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ST LAWRENCE CHURCH, LECHLADE

MECHANICAL AND ELECTRICAL SERVICES FEASIBILITY REPORT

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1. INTRODUCTION

Martin Thomas Associates have been commissioned by St Lawrence Church, Lechlade to undertake a feasibility study to investigate the options for new heating, lighting and small power within the Grade I listed church.

There are plans to reorder areas of the church, including the provision of a raised gallery, WC and kitchen at the west end, new internal glazed lobby, and provision of a new floor throughout the nave raised to the same level as the chancel floor.

The Church of England has recently set a target to reduce their carbon emissions to net zero by 2030. This is an ambitious target and meeting it will require energy-efficient and low carbon technologies to be used, where feasible, for heating church buildings.

The contents of this report are based on a visual survey only, with no intrusive studies undertaken to date.

2. SCOPE OF WORK

The following studies are covered within this report:

- Review of the existing mechanical and electrical services within the church
- Estimation of the heat loss of the church
- Evaluation of heat generation options
- Evaluation of space heating options
- Recommendations for the refurbishment/replacement of the heating system based on findings
- Proposals for other mechanical services (mains water, ventilation, etc)
- Budget estimates for the heating system options
- Recommendations and proposals for refurbishment of electrical systems
- Proposals for new lighting and controls
- Budget estimates for electrical works.

3. EXISTING MECHANICAL SERVICES

3.1 EXISTING HEATING SYSTEM

Heating for the church is currently generated using two fairly modern domestic Vaillant boilers that appear to have been connected together in parallel, located within a boiler room under the south side of the nave.

Natural gas is supplied to the boilers from a U16 gas utility meter located in the same room as the boiler. This meter should have a maximum connected capacity of around 170kW, which we would expect to be in excess of the gas requirement to heat the church.

The boilers are modern condensing boilers with balanced concentric flues, which have been run to outside through the door frame. Black flue extender sections have been run up the wall in order to get flue gases further away from the steps and above ground level.

We are aware that the boilers have had their issues, most recently regarding the boiler flues and corrosion, however this is to be repaired. The general plumbing set up is not ideal and could be limiting the performance of the boiler, as primary and secondary pumps are plumbed together in series instead of being hydraulically separated with a low loss header.

It is always difficult to say how much life is left in existing equipment, however we would normally expect domestic boilers to last 15-20 years when located in good environments and are well looked after. This may have been shortened due to the issues the boiler have had over the years, however it would not be unreasonable to expect them to last another 5-10 years considering their age.

The system circulation pump is an old Grundfos model, identified as containing asbestos, probably in the gaskets. Heating flow and return pipework is run through the north wall below the church with the cold fill and expansion pipes run above this. The pipework in the below ground room is mostly installed in steel with threaded fittings, except where modern intervention has taken place where it is installed in copper with soldered fittings.

Space heating within the church is provided primarily using steel panel radiators, with 4 floor standing fan convector heaters evenly spaced around the perimeter. We understand that the heating system was installed in the 60s, which would align with the fact that the fan convector heaters are labelled as containing asbestos. Heating pipework is generally run around the perimeter of the church above the floor in steel, in a 2-pipe arrangement. The exception to this is where it drops to run within a tunnel which runs across the west entrance to get back to the buried boiler room. Pipework is poorly clipped and supported, with a lot of the wall crumbling behind. It would appear at the moment that the pipework is only being held in place by the fittings holding it together placing strain on all of these joints.

The cold feed and expansion pipes follow the same route into the church through the tunnel, appearing near the west entrance, and rising up to the feed and expansion tank in the tower.

The pipework appears to be generally in good condition, but the internal condition cannot be determined from a visual survey.

The existing steel radiators are of no historic value, with some unusually long and likely to be fairly heavy. The condition of the wall brackets behind are unknown, along with the internal condition of the radiators. Internal sludge build up is a common issue with these, although the two Magnaclean magnetic filters installed on the feeds to the two boilers will hopefully be reducing this.

