Calon Llanarth - St. Teilo's Community Wellbeing Centre

Heating Feasibility Study

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Final issue

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Contents

1 Executive summary

Holloway Partnership has been commissioned by The Village Alive Trust to undertake a feasibility study for a new heating system to be installed at the redundant St. Teilo's Church, Llanarth near Raglan.

The Church in Wales policy to move towards net zero carbon is noted.

A description of the building and the existing services installations is provided.

A description of typical traditional church building heat loss is given and potential reduction that could be made if the roof insulation were to be improved.

Issues and concerns are raised regarding the lack of utility services and the limited electrical installations being beyond repair and potentially unsafe and requiring complete replacement.

The Village Alive Trust plans to redevelop the building into a community well-being centre which is used seven days a week, although the kitchen or café may not be used every day.

Descriptions of typical heating systems and heat emitters are provided including boilers, heat pumps, underfloor heating, radiators, direct electric heaters and solar photovoltaic (PV) panels.

An options appraisal is undertaken, firstly listing unsuitable technologies or systems based on the location, type of building and proposed future use as follows:

- Boilers.
- Ground source heat pumps.
- Gas radiant heating.
- Electric storage heaters.
- Solar thermal panels.

An assessment is then made of the following options including The scope of the work, advantages and disadvantages are:

Do nothing	There would be no functional heating in the building which would not incur any cost, but the building would likely be unoccupiable and deteriorate.
Do minimum	Install the simplest, lowest cost system which we consider direct electric heaters such as panel heaters or overhead electric radiant heaters. These are low cost to install and maintain but expensive to run, especially if the building is used seven days a week
Do maximum	Install the most appropriate system for the building. Install air source heat pumps in a compound near the building with below ground pre-insulated pipes to a small plantroom inside the building. Connect the heat pumps to wet underfloor heating installed throughout the building with each room installed as a separate control zone allowing flexibility of operation. This system will operate to maintain the building at a background temperature suitable for building conservation. Subject to detailed design calculations the full height Multi-Use space and Quite Space may require supplementary heaters, most likely electric radiant heaters, to achieve reasonable temperatures in colder weather.

The discussion section notes the following points:

- Irrespective of the services systems and heating systems installed, the building will require new upgraded electricity, water and broadband utility services to be installed.
- The Trust should contact NGED and ask for a budget cost estimate for installing a new 100 Amp, 3-phase supply into the building.
- The proposed future use of the building is very different from when the building was used as a church so the services systems, and heating system in particular, may also be very different.
- Heat pumps with underfloor heating are a good option for the proposed future use.
- The extent to which the thermal performance of the building is upgraded, and the type of floor finishes will impact the effectiveness of underfloor heating.
- A “hybrid” heating system, using heat pumps with underfloor heating as the primary heat source operating continuously then local direct electric heaters, are becoming commonplace in traditional buildings which have limited opportunities for improving the thermal performance of the building.
- A solar photovoltaic panel system would only directly reduce energy bills if the building is regularly used and would offset electricity for lighting and hot water in the summer. Because there is less solar energy in the winter the PV will not offset the energy used by an electric heating system, but there will be some offset.
- If an initial enquiry to the planning authority suggests such an installation might be accepted advice should be sought from a PV specialist that can calculate the size and annual yield of a suitable system and provide an estimate of revenue generation from the SEG.

A budget cost estimate of the potential mechanical and electrical services systems is as follows and notes on the limitations of the budget cost estimate are given.

Scope of work cost estimate	
National Grid Electricity Distribution (NGED) electrical supply upgrade.	£20,000
Dwr Cymru Welsh Water (DCWW) mains water supply.	£10,000
Hot and cold water services.	£10,000
Air source heat pump system.	£60,000
Underfloor heating.	£40,000
Supplementary heating	£5000
General electrical power distribution.	£10,000
Internal general lighting and emergency lighting.	£20,000
Fire detection and alarm system.	£7000
Internal broadband and data distribution.	£5000
Intruder detection and alarm.	£5000
Total	£192,000

2 Introduction

Holloway Partnership has been commissioned by The Village Alive Trust to undertake a feasibility study for a new heating system to be installed at the redundant St. Teilo’s Church, Llanarth near Raglan.

A visit to the building was undertaken by Keith Patterson, Director, Chartered Engineer (CEng), Member of the Chartered Institute of Building Services Engineers (MCIBSE) on in June 2024 accompanied by Pat Griffiths, Trustee.

This report presents an assessment of the opportunities for replacement of the heating system in St. Teilo’s Llanarth.

3 Towards "Net Zero"

The Church in Wales (CiW) has set a target of achieving net zero carbon across its estate by 2030 and provides guidance and practical steps for churches to adopt.

[The Church in Wales - Climate change guidance]

Historically, the carbon factor of mains electricity has been twice that of mains gas. The carbon factor of grid electricity is dropping rapidly with the phase out of coal and gas power stations and the increase in renewable energy generation. At present, mains gas and grid electricity have very similar carbon factors but it will continue to reduce for mains electricity. Mains gas will drop slightly but the overall direction for technical solutions and regulation is away from mains gas and towards all electric building.

Therefore, a significant part of any decarbonisation strategy is eliminating or reducing the burning of fossil fuels to generate heat and move to electrically powered solutions.

However, CiW acknowledges that some buildings present significant challenges, in particular when considering heating systems, and may never achieve net zero carbon.

When undertaking more significant works, such as reordering, the opportunities arise to consider more significant changes which might include a complete change of heating system.

The key is to take small steps to move towards net zero carbon. Do nothing is not an option.

4 Existing system

4.1 Building description

St. Teilo's Church, Llanarth, Monmouthshire is a Grade II* building dating from the 13^{th} century with later additions in the 14^{th}, Porch, and 16^{th}, Tower.

The building was closed as a church in 2013 and offered for sale in 2019. In 2021, the Village Alive Trust reached an in-principle agreement with the Church in Wales (CiW) for a 99 year lease on the building while CiW retains responsibility for the churchyard.

4.2 Mechanical and electrical services

There are no mechanical services installed and there is no mains water connection to the building.

There is an electrical supply into the building which appears to be a “split-phase” service as is common in rural agricultural areas where the network has not been fully upgraded to three-phase. “Split-phase” is sometimes called “two-phase” and is essentially two single phase supplies taken from different network phases. While a meter is installed the service does not appear to be live.

