to identify which energy-saving measures can be installed/ carried out in order to reduce the heat demand of each church and avoid drafts;
- **obtaining planning permission:** to apply for planning and listed building consent for any relevant additions/alterations;
- **securing grid connections:** to apply for, and gain cost-certainty over grid connections for any new loads found to require additional import capacity;
- **business case development:** to produce a business case document that can be used for grant funding/loan applications, etc;
- **financial planning:** to create a plan for raising the funds required to implement the projects; and
- **procurement planning:** to create a plan for identifying and selecting contractors to design, install and commission the proposed energy systems.

Further information on Stage 2 funding can be found here: https://www.energyhub.org.uk/wp-content/uploads/2021/03/5.-Stage-2-RCEF-Guidance-Notes-FINAL-V0.4.pdf

Appendix A. Grant funding and loans

Government incentives

Currently, the UK government is incentivising the uptake of small-scale renewable energy installations through the Sustainable Export Guarantee (SEG). The SEG provides an income proportional to the volume of renewable energy exported. The SEG is administered by energy companies, who are able to set their own tariff rates. A list of SEG suppliers can be found on Ofgem's website. At present there is no government incentive for renewable heat installations, apart from the Clean Heat Grant, which is expected to offer up to £4,000 for renewable heating for small non-domestic buildings from March 2022.

Grant sources

Regardless of these incentives, capital funding is key to realising renewables projects, especially for community groups who tend not to have large cash reserves. Locogen has identified the following funding pots which the client may be eligible to apply to. This a non-exhaustive list, and further lists are available on the Community Energy England, Centre for Sustainable Energy and other websites.

- **The National Lottery Awards for All:** £300 to £10,000 for community projects including refurbishments and equipment: https://www.tnlcommunityfund.org.uk/funding/programmes/national-lottery-awards-for-all-england
- **Reaching Communities England:** £10,000+ for community projects including refurbishments and equipment: https://www.tnlcommunityfund.org.uk/funding/programmes/reaching-communities-england
- **People and communities:** £10,001 to £500,000 for community projects including systems and equipment: https://www.tnlcommunityfund.org.uk/funding/programmes/people-and-communities
- **Tesco Bags of Help**: small grants for community projects including environmental improvements: https://tescobagsofhelp.org.uk/home/community-apply-bags-help-grant/
- **Energy Redress Scheme**: large grants for charities conducting emissions reductions projects: https://energyredress.org.uk/apply-funding
- **Aviva Community Fund**: Up to £50,000 for community resilience projects:https://www.avivacommunityfund.co.uk/uploads/terms/aviva-community-fund-eligibility.pdf
- **Churches and Community Fund:** grants to community projects run by parish churches, deaneries, dioceses and other bodies connected to or working in partnership with the Church of England: www.churchandcommunityfund.org.uk
- **National Churches Trust:** several grants for churches, chapels and meeting houses throughout the UK: www.nationalchurchestrust.org

Many grant pots do not fund projects for religious groups or activities. However, an extensive list of sustainability grants for UK churches can be found here: https://www.parishresources.org.uk/wp-content/uploads/Charitable-Grants-for-Churches-Jul-2020.pdf

Although grant funding is likely to be the preferred option for financing renewable installations, there are several opportunities to take out loans, such as the following:

- **Rural Community Buildings Loan Fund:** Loans of up to £20,000 for energy efficiency in community buildings: https://acre.org.uk/our-work/rural-community-buildings-loan-fund.php
- **Social and Sustainable Fund:** Loans of £250,000+ for community projects including those addressing fuel poverty and energy efficiency: https://www.socialandsustainable.com/community-investment-fund/

Appendix B. Financial and carbon model assumptions

Financial assumptions

Other than costs stated, the following standard assumptions are consistently used in the financial modelling for each project.