It is reported that the heating is not particularly effective, especially towards the centre of the church. This could be partly down the heat emitters, but also that the domestic boilers may be unable to cope with the required heat output to keep the church warm.

It is understood that the church is currently does not suffer from any problems with damp or condensation.

It is understood that the heating currently set on a timeclock with no temperature control.

Recommendation

Following our survey, with the possible exception of the boilers, we would not recommend any of the existing heating system is considered for retention or reuse. This is due to the following:

- The boilers, although fairly new, are domestic and less robust than their commercial equivalent. The copper pipework used for connections will be suspectable for galvanic corrosion due to the predominantly steel heating system. They however could be retained on the assumption that their expected life would suggest they have close to 10 years of further life. This however may have been shortened due to the issues the boilers have had, and may be shortened further during any large refurbishment project.
- Many components, such as the fan convector heaters in the church and main circulation pump in the boiler room, are noted to contain asbestos.
- The poor pipework support has the potential to have provided strain on certain elements of the pipework increasing the risk of future leaks.
- Much of the internal heating system, such as the steel panel radiators, hold little historical value and are likely to have poor internal condition.

3.2 OTHER MECHANICAL SERVICES

Mains water enters the church in the vestry in a fairly new 20mm blue MDPE supply with stopcock. A 15mm copper pipe is then run around the perimeter of the church attached to the wall to supply the feed and expansion tank in the tower.

4. APPROACH TO HEATING THE BUILDING

There are several factors that should be considered when deciding on the approach to heating churches that hold cultural or heritage value, including:

- Providing comfort to occupants during winter/colder periods.
- Protecting internal plaster and mortar (particularly lime-based) from deterioration caused by extreme temperatures or sudden swings in temperature.
- Protecting delicate internal finishes such as timber, joinery, murals, etc., from conditions that would lead to deterioration or damage.
- Reducing the risk of internal surface condensation, damp and mould that results from cold internal surfaces within the church.
- Providing frost protection to the internal environment to prevent pipes freezing, etc.

Any new heating system proposed for the church should be designed with the above factors taken into account.

The two general approaches to heating a church are 'local' heating or 'whole building' heating.

'Local' heating is where heat is only provided close to where the people are, for the sole purpose of providing an improvement to comfort for the building's occupants. This can take the form of under-pew heaters or radiant heaters at high level pointing towards the main pew areas. Additional heaters may be located in the pulpit, chancel, chapel and vestries. This form of heating often provides very little benefit to the building fabric in terms of conservation heating, as the walls of the church do not benefit from the localised heating. The main benefit to this heating strategy is the lower running costs, as less heat is used heating the building fabric and air.

'Whole building' heating is where the internal temperature of the entire building is elevated, rather than providing local heating to certain areas. This strategy requires heat emitters to be located more evenly around the building. A combination of both convective and radiant heat is preferred so that the air temperature and surface temperatures in the building are elevated together, reducing the chance of condensation forming. Often, to minimise the temperature swings in the building and reduce warm-up times, the system maintains a minimum 'setback' temperature at all times, even when the building is not occupied.

Based on the fairly regular and varied usage of this church, we would suggest that a 'whole building' heating approach is taken. We would recommend that the building is maintained at a minimum internal temperature of 8°C. This criterion has been recommended in previous churches and in CIBSE articles to minimise the risk of condensation and damp caused by low surface temperatures, as well as providing frost protection. If this is not required, this setting can be reduced to 5°C to provide frost protection in the building only.

The form of heating is also important. Convective heating heats the air in the church and can provide a comfortable temperature for occupants, but provides little heat into the building fabric. This means the walls and ceilings remain cold and remain susceptible to condensation and deterioration. With an uninsulated roof, a lot of the convective heat will be quickly lost. We would therefore recommend that some form of radiant heating is provided where conservation is an important factor. Radiant heating heats surfaces rather than the air and can protect the building from condensation.