Incoming supply at the base of the tower.

Distribution boards.

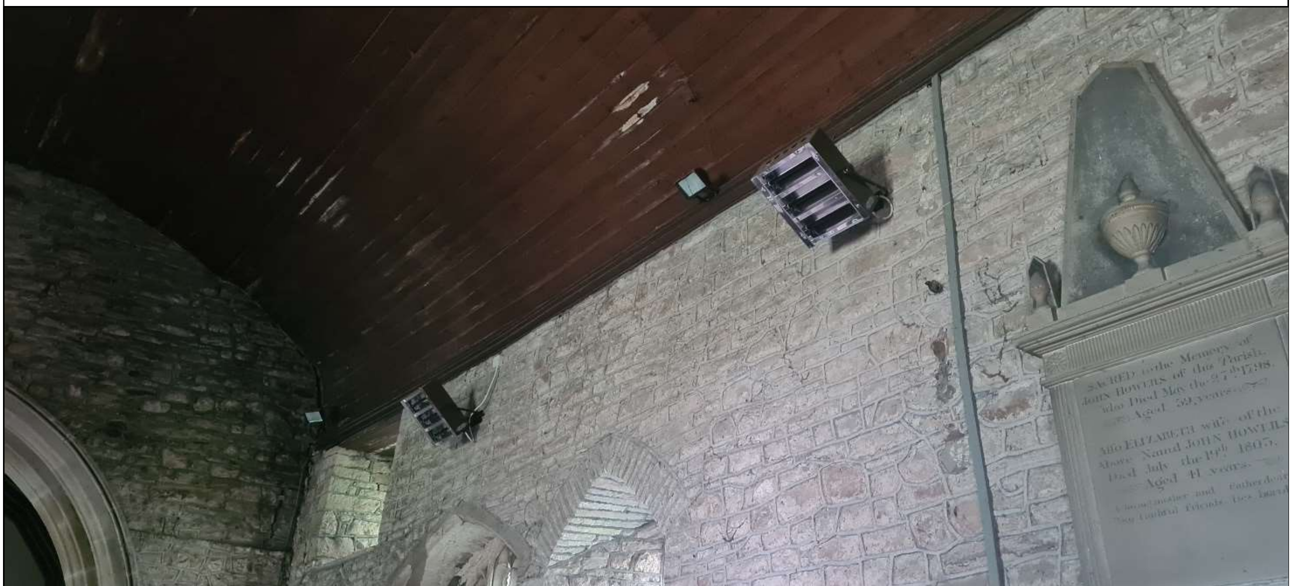
Due to the height of the incoming supply installation it was not possible to inspect the fuse carriers but they are typically 60 to 100 Amp.

Given the nature of the heating system in the church the supply capacity was likely at the upper end of this range.

The electrical distribution boards are all isolated and appear to be redundant and beyond their anticipated service life.

Heating appears to have been provided by electric tube heaters fixed to pews and electric infrared radiatn heaters at high level on perimeter walls.

Electric tube heaters fixed to pews.



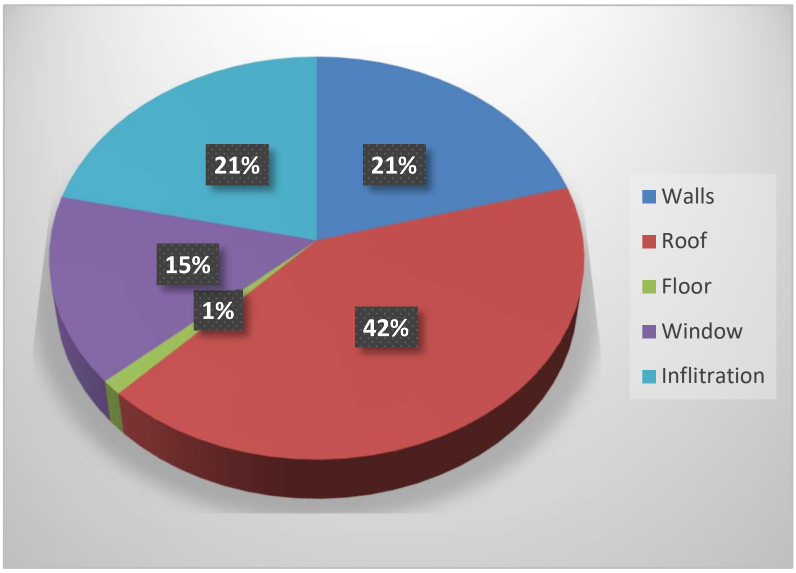
Electric radiant heaters at high level on the perimeter walls.

4.3 Energy use

The energy use of the building has not been specifically examined at this stage. An assessment of energy bills over the past three to five years would usually give an idea of how the building uses its energy. However, since the building has not been in use since 2013, no such records are available.

Typically, energy used for heating a traditional church building represents 80-90% of overall energy use so offers the most potential for reducing carbon emissions and running costs.

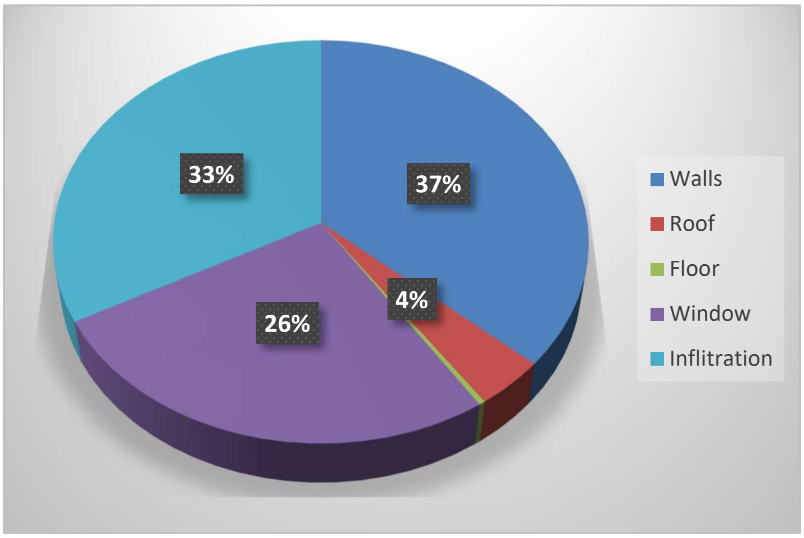
The typical heat loss from a reasonably large traditional solid stone church building with an uninsulated slate roof is 100-130 kW and spread across the building elements as the chart below.