Variable	Value	Notes
Solar yield degradation	0.4%	Per annum
Battery efficiency	92%	Per charge/discharge
SEG rate	5 p/kWh	
RPI	1.00%	Applies to electric/gas/oil prices, SEG, OPEX
Discount rate	3.5%	
Year 1 grid carbon	0.113 kg/kWh	BEIS figures
Year 20 grid carbon	0.027 kg/kWh	BEIS figures

Table 24: Financial assumptions

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 25: 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.

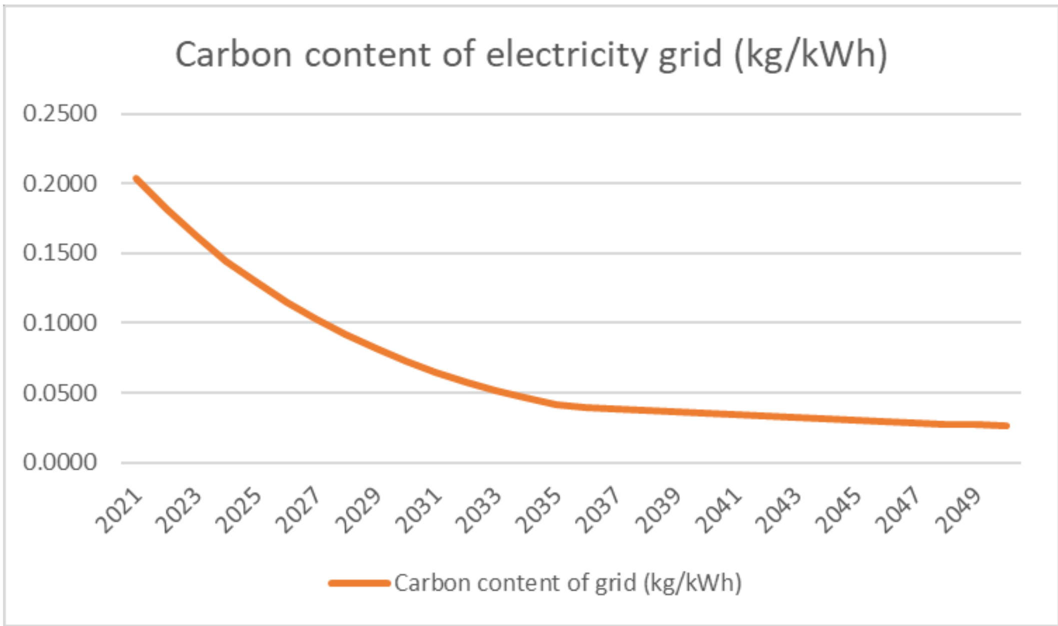

Figure 15: Carbon degression profile

Appendix C. MCS-Certified installers

The list below has been compiled from the Microgeneration Certification Scheme's 'Find a Contractor' search. The following installers are certified to install renewable energy technologies and are based near to the churches included within this project.

Installer	Technology	Location	Contact
J D Mounsey Ltd	Solar PV	Settle	electrics@jdmounsey.co.uk
K Horne Projects Ltd	ASHPs	Skipton	skiptonstovesandranges@btconnect.com
Ashburn Stoves Ltd	Solar PV ASHPs	Earby	hello@ashburnstoves.co.uk
Phuse Energy Ltd	Solar PV ASHPs	Hawes	info@phuse.co.uk
Howsons Limited	Solar PV ASHPs	Carnforth	info@howsonsecurity.co.uk
JB M&E Ltd	Solar PV	Keighley	john@jbmande.co.uk
D Barlow & Sons Ltd	ASHPs	Clitheroe	info@dbarlowandsons.co.uk
Robinson & Lawlor Ltd	Solar PV	Nelson	Pete@robinsonandlawlor.co.uk
R J Solar Ltd	Solar PV	Carnforth	info@rjsolar.co.uk