5. REVIEW OF CHURCH HEATING

5.1 HEAT LOSS

The heat loss of the church has been estimated based on our knowledge of similar buildings of this age and type of construction.

Factors that affect the heat loss of the building include:

- Material and thickness of building fabric elements, i.e. walls, roof, floor, windows and doors.
- External temperature, i.e. the worst-case (minimum) outdoor temperature.
- Internal temperature, i.e. the heating setpoint.
- The airtightness of the building, i.e. how 'leaky' it is and prone to draughts.

We note that the current proposals include for a new insulated floor, and includes the provision of lobbies to reduce draughts, both of which will assist comfort but have only a small impact on the building's overall heat loss.

The indoor temperature will depend on the purpose of the heating. We have considered two scenarios which serve different purposes:

Scenario 1 – Building Fabric Protection

We would recommend that a minimum temperature of 8°C is maintained within the church at all times to protect the building fabric. Maintaining this temperature acts to reduce the risk of condensation and damp, as well as reducing temperature swings associated with intermittently heated buildings. A higher setpoint would further reduce temperature swings, but would increase energy use and running costs, so the 8°C is a compromise between these two considerations.

Further to issuing the first draft of this report we understand that this will not be required and instead we have set this minimum temperature at 5°C in order to provide basic frost protection.

This temperature is to be maintained (as a minimum) at all times, including during the coldest parts of the year, so we have used a worst-case external temperature of -4.6°C for this scenario *(based on CIBSE Guide A Table 2.5 Swindon DB 99.6% exceedance)*, equating to approximately a 13°C temperature uplift.

Scenario 2 – Occupant Comfort

This scenario is based on keeping the church at a temperature comfortable for occupants. CIBSE Guide A Table 1.5 suggests a comfort temperature of 19-21°C. However, for older churches which are poorly insulated, this can be difficult to maintain at the worst-case external temperature of -4.6°C and can result in very large systems that, in reality, are rarely used to their full potential.

As the building will not be occupied overnight, we can use a higher external temperature than in Scenario 1. For this estimate, we have assumed a temperature uplift 17°C temperature uplift. This system will provide conditions within the comfort criteria when the external temperature is above 2°C. When external temperature is below 2°C the corresponding internal temperature may drop below this for short periods, however the large thermal lag in the building helps to reduce this as much as possible. CIBSE Guide J (2002) weather data suggests that the external temperature drops below a mean temperature of 1-2°C 15 times a year over a 24 hour period, although with the recent trend towards warmer winters this may have reduced since then.

Increasing the temperature uplift that the heating system is designed to achieve is unlikely to have a significant impact on ongoing running costs, as the number of incidences this extra capacity will be used will be limited to only a few times a year. It will however increase the size and cost of the heating installation proportionally with the increase in capacity.

For example designing for a temperature uplift of 20°C instead of 17°C corresponds to a 15% increase in size of the system, size of boilers, size of pipework, and size of heat emitters such as radiators.