The roof is almost always the most significant heat loss element, generally having the largest surface area and worst thermal performance.

Thick stone walls have a reasonably stable thermal performance, so long as they are not damp, controlled by the significant thermal mass.

Infiltration describes the air tightness, “leakiness” or “draughtiness” of a building and is often assumed to be around 0.5 air changes per hour, which leads to a significant number for a very large volume space, but assumes the doors, windows and roof are very leaky.



If it were possible to add insulation to the entire roof to modern insulation standards, the loss from the roof would reduce significantly to only 4% of the overall building heat loss, meaning something in the order of 40 kW less heat is lost.

Insulating the roof would also improve its air tightness so reducing infiltration.

Fitting draught excluders to doors, ensuring windows are in a good state of repair, or fitting secondary glazing, can make significant reductions to infiltration which will improver thermal comfort in the space.

Any building fabric improvements will likely require Listed Building Consent and Planning Consent and advice should be sought from a conservation architect.

5 Issues and concerns

5.1 Existing system issues and concerns

The electrical system is beyond economical repair and unlikely to be safe to re-energise so will need to be completely replaced.

Any heating equipment is also likely to be unusable so will need to be replaced.

The incoming electrical supply may not be safe to re-energise and may need to be completely replaced. Any new incoming electrical supply will most likely need to enter the building from below ground, not via overhead wires, so will require excavation through the church yard. Cables are usually installed at around 450-500mm below ground surface level.

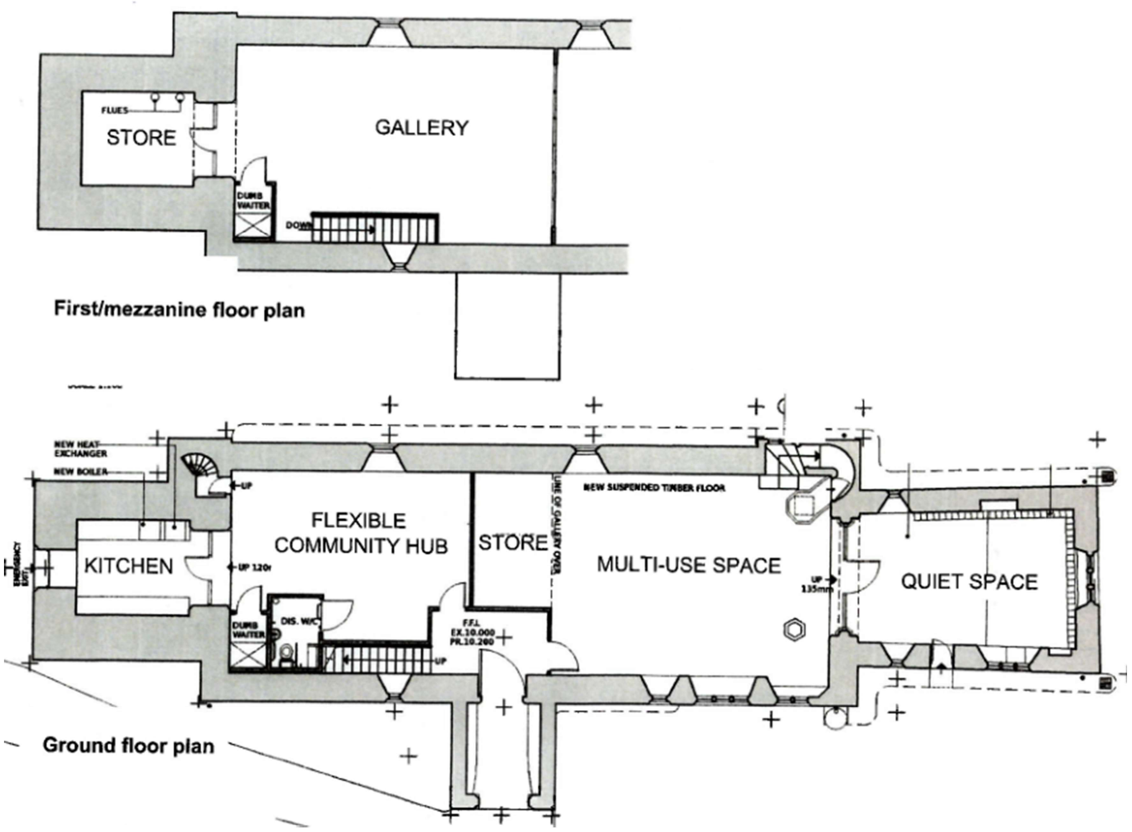
There is no incoming mains water supply which will be necessary for the proposed future use with catering and toilet facilities being introduced. Any new incoming water supply will need to enter the building from below ground so will require excavation through the church yard. Mais water pipes are usually installed at around 750-900mm below ground surface level.

Ideally, a fibre broadband service will also be installed in the building requiring a below ground fibre cable, which is usually installed through a below ground plastic cable duct.

Incoming utility services should be planned to follow the same route through the churchyard so only one combined service trench excavation is needed.