Table 26: Local Certified installers

Appendix D. Risk Register

ID	Phase	Section	**Risk** (Description of the risk)	Severity	Likelihood	Risk level	**Required mitigation** (How to reduce the risk)	Severity	Likelihood	New Risk	Risk owner
R1	Design and procurement	Financial	Project does not secure grant funding	4	2	8	Prior to any applications, engage actively with funders and to confirm eligibility and address their concerns about the project	4	1	4	Church
R2	Design and procurement	Financial	Project does not have budget available for match funding	4	3	12	Seek several alternative means of fund raising, such as crowd funding or opportunities to invest in the projects	4	2	8	Church
R3	Consenting	Planning	Planning application rejected	5	2	10	Engage with local authority at an early stage and follow advise from application feedback.	5	1	10	Church
R4	Consenting	Grid	G99 grid application too expensive / or fast-track battery storage application rejected	3	2	6	Seek budget estimate for G99 application from DNO at an early stage. Install G98-compliant PV array if too expensive.	2	2	4	Church
R5	Construction	Programme	Equipment delivery is held up and delivered late to the project.	3	3	9	Project to allow suitable time for procurement/mobilisation	2	2	4	Contractor
R6	Construction	Programme	Bad weather delays programme	3	2	6	Allow float in the programme to allow for uncontrollable weather delays. If possible, prioritise summer period for installation works.	2	2	4	Contractor
R7	Construction	Programme	Contractor takes longer than programmed to undertake the work as identified in their programme	4	2	8	Contractor to confirm their programme and provide regular updates. Contractor to apply additional resources if required to keep to the project programme.	3	2	6	Contractor
R8	Construction	Financial	There is an increase in capital costs	4	3	12	Consultant to actively engage with suppliers at feasibility stage to identify costs. Contingency of 5% capital cost increase has been included, and costs should be agreed upon prior to construction phase.	2	2	4	Church
R9	Construction	Financial	There is an increase in operational costs	4	3	12	Contingency should be allowed at an appropriate level (5% highlighted in feasibility study)	2	2	4	Church
R10	Operational	Financial	Solar performs poorly compared to expected generation	2	4	8	Financial modelling includes appropriate generation losses to ensure anticipated returns are robust.	2	2	4	Church
R11	Operational	Security	Equipment is stolen or damaged	4	4	16	In the detailed design phase, it may be decided that security measures beyond those anticipated are required.	2	2	4	Church

Appendix E. Further financial projections

The following tables demonstrate alternative 20-year Net Present Value returns from the financial modelling, based on discount rates of 6% and 0%, as requested by the client. The whole system capex and baseline Y20 NPV (using a discount rate of 3.5%) are presented for clarity.

Indicator	No grant	50% grant funding	No grant	50% grant funding
Variant	ASHP only		PV only	
Whole system capex	£60,000	£30,000	£8,480	£4,240
Y20 NPV (3.5% DR)	-£58,519	-£29,554	£630	£5,089
Y20 NPV (6% DR)	-£57,032	-£28,730	-£1,050	£2,950
Y20 NPV (0% DR)	-£60,807	-£30,807	£4,426	£8,666

Table 27: St Mary's, Embsay - NPVs with alternative Discount Rates (1)

Indicator	No grant	50% grant funding	No grant	50% grant funding
Variant	HP with PV		HP with PV & battery	
Whole system capex	£68,480	£34,240	£70,480	£35,240
Y20 NPV (3.5% DR)	-£48,794	-£15,023	-£50,462	-£15,676
Y20 NPV (6% DR)	-£50,970	-£18,668	-£52,620	-£19,375
Y20 NPV (0% DR)	-£42,985	-£8,745	-£44,630	-£9,390

Table 28: St Mary's, Embsay - NPVs with alternative Discount Rates (2)

Indicator	No grant	50% grant funding	No grant	50% grant funding	No grant	50% grant funding
Variant	ASHP only		Rooftop PV only		Groundmount PV only	
Whole system capex	£123,750	£61,875	£9,500	£4,750	£8,500	£4,250
Y20 NPV (3.5% DR)	-£108,739	-£48,541	£24,707	£30,619	£28,292	£33,820
Y20 NPV (6% DR)	-£108,279	-£49,906	£17,586	£22,068	£20,580	£24,590
Y20 NPV (0% DR)	-£107,802	-£45,927	£40,327	£45,077	£45,179	£49,429