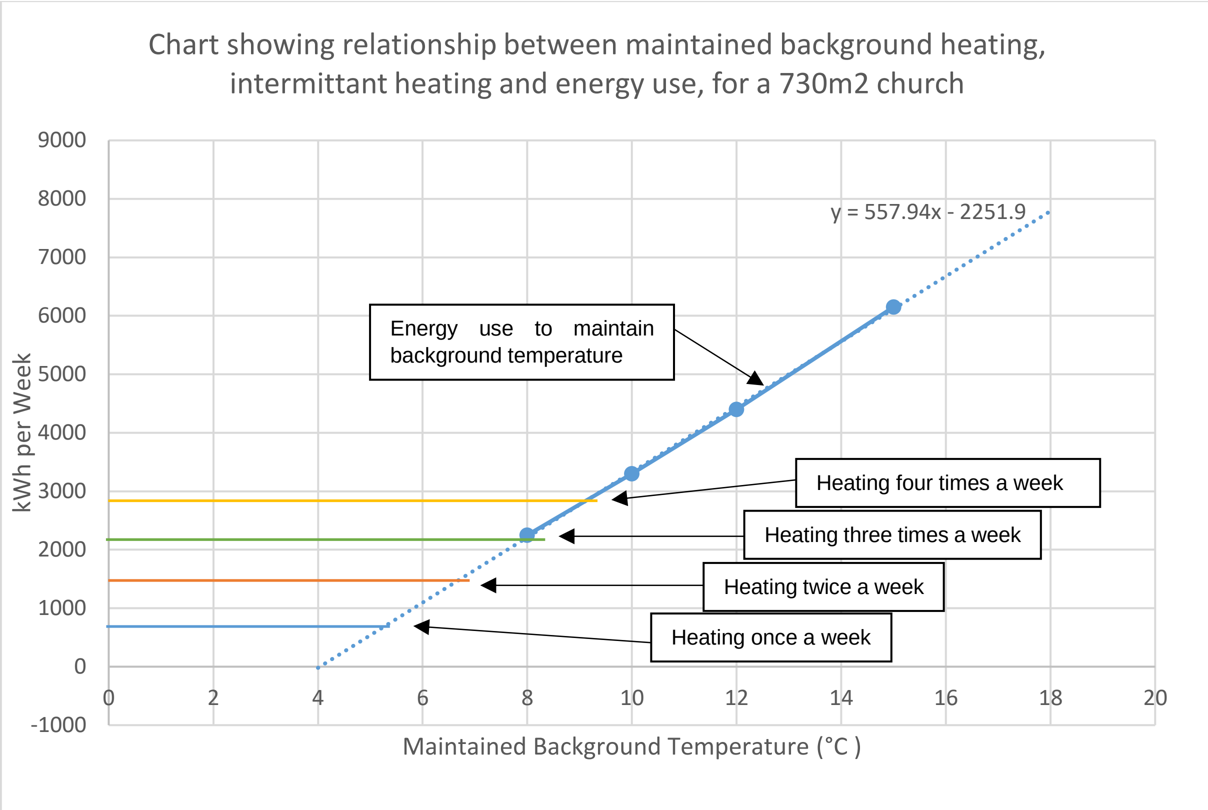
We are happy to adjust this and make the heating system bigger if further coverage is desired.

Energy use of intermittent heating with low temperature fabric protection

It should also be noted that the two conditions above do interact with each other. Where churches are used frequently throughout the week the internal temperature is naturally held higher throughout the year naturally just by the intermittent heating.

For example, churches that are heated 3 to 4 times a week to 19-20°C are unlikely to drop to below 8°C in between these heated periods, therefore rarely triggering the fabric protection heating. It would only be when the church is not heated for longer periods of time that the fabric protection heating would come into effect,

The below chart is an approximation based on calculated data for CIBSE for a much larger church. The blue line with the 4 dots is the calculated energy use for a church heated to maintain a background internal temperature shown at the bottom of the chart. The lines running horizontally indicate approximate the energy used to intermittently heat the church for one hour for a number of times during that week, with the bottom line being once a week and the top line being four times a week.



The chart suggests that maintaining an internal temperature of 8°C roughly corresponds to the same energy used to intermittently heat the church 3 days a week. Although this is not truly proportional with each other (as heat loss will be higher when the church is warm when fully heated), this suggests that if the church is to be intermittently heated to this extent the internal temperature is likely to drop below 8°C only on rare extreme weather occasions or during periods of lower than normal use.

The energy use to maintain 5°C corresponds rough to the same energy as being heated once a week, which is what the calculations originally assumed. This suggests that the modelling was indicating that if heated once a week the church will rarely drop below 5°C and trigger frost protection heating.