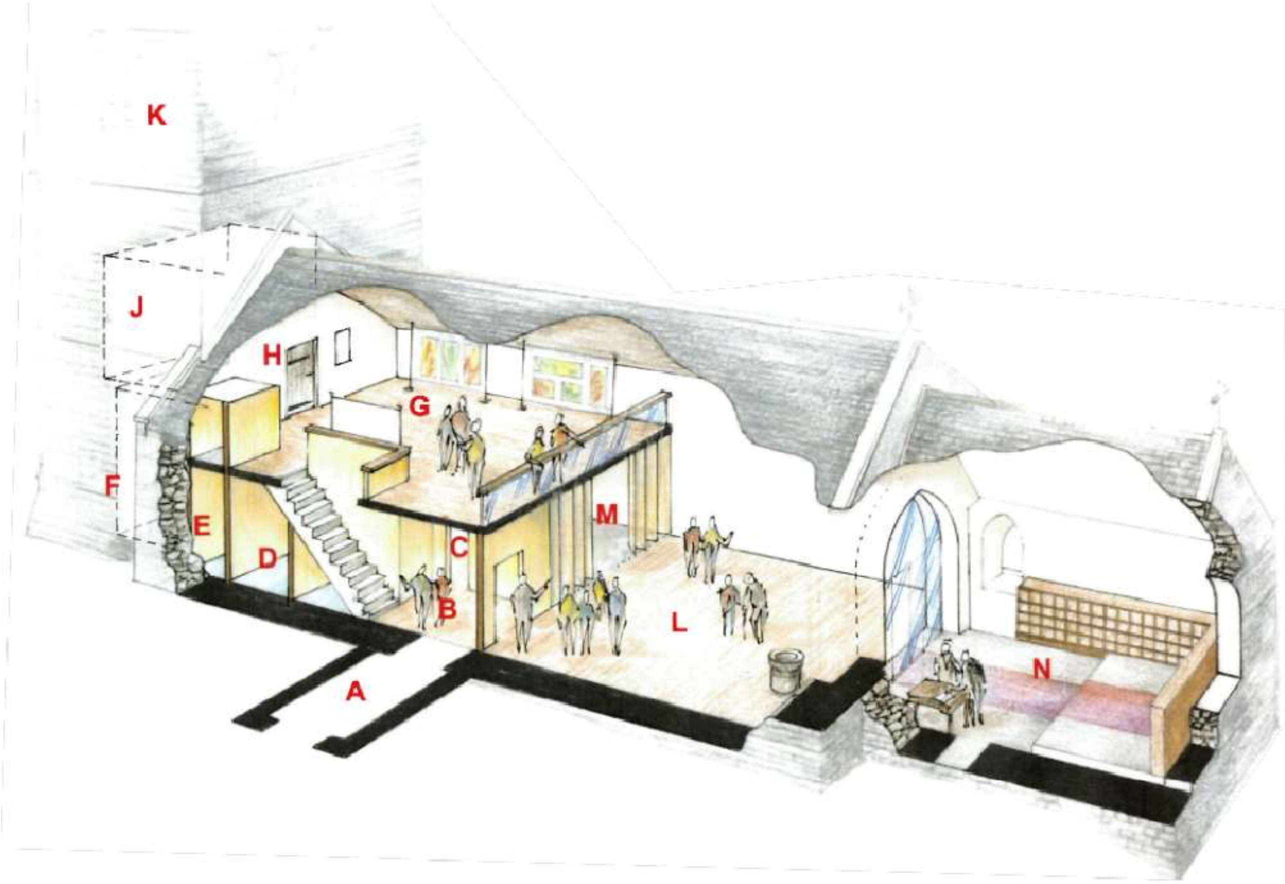
5.2 Future use

The Village Alive Trust are proposing to restore the building to use as a community well-being centre as the illustrations below.



It is the aspiration that the building will be used seven days a week to some degree although the kitchen or café may not operate full time.

The Trust have already considered that re-roofing the building will be a worthwhile long-term investment, facilitating the installation of insulation and potentially solar photovoltaic panels.



6 Systems

The following sections provide descriptions of potential systems and equipment based on the Building Services Research and Information Association (BSRIA) series of illustrated guides to building services which provide unbiased information on features and limitations.

6.1 Boilers

Boilers, whether mains gas, oil or LPG are a "standard" in the UK as a heat source for heating and hot water systems.

Modern boilers are "condensing boilers" which have higher operating efficiencies than older atmospheric or forced draught boilers but have different operating characteristics to achieve those higher efficiencies.

The technology is well established, and the controls are now relatively straight forward.

Boilers can generate hot water at varying temperatures from 50°C up to around 90°C to circulate through the hearing system pipework and heat emitters. Older systems tended to run with water temperature at around 80°C while modern systems with condensing boilers operate around 50°C.

Boilers require flues to discharge the products of combustion, the design of which is dictated by many factors including the type of boiler, the location of the flues and compliance with the Clean Air Act to avoid or minimise local pollution.

6.2 Air source heat pump

A heat pump is a device that can extract heat energy from a low temperature source and covert it to a higher temperature heating medium, like water. An important characteristic is that it can generate more heat energy than it needs electrical energy to drive it. The ratio of heat energy produced, and electrical energy used is known as the Coefficient of Performance (CoP). Typically, machines used for space heating have a CoP in the region of 3.5, meaning that 3.5kW of heat are produced for every 1kW of electrical energy used to drive the machine.

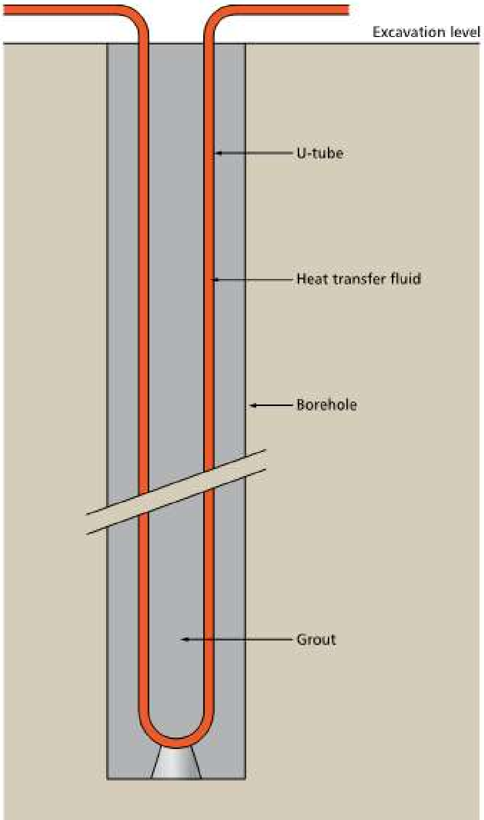
The machines work at their most efficient when they produce water at around 40°C which makes them a good choice for underfloor heating or low temperature radiator applications. Their efficiency reduces when air temperature falls below 0°C, although new technology is reducing the degree of efficiency reduction.

The CoP is the main reason why heat pumps can be much more efficient, use less energy and produce fewer carbon emissions than boilers or direct electric heating.

An air source heat pump (ASHP) extracts heat energy from the air so must be installed outside or in very well-ventilated enclosure which is essentially in free air. They have compressors and fans so can generate low volume, low frequency noise which, although they are not particularly noisy, can be noticeable in quiet locations. They are bigger than conventional boilers with a similar heat output.