Table 29: Holy Trinity Church, Skipton - NPVs with alternative Discount Rates (1)

Indicator	No grant	50% grant funding	No grant	50% grant funding
Variant	HP with PV		HP with PV & battery	
Whole system capex	£132,250	£66,125	£136,250	£68,125
Y20 NPV (3.5% DR)	-£92,658	-£27,401	-£99,075	-£31,893
Y20 NPV (6% DR)	-£97,249	-£34,867	-£102,977	-£38,708
Y20 NPV (0% DR)	-£80,612	-£14,487	-£88,390	-£20,265

Table 30: Holy Trinity Church, Skipton - NPVs with alternative Discount Rates (2)

Indicator	No grant	50% grant funding	No grant	50% grant funding
Variant	ASHP only		PV only	
Whole system capex	£7,000	£3,500	£4,000	£2,000
Y20 NPV (3.5% DR)	£20,245	£24,661	-£2,761	-£776
Y20 NPV (6% DR)	£14,517	£17,819	-£2,892	-£1,005
Y20 NPV (0% DR)	£32,785	£36,285	-£2,408	-£408

Table 31: St. Augustine's, Draughton - NPVs with alternative Discount Rates (1)

Indicator	No grant	50% grant funding	No grant	50% grant funding
Variant	HP with PV		HP with PV & battery	
Whole system capex	£11,000	£5,500	£13,000	£6,500
Y20 NPV (3.5% DR)	£19,639	£26,122	£17,218	£24,687
Y20 NPV (6% DR)	£13,311	£18,499	£11,072	£17,204
Y20 NPV (0% DR)	£33,551	£39,051	£30,796	£37,296

Table 32: St. Augustine's, Draughton - NPVs with alternative Discount Rates (2)

Indicator	No grant	50% grant funding	No grant	50% grant funding
Variant	ASHP only		PV only	
Whole system capex	£54,750	£27,375	£9,500	£4,750
Y20 NPV (3.5% DR)	-£37,694	-£10,663	-£324	£4,626
Y20 NPV (6% DR)	-£39,761	-£13,936	-£1,985	£2,496
Y20 NPV (0% DR)	-£32,353	-£4,978	£3,443	£8,193

Table 33: St. Mary's, Carleton - NPVs with alternative Discount Rates (1)

Indicator	No grant	50% grant funding	No grant	50% grant funding
Variant	HP with PV		HP with PV & battery	
Whole system capex	£64,250	£32,125	£66,250	£33,125
Y20 NPV (3.5% DR)	-£31,170	£1,074	-£33,269	-£26
Y20 NPV (6% DR)	-£36,390	-£6,084	-£38,377	-£7,127
Y20 NPV (0% DR)	-£18,822	£13,303	-£21,102	£12,023

Table 34: St. Mary's, Carleton - NPVs with alternative Discount Rates (2)

Indicator	**No grant**	**50% grant funding**	**No grant**	**50% grant funding**
Variant	ASHP only		PV only	
Whole system capex	£71,250	£35,625	£9,500	£4,750
Y20 NPV (3.5% DR)	-£56,671	-£21,784	-£1,602	£3,300
Y20 NPV (6% DR)	-£57,700	-£24,092	-£2,984	£1,497
Y20 NPV (0% DR)	-£53,323	-£17,698	£1,562	£6,312

Table 35: All Saints, Burton-in-Lonsdale - NPVs with alternative Discount Rates (1)

Indicator	**No grant**	**50% grant funding**	**No grant**	**50% grant funding**
Variant	HP with PV		HP with PV & battery	
Whole system capex	£80,750	£40,375	£84,750	£42,375
Y20 NPV (3.5% DR)	-£52,971	-£12,980	-£57,521	-£15,547
Y20 NPV (6% DR)	-£56,538	-£18,448	-£60,789	-£20,813
Y20 NPV (0% DR)	-£43,952	-£3,577	-£49,029	-£6,654

Table 36: All Saints, Burton-in-Lonsdale - NPVs with alternative Discount Rates (2)