Estimates

The heat loss of similar churches we have studied has been calculated as 130-170 W/m^2 for a 13°C uplift in temperature. Based on a floor area of around 350 m^2, this results in a heat loss of 45-60 kW for the building. For a 16°C uplift in temperature, the heat loss would be 160-220 W/m^2, resulting in a heat loss of 55-80 kW for the building.

Heating Scenario	Temperature uplift	Heat Loss
1 – Building Fabric Protection	13°C	45-60 kW
2 – Occupant Comfort	16°C	55-80 kW

More accurate heat loss calculations will be performed as part of the detailed technical design.

In total, 9 radiators and 3 fan convector heaters are currently installed, with an additional radiator provided in the vestry. It is difficult to estimate the output of the existing system, however we would suggest that the radiators would have a combined heat output in the region of 25kW, with each fan heater typically 5-10kW, and the bare pipework probably around another 5-10kW assuming an average ΔT of 50°C.

We would therefore consider that the number of heat emitters would be slightly down on what we would suggest would be required for this size of the church. In addition to this, the existing heat emitter may not be working to their full potential due to their age and condition, as well as having issues with poor distribution, particularly in the centre of the church, and poor delivery of heat from the boilers.

5.2 IMPROVING BUILDING THERMAL EFFICIENCY

The most cost effective way of reducing the heat loss, improving the temperature stability, and reducing carbon emissions within the building is to improve its thermal performance. The most effective way of doing this would be to insulate the roof, as this is where the majority of heat is lost.

The roof could be insulated without altering the internal appearance of the ceiling. This could be done by lifting the roof and installing insulation externally. An example of such products include Actis Boost Hybrid which combines insulation with a breather membrane and can be installed between the rafters and battens. The depth of the roof is likely to be slightly increased to make room for the insulation, and there are many factors that will need to be considered, such as interstitial condensation, increased snow load, structural considerations, etc. It is likely that such projects may only be valid when reroofing works are necessary for other reasons. We also appreciate that for some buildings it may not be achievable. We would recommend, if pursued further, that advice on this is sought from the Architect.

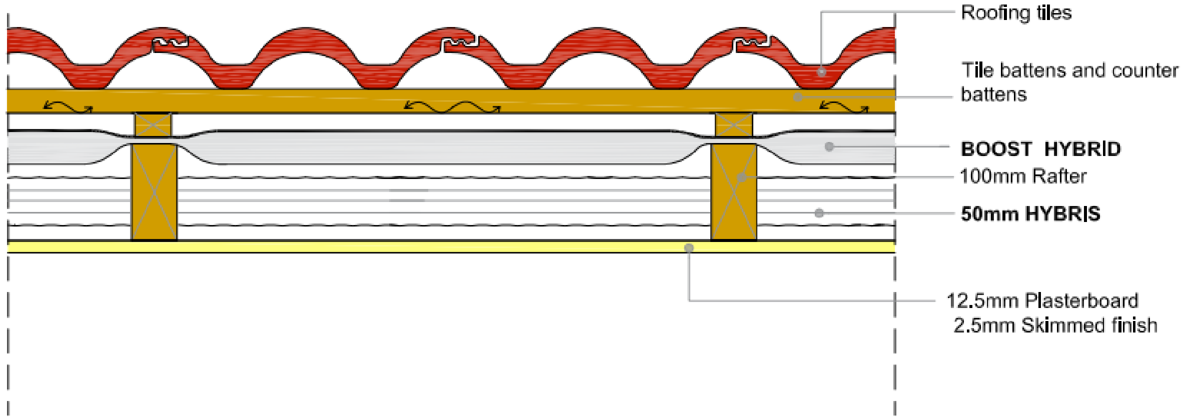


Figure 1: Insulation installed between the rafters and battens

Other possible ways of reducing the heat loss and improving temperature stability include:

- Draught-proofing doors and windows wherever possible.
- Installing secondary glazing (however this is unlikely to be appropriate for churches that are Listed in most cases).
- Installing draught lobbies at the building entrances so heat is not lost through open doors. This is already being considered as part of the proposals.