The technology is moving quickly and with the carbon content of grid electricity reducing and becoming similar to main gas, they offer a low energy and low carbon heat source option.

6.3 Ground source heat pump



The same technology as described above but, where an air source heat pump uses the outside air as its heat sync a ground source heat pump (GSHP) uses the ground. CIBSE TM51 provides guidance on ground source heat pumps.

Ground conditions must be assessed by a suitably qualified and competent geologist or hydrogeologist then a specialist ground loop designer must develop the group loop design to suit the ground conditions. Ground conditions may dictate that the system can only be used for heating or cooling or both or that it may need to be switched off for a period to allow ground conditions to be restored.

Since ground temperature varies much less than the outside air, GSHPs can offer improved efficiency over ASHPs with CoP in the order of 4.0-5.0.

To use the ground as the heat sync, pipes carrying a thermofluid need to be buried in the ground which may be using vertical boreholes or horizontal “slinky” coils.

Boreholes tend to be 100-200mm diameter and formed by drilling down to depths of 80-120m, installing an “U” pipe loop then pumping in a thermally conductive grout to fill the space between pipes and ground. Boreholes have an energy extraction rate of 20-55 W/m with a typical figure being 35 W/m. For a heat requirement of 60kW, it is estimated that 14 boreholes of 100m depth and spaced at least 5m apart may be required.

“Slinky” pipe coils are buried directly in the ground at a depth of 1.5-2.0mtypically have a capacity of 20-40 W/m². For a heat requirement of 60kW, it is estimated the area of ground needed would be 1500-3000m² which is an area of 40m x 40m up to 55m x 55m or equivalent. This area cannot be built over.

Boreholes are more expensive than horizontal pipe coils but are more thermally and space efficient.

6.4 Radiators

Radiator systems are generally used in naturally ventilated buildings. In older buildings with single-glazing and low levels of thermal insulation, radiators tended to be below windows to offset cold downdraughts caused by room air coming into contact with the cold surface of windows. The enduring popularity of radiator systems is testament to their simplicity and all-round performance.

A large range of radiator styles are available including heritage style cast iron column radiators which are heavy and robust and suited to spaces like churches with fixes pews but low surface temperature radiators are better suited to spaces with flexible seating and a wide range of uses including more vulnerable groups such as older people or very young children.

Because their heat output is largely convective, rather than radiant as the name suggests, their heat output can create an uneven temperature distribution, especially in large volumes and heat up times can therefore be slow.

6.5 Fan convectors

Convectors have a casing with top and bottom openings and a finned hot water pipe at low level. The hot water pipe creates an upward convection current of hot air inside the casing, pulling room air in at the bottom and pushing hot air out at the top.

Fan convectors incorporate one or more fans which increase the heat output per unit size and improve air movement in a space. Fan speed can be controlled to suit requirements and can include a boost setting for the rapid warming up of a space.

The main benefit of convectors, especially fan convectors, over radiators is they have a much greater heat output for their size and warm a space up quicker.

The fans need to be regularly maintained to ensure they do not become noisy.

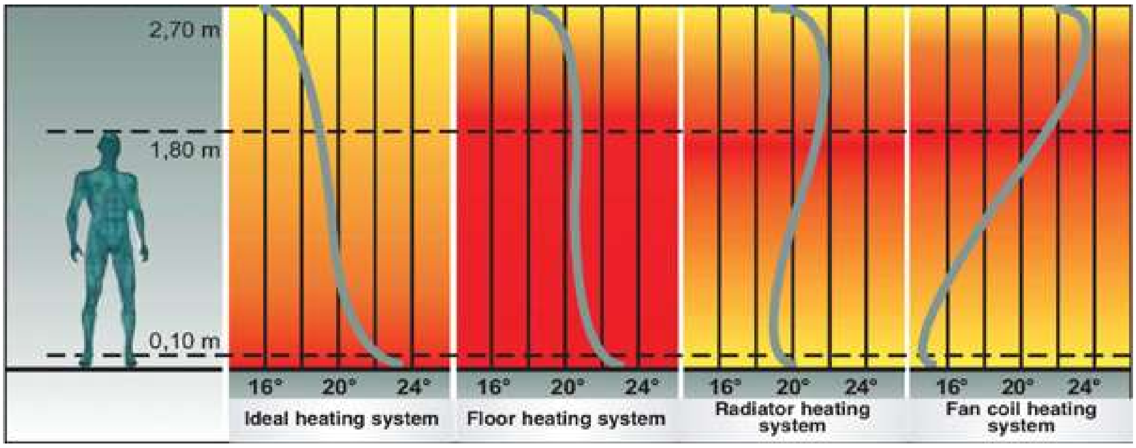
6.6 Underfloor heating

BSRIA Guide BG4/2011 “Underfloor heating and cooling” is a detailed reference for these systems.

Plastic pipe is embedded between a top layer of screed and the floor slab below has a layer of insulation below, although in some cases the order may be reversed. Hot water systems use water at a temperature of approximately 40°C to prevent an excessive floor surface temperature which makes them particularly well-suited to systems with heat pumps.

Underfloor heating overcomes the problem of a cold surface normally associated with stone floors and provides an invisible heating system with nothing on the walls.

The thermal profile of underfloor heating in the occupied zone 2m above the floor is almost close to ideal which is improved in very tall spaces. Thermal comfort can be achieved with lower energy use than the equivalent radiator or convector systems spaces with a high heat loss.



The "feel" of the heat from an underfloor system and in the space is different to that from radiators or fan convectors.

Emitters like radiators and fan coil units rely on the air in the whole space reaching a similar temperature, whereas underfloor heating has a radiant heat effect where the temperature gradient reduces as indicated in the diagram above.

While a person will feel the warmth from the warm floor, the air temperature around them is likely to be lower than the floor temperature.

Because the radiant surface temperature is low, the output from the floor is limited. Depending on water temperature, floor construction and floor finish the output can range from 45 to 100 W/m². Solid concrete floors with a concrete or stone finish can achieve around 75-100 W/m² whereas wooden floors are limited to around 55-65 W/m².

Underfloor systems have a slow response to changes in temperature and are not suited to intermittently occupied spaces. Systems will ideally be switched on at the start of the heating season then left to run at a continuous temperature, with a small drop for night unoccupied hours, until the end of the heating season. When large numbers of people arrive in a space, a heavy weight floor like concrete with stone slabs will take some time to cool down due to the thermal mass which can cause problems with overheating. This is not such an issue with lightweight floors like suspended timber which will warm up and cool down quicker or in very large volume spaces where there is no "build up" of heat from the ceiling.

Floor finishes, such as wood or carpet act as insulators so reduce the amount of heat released into the room which may require supplementary heating, especially during colder weather.

6.7 Gas radiant heating

Radiant heating systems are typically used in large volume spaces because the heaters can be installed at high level and provide a radiant output downwards towards the occupants and they warm people directly without heating the air in a space. This enables an acceptable level of comfort to be maintained with a relatively low air temperature which is an efficient way to heat large volume spaces which have a lot of cold air continually entering through doorways and other openings.

Radiant heating is generally directly gas-fired, and most commonly a system where gas is burnt in a long metal tube which consequently radiates heat. A metallic reflector installed behind the tube directs the heat into the occupied space below. A fan is used to draw gas/air through the tube and there is a connection to an external flue. Efficiencies of 80-90% are possible with these systems.

Pre-heating of the space is not required, as the radiant effect is virtually instantaneous. Air movement is not required to distribute heat throughout the space. High-level mounting of heating equipment frees up floor space and reduces risk of damage.

However, gas burners require regular checks, typically every six months, to ensure correct operation. Radiant heat can cause some materials to become discoloured.

6.8 Direct electric heaters

6.8.1 Electric panel heaters

Electric panel heaters are sometimes known as convection heaters because of the way they heat up. Inside an electric panel heater is a heating element – usually made of ceramic or another heat-conducting material – which heats up to a set temperature. The heat from this heating element is then circulated around the room using a small fan, warming the air around the room. Panel heaters tend to be slimline and come in a variety of shapes, sizes, and styles.

They have a fast heat-up time, have simple controls, and can be controlled individually or as a whole house using WiFi, like a central heating system, and smart phone or tablet apps are available to make setting and monitoring controls easier.

Because of this, they can be pre-set to come on or off or be manually switched on or off when someone wants to use a room that needs some heating.

While they can be used on a “time of use” tariff, they tend to be used on a standard electric tariff so making installation simple and cost effective.

6.8.2 Oil Filled Radiators

Oil filled radiators contain a thermally conductive oil heated by electric elements. They give off more radiant heat, which, unlike convective heat, warms objects or people directly rather than warming the air. The oil inside oil filled radiators is only used to conduct heat, so never needs to be replaced and are usually very small and light and they make good portable heaters.

Oil filled radiators usually (but not always) heat up slightly slower than panel heaters, but they use less energy to do so. They also stay warm for longer without power, making them a good using through the night.

Small and light, oil filled radiators can be wheeled around to any room and they are more effective in poorly insulated rooms.

6.8.3 Storage heaters

Also known as night storage heaters, electric storage heaters store thermal energy by heating up internal ceramic or clay bricks at night when time of use tariffs, such as Economy 7, tend to make electricity units cheaper. This heat is then released during the day spreading heat around the room by pulling in cooler air, warming up the air through the heater, then releasing it into the room.

Newer models of storage heaters will control the input and output automatically once the desired room temperature has been set using an integral thermostat.

Because of new rules set in 2018, modern designs have casings to hold extra heat or fans to distribute the heat around the room. More sophisticated heaters have intelligent charging to store the right amount of heat and can connect to your WiFi network.

6.8.4 Radiant heaters

Electric radiant heaters can be "visible" infrared type or "invisible" zero light far infrared. The adjacent image shows visible infrared heaters.

They are often installed at a high level and "shine" downwards into the occupied zone to warm people and surfaces rather than warning the air.

They are an instantaneous source of heat, so do not need any pre-heating time, and people will feel the benefit as soon as they are switched on.

They can be switched on and off individual or in groups to suit areas of use of the building.

They can provide some heat to the volume of the space by reflected heat off hard reflective surfaces such as stone walls and floor.

6.8.5 Under pew heaters

Under pew heaters are essentially small electric panel heaters which are installed under fixed pews at intervals along their length which generate warm air "plumes" to rise up over the occupants.

They can be switched on and off individually or along the length of a pew or in blocks. Maximum energy savings are achieved by only switching on the heaters where people are sitting.

They are an instantaneous source of heat, so do not need any pre-heating time, and people will feel the benefit as soon as they are switched on.

They deliver very localised heat and do not provide any useful heat into the volume of the space.

They require extensive fixed wiring installations and are not suitable if there is any intention to move pews.

6.9 Solar energy

6.9.1 Solar thermal panels

These convert sunlight into hot water which can be used to preheat water in hot water cylinders. These systems have been increasing in popularity in recent years and are now frequently installed as part of an air source heat pump system.

They can work with cylinders with electric immersion heaters, or they require a twin coil hot water cylinder and a pumped thermofluid loop between the cylinder and the panels, which must be installed as close as possible to the cylinder for best performance and efficiency.

They can provide significant quantities of hot water during sunnier periods reducing the need for additional heating from a heat pump or electric immersions.

Since they rely on direct solar radiation, they are not particularly effective in the winter when there is no sunshine and are more affected by this than PV panels, as described below.

A typical domestic solar thermal panel system using two 3m² solar collector panels will cost around £5000 and a 150-litre solar coil cylinder with an electric immersion heater costs around £1000.

6.9.2 Photovoltaic panels

Photovoltaic (PV) systems use cells to convert solar radiation into electricity. The PV cell consists of multiple layers of semi-conducting material which creates an electrical field when exposed to sunlight, causing electricity to flow. The greater the intensity of the sunlight, the greater the flow of electricity.

There are a number of different PV cell materials with the most energy efficient at around 15% and the least efficient around 7%.

Domestic PV systems are commonly between 3 and 4 kW peak output, taking up 20 to 30 square metres of roof.

A typical domestic array of 3.7kWp (about 25 square metres) would cost about £5,500.

A larger 16 kWp requires 36 panels at around 78m² total area and would cost in the order of £15,000 plus VAT.

The cost of PV technology is decreasing, and their efficiency is improving. It is common for all-electric buildings to have PV panels installed, almost by default, to assist in offsetting grid electricity use and associated carbon emissions.