The diagrams below show the approximate proportion of heat lost through the various elements of the building fabric, with an uninsulated roof and if the roof were to be insulated using a detail similar to the above to provide a U-value of around 0.35 W/m^{2}K. Insulating the roof to the above standard could result in the overall fabric heat loss of the building, along with corresponding energy bills and carbon emissions, being reduced by around 35%.

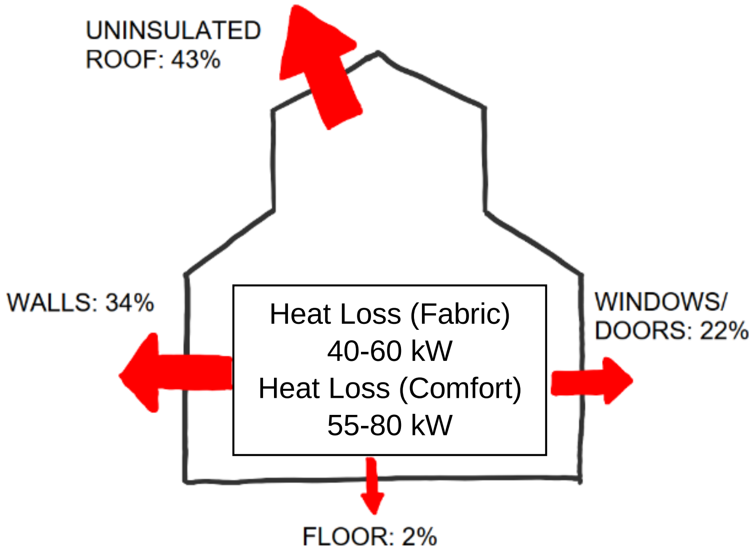


Figure 2: Proportion of heat lost through building elements (uninsulated roof)

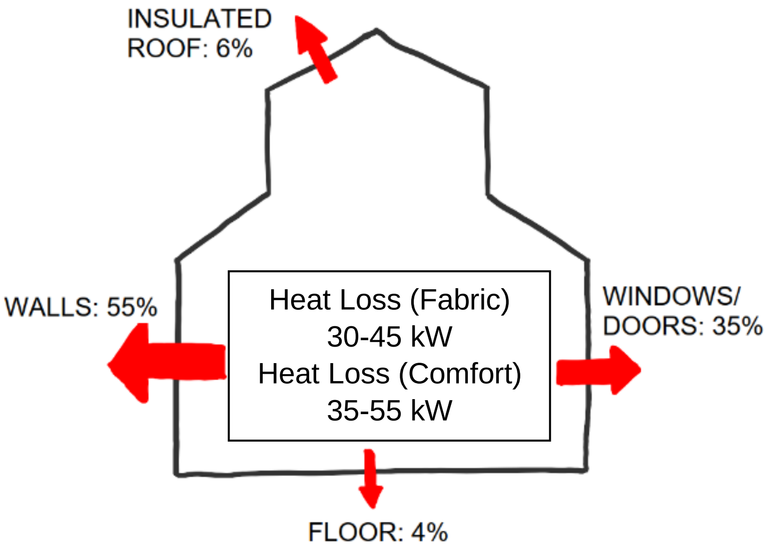


Figure 3: Proportion of heat lost through building elements (insulated roof)

Insulating the walls would not be feasible without drastically changing the interior of the church.

It is often recommended to prioritise allocating finance towards insulating a building over installing energy-efficient and/or low carbon heat generation. As shown above, this can drastically reduce energy usage and will continue to be of benefit for the rest of the building's lifespan. As it significantly reduces peak heating demands, it provides the extra benefit of making more efficient, lower temperature heating systems, such as heat pumps and underfloor heating that may have previously been unviable, an option going forward.