Electrical cabling needs to be routed to where inverter equipment would be installed.

The local electricity distribution network operator (DNO), Western Power Distribution (WPD), must be informed of any PV panel installation, but this can be done by the MCS registered specialist.

The panels can now be supplemented with battery systems to store the collected solar energy, then used to run appliances such as the fridge, freezer, TV, computers etc through the night.

A 16 kW battery store formed from three linked battery modules would cost in the order of £5000 plus VAT.

6.9.3 General issues for solar panels

Solar panels should be installed in a location and orientation to maximise exposure to solar radiation throughout the year, so ideally should be in a south facing roof with no overshading.

A micro-generation certification scheme (MCS) registered solar panel specialist should be consulted on the potential for a solar systems.

The MCS has set calculation methods for energy generation and payback which can be used to make a cost benefit assessment. Having the system potential assessed in this way can improve the opportunity to benefit from the ‘Smart Export Guarantee’ for PV systems.

Solar thermal panels are a more efficient option than PV for generating domestic hot water in the summer although there may not currently be much difference in cost.

Structural advice should also be sought to ensure the panel weight can be adequately supported by the roof structure, although the panels could be installed on the ground, remote from the building.

The benefit of solar panels is only realised if the solar energy generated can be used directly in the building. Selling energy back to the grid via a Smart Export Guarantee contract has a much lower rate then the cost of buying electricity from the grid.

It is very unlikely that a sufficient area of solar panels can be installed to make a building of this type grid independent and while batteries can provide some storage, they are usually designed to cover “parasitic” energy use, such as running fridges, freezers, maybe washing machines or dishwasher through the night having been fully charged through the day.

Photovoltaic panel systems will generate most of their electricity during sunnier months which is usually when the heating system is switched off. The generate the least amount of energy during mid winter, which is when heating demand is at its highest. Photovoltaic panel systems with battery storage are therefore usually designed to cover the building base electrical load which requires careful assessment of the electrical energy systems in the building along with the likely use of the building.

6.9.4 Solar panels and planning

Installing solar panels typically falls under Permitted Development, meaning planning consent is not generally required.

However, there are caveats to this as the panels must not protrude more than 150mm off the profile of the roof and must not be higher than the highest part of the roof (excluding the chimney), for instance.

There are also exceptions, notably conservation areas and installing solar thermal panels on or in the vicinity of a listed building will require consent.

For church developments the DAC should be consulted, and approval will likely be necessary.

7 Options appraisal

7.1 Improve the building fabric

Ahead of upgrading or replacing heating systems, the energy needs of the building should be reduced by improving the building fabric which may include:

- Improving air tightness – reducing "leakiness".
- Increasing insulation.
- Adding secondary glazing to windows.

An architect or surveyor with appropriate knowledge of heritage buildings should be consulted to assess the risks and practicalities of improving the building fabric.

Listed Building Consent will be required for any building fabric improvements.

The following appraisal assumes that the roof will be insulated to current standards. And air tightness will be improved through better fitting doors, draught excluders and restoration of windows.

7.2 Unsuitable options

Given the location and nature of the building, there are some systems which are unsuitable.

There are also some options which are unsuitable due to the proposed future use.

The options we consider unsuitable are discussed below.

Boilers
There is no mains gas in the area so any boiler would need to be oil or LPG. Burning fossil fuels does not align with current best practice, which is to move towards lower carbon system driven by main electricity. Boiler flues can be challenging to install in listed and heritage building where no previous chimney or flue route is available.
Ground source heat pump
Excavation in the churchyard will be challenging, and the extent of excavation required for ground loops, whether horizontal loops or boreholes is significant and disruptive. The cost of excavations can often outweigh any long-term efficiency benefit so the system payback means they are overall more expensive than air source heat pumps.
Gas radiant heating
There is no mains gas so the system would require LPG. Burning fossil fuels does not align with current best practice, which is to move towards lower carbon system driven by main electricity. While radiant heaters are good for heating people standing immediately below them, they are not ideal for providing background heating for protection of the building fabric and fittings.
Electric storage heaters
Given the high heat loss and intended use of the building these would be very expensive to operate and not provide sufficient flexibility for the various uses of the spaces in the building.

Solar thermal panels
Although hot water use from the café kitchen may be quite high at times, generally use will be low. The use of photovoltaic panels generating electricity is usually more useful than the hot water generated by solar thermal panels as the electricity can be used for other things when there is not requirement for hot water.

7.3 Replacement options

The need to maintain or replace the existing system should firstly be considered:

Do nothing	Leave everything as it is.
Do minimum	Install the simplest, lowest cost system.
Do maximum	Install the most appropriate system for the building.

7.3.1 Do nothing

Scope of work
There is no functional heating in the building.

Advantages and opportunities
No cost.

Disadvantages and risks
The building is unlikely to be useable and will likely deteriorate without any functional heating.

7.3.2 Do minimum – Install the simplest, lowest cost system

Scope of work
The simplest lowest cost system to install would be electric panel heaters which may need to be supplemented by electric radiant heaters. Heaters in individual rooms can be separately controlled to allow for flexible use.

Advantages and opportunities
Lowest cost option other than do nothing.
Technology is simple and easy to use.
Low maintenance requirement.

Disadvantages and risks
Will require a very large new electrical supply, ideally three phase, which will increase installation costs.
Will be very expensive to operate.

7.3.3 Do maximum – Install the most appropriate system for the building

Scope of work
Install air source heat pumps in a compound near the building with below ground pre-insulated pipes to a small plantroom inside the building. Connect the heat pumps to wet underfloor heating installed throughout the building with each room installed as a separate control zone allowing flexibility of operation. This system will operate to maintain the building at a background temperature suitable for building conservation. Subject to detailed design calculations the full height Multi-Use space and Quite Space may require supplementary heaters, most likely electric radiant heaters, to achieve reasonable temperatures in colder weather.

Advantages and opportunities
ASHP is a recognised low carbon technology so significant move towards net zero carbon.
Underfloor heating well suited to the type of building and proposed future use.
Underfloor heating is no more expensive to install than a complete new radiator system.
Best operational efficiency achieved between heat pump and underfloor heating.
Relatively simple ongoing maintenance.

Disadvantages and risks
Heat pumps are more expensive to install than other heat sources such as boilers.
Air source heat pumps must be installed outside in a secure compound which creates planning, archaeology, and LBC challenges.
Pipes from the heat pumps into the building will require excavation through the churchyard which creates planning, archaeology, and LBC challenges.
Will require upgrade of electrical supply, ideally to three-phase, of greater capacity than a boiler system.

7.4 Discussion and recommendations

7.4.1 Further reading

There is no "one size fits all" solution to heating a church building as each has its own particular requirements such as frequency of use, number of occupants, activities taking place, installation and operating costs and the architectural and historical significance of the building.

The Representative Body of the Church in Wales has written a guidance document to assist in making a decision about the choice of heating system, although it was written in 2019 so some aspects and references are out of date.

Church in Wales Heating in Churches

The Church of England have much information on climate change and heating in churches along with case studies.

Church of England - Net Zero Carbon and Environmental case studies

7.4.2 Utility services

Irrespective of the services systems and heating systems installed, the building will require new upgraded electricity, water and broadband utility services to be installed.

The services systems, especially the heating and hot water systems, will influence the capacity of the new mains electricity supply. Ideally it will be a new three-phase supply, but that is dependent on the nearby electricity network capacity.

We have obtained a plan of the National Grid Electricity Distribution (NGED) network in the village which suggests that the pole mounted transformer across the road form the church is connected to a three-phase distribution line.

We would suggest the Trust contact NGED and ask for a budget cost estimate for installing a new 100 Amp, 3-phase supply into the building. This will allow cost planning for the installation as will as flagging the need for the service on the NGED system which will help them with network planning especially if any other development takes place in or around the village.

7.4.3 Future use

The proposed future use of the building is very different from when the building was used as a church so the services systems, and heating system in particular, may also be very different.

The heating system will need to respond to the potential seven day use, meaning it will be running constantly during the heating season, and also needs to ensure that reasonable internal conditions are maintained for conservation of the building fabric and fittings.

Heat pumps are the most efficient technology, especially when used with underfloor heating which is ideally suited to the lower water temperatures they generate at their highest efficiency.

Underfloor heating is a very comfortable form of heating for activities such as yoga or Pilates or where young children and babies are playing on the floor.

7.4.4 Direct electric systems

While direct electric heaters are low cost to purchase and install, they are expensive to operate especially if they are running constantly during the heating season due to the need for building conservation heating or the building is in daily use.

They do respond quickly so are useful if there is no need for building conservation heating and the building is unoccupied most of the time.

However, these heaters are ideally suited to providing supplementary or “top-up” heating if, for example, underfloor heating cannot meet the heat requirement for colder weather conditions.

A “hybrid” heating system, adopts heat pumps with underfloor heating as the primary heat source operating continuously then local direct electric heaters, which might be panel heaters in smaller rooms or overhead radiant heaters in larger rooms, are used to provide some additional heating when the weather gets colder.

The direct electric heaters are then only used for short intervals when the building is occupied and the weather colder which may only be a few days or a few weeks in the year.

“Hybrid” system are becoming commonplace in traditional buildings which have limited opportunities for improving the thermal performance of the building.

7.4.5 Heat pump with underfloor heating

Because of the proposed future use of the building the floor needs to be lifted and replaced to improve level access. This means there is an ideal opportunity to install underfloor heating throughout the building.

Heat pumps are ideally suited for use with underfloor heating as they operate most efficiently when generating water at around 40-45°C which is typical for underfloor heating systems.

The choice of floor finishes will have a significant influence on the overall performance of the underfloor heating, with hard finishes, such as stone flags or ceramic tiles performing best. Engineered wooden can perform reasonably well but increases the likelihood of supplementary heating being required. Soft floor finishes, such as vinyl or carpet or not ideal as they effectively insulate the floor surface from the room so reducing potential floor output which can mean that supplementary heating becomes essential, and the capacity can become the same or greater than that from the floor.

Irrespective of the floor finishes, using underfloor heating does require the thermal performance of the building to be improved as much as is practically possible, with insulation of the roof and eliminating cold draughts through leaking doors and windows being essential.

In a building of this type, the main challenge with this type of system is determining a suitable location to install the heat pumps in an external secure compound and installing the pre-insulated below ground pipes from the heat pumps to the building due to the required excavation through the churchyard.

7.4.6 Adding renewables

Adding solar panels on this project would require planning and Listed Building Consent.

The system would only directly reduce energy bills if the building is regularly used and would offset electricity for lighting and hot water in the summer. Because there is less solar energy in the winter the PV will not offset the energy used by an electric heating system, but there will be some offset.

The building has a significant south facing roof pitch which could easily accommodate a large PV array that could generate revenue via a “Smart Export Guarantee” contract.

If an initial enquiry to the planning authority suggests such an installation might be accepted advice should be sought from a PV specialist that can calculate the size and annual yield of a suitable system and provide an estimate of revenue generation from the SEG.

The Renewable Heat Incentive for Non-domestic building has closed and there is no replacement scheme.

7.4.7 Budget cost estimate

Scope of work cost estimate	
National Grid Electricity Distribution (NGED) electrical supply upgrade.	£20,000
Dwr Cymru Welsh Water (DCWW) mains water supply.	£10,000
Hot and cold water services.	£10,000
Air source heat pump system.	£60,000
Underfloor heating.	£40,000
Supplementary heating	£5000
General electrical power distribution.	£10,000
Internal general lighting and emergency lighting.	£20,000
Fire detection and alarm system.	£7000
Internal broadband and data distribution.	£5000
Intruder detection and alarm.	£5000
Total	£192,000

7.4.8 Notes on estimated costs

The scope of work cost estimate given above is intended to be indicative based on the level of information and detail developed at the time of writing this report and with no design development having been done.

We have provided some indicative cost estimates for general mechanical and electrical services systems although they are not specifically discussed in this report but are to assist in overall project budget planning.

These costs do not include for the excavations, backfilling and making good for below ground services.

The costs do not include a photovoltaic panel and battery system which should be obtained from a system specialist.

All figures exclude VAT.

At this stage it is very difficult to predict how contractors would price the timescale and complexity of the project until design development has progressed.

The figures are not based on measurements or quantities but are based on our experience of work on other similar projects.

We would always advise that a degree of contingency should be allowed for when working with existing buildings to cover unforeseen issues that may become evident after work commences and may be in the order of 10% of overall budget.