We understand that the provision of thermal improvements such as roof insulation are a costly undertaking that is beyond the current scope of this project. However, we do feel it is important to raise this within our reports in order for them to be appropriately considered towards the ultimate goal of becoming net zero carbon in the years to come, and reducing energy consumption is an important factor even if not addressed in the immediate future.

6. HEAT SOURCE OPTIONS

Due to the condition, performance, and layout of the current heating installation we suggest that an entirely new heating system is installed as part of the proposals in order to improve efficiency. This, coupled with the Church of England's new target of net-zero carbon emissions by 2030, means there is an opportunity to explore more energy efficient ways of heating the church.

The available fuel sources and associated technologies are described below. Each have their individual advantages and disadvantages and the feasibility of each will largely depend on the Church's priorities with respect to capital cost, running costs and CO_2 emissions.

6.1 LTHW SYSTEMS

A low temperature hot water (LTHW) system is a heating system where water is heated by a central boiler or heat pump and distributed by pipework to heat emitters throughout the building. The current system is an LTHW system with heat generated by gas-fired boilers.

It is our opinion that any new LTHW system installed now should be future-proofed so that it can be used with a heat pump or alternative low carbon technology in the future, even if a boiler is installed now. This will generally require slightly more infrastructure than if designed purely for a boiler, but allows the changeover to happen at a later date without major upheaval.

In many traditional church buildings, an LTHW system is the most appropriate, for the following reasons:

- The heat generation equipment can be remote from the areas requiring heat.
- Pipework can be used to distribute heat around the building. Pipework can be relatively small, well insulated and hidden from view where required.
- LTHW heat generators are very efficient. Condensing boilers have efficiencies up to 95%, electric boilers are almost 100% efficient and heat pumps can have efficiencies of 350% or more.
- LTHW generators tend to have better modulation and control options than direct gas or electric heaters, resulting in less energy wastage.
- LTHW systems can be used with many types of heat generators and emitters, including low carbon options, allowing them to be future-proofed.
- Boilers and heat pumps are both commonly used and can be easily maintained.

6.1.1 FUEL SOURCE AND NET ZERO CARBON TARGET

The most common fuel used in LTHW systems is natural gas, which is preferable over oil or LPG as no fuel storage is required and it is a 'cleaner' fuel in terms of pollution and carbon emissions. As natural gas is readily available on site, LPG and heating oil are not considered as suitable options for further consideration.

Although decarbonising the natural gas network through the use of bio-gas is planned, at the time of writing it is unclear how practical this will be, the quantities that will be available, or at what timescales this will be delivered. Gas tariffs that label themselves as 'zero-carbon' are commercially available, however most currently require carbon offsetting to achieve this rather than providing 100% bio-gas due to limitations of supply.

There is ongoing research into the use of hydrogen as a future fuel (or possibly a natural gas/hydrogen mix), however these are all still theoretical at this stage, and it is not known how practically feasible this will be in the future. As a minimum this would likely require a significant upgrade to utilities infrastructure, as well as heavy adaption, or more likely full replacement, of existing boilers which currently cannot run on this fuel.

If total decarbonisation of the gas network is planned, it will likely require a significant reduction in the amount of natural gas currently used in the UK, and will require the majority of buildings to switch to electric heating in some form.

Zero-carbon electricity tariffs are commercially available with around 50% of tariffs now claiming some sort of renewable credentials. However, the picture is mixed, with some suppliers who either own or directly buy from renewable energy generators, and some don't and sell 'brown' electricity with REGO certificates (which are produced alongside renewable electricity generation but can be bought separately on the market).

Even with the complications above, commercially available zero-carbon electricity tariffs are available today, and we would expect this to improve over the next 10 years as more renewable generators come online. We therefore see the switching of heating fuel from gas to electricity to be an important part of achieving net-zero carbon by 2030. However, due to the other factors involved, we suggest all options are considered based on their individual merit.

6.1.2 GAS BOILER

The existing pair of domestic boilers are not really fit for purpose, however could be retained if cost savings were needed and the risks associated with this are understood. At best we would suggest they maybe have 10 years of life left, however this may have been reduced following the issues they have had, and may be reduced further during the refurbishment. They are also slightly undersized for the heat loss requirements we have mentioned above.

Alternatively, we would suggest that these are replaced by a new, slightly larger, commercial gas-fired condensing boiler with stainless steel heat exchanger for robustness.

Replacing the boiler, along with the rest of the heating distribution system, raises the question of whether the basement is the correct location. It would appear that the space has had issues with damp and this has in turn resulted in corrosion and rust as noted on the Unistrut fixings. From what we have seen, we would expect the life expectancy of any equipment located in this room to be reduced. This however could be overcome by adding separation between equipment and the walls, improving the room ventilation, and improving the surface water drainage around this area.

We would suggest that the current flue route and termination is not ideal for a heat output of this size, although it is strictly speaking legal with domestic sized boilers. If the proposals suggest retaining a boiler in this location, we would look to route the flue gases much higher and away from the church.

The unused chimney adjacent to the boiler could be relined and used as a boiler flue, however this would require substantial works at the base of the chimney to install this.

We see an alternative boiler location as within the Vestry, planned to become an office space under the proposals. This would involve moving the gas supply around to this side of the church, and the flue route would need to be considered, likely to be routed through the roof sufficiently far enough away from the church. We understand that this is not preferred and only to be considered if no other option is available.

The current G16 gas meter is suitable for retention for the new system unless it is required to be moved.

Advantages	Disadvantages
Can possibly retain and reuse existing boilers, however this comes with risk with unknown remaining operational life	New boiler and flue may be required. Gas meter may need to be moved.
Existing gas supply on site	Location of current boiler not ideal and conditions are likely to be affecting lifespan. Boiler room may need further work to improve this
Cheapest installation cost	‘On-site’ emissions
Can be linked to ‘green’ gas tariff for net zero carbon target (however see ‘disadvantages)	Most green gas tariffs achieve this mostly through carbon offsetting. There are very few 100% bio-gas tariffs available

6.1.3 BIOMASS BOILER

Biomass boilers burn timber fuel to generate heat for a heating system. The fuel is generally provided in two types; woodchip and wood pellets. Wood pellets are manufactured to a particular standard and are therefore generally a more expensive fuel. They are less likely to cause maintenance issues than woodchips, which can be more variable as a fuel source. As timber is a renewable source of fuel, biomass is seen as a carbon-neutral technology.

Key factors to consider when selecting a biomass boiler approach are:

- Biomass systems generally work better on larger scales, such as estate-wide district heating schemes where the boiler can remain running for long periods. They are not ideal for single buildings with intermittent usage patterns, and are therefore not generally well suited for churches.

- Increase in equipment space as biomass boilers are significantly larger than a similarly rated gas or oil boiler and require a fuel store adjacent. Locating this within the church is likely to be impossible without major intervention that is unlikely to get consent, and space around the church is limited.

- Typically, a biomass boiler of this size will be automatically fed fuel via a feeder auger. The automatic feeder system will require a large fuel store next to the boiler (typically a

4 m x 4 m x 2.5 m hopper) which is filled directly by the delivery lorry which either tips or blows the fuel into the store.

- To run efficiently, a biomass boiler should be paired with a buffer vessel (large water tank). These can be typically between 5,000 to 10,000 litres in size.

- There is a considerable increase in maintenance over a conventional boiler. Typical issues include blocking in the fuel line due to inconsistent fuel quality. The ash tray also requires cleaning daily to remove ash produced by the boiler.

- The boiler flue gases can be high in NOx and high in particulates. Supplementary flue components are sometimes necessary to ensure there is no impact on air quality.

Biomass boilers have been used successfully in many buildings. They do, however, require a big commitment from those running the church to keep on top of fuel deliveries, manually clearing out the ash and keeping up to speed with the day-to-day running of the boiler.

With consideration of the above, the church's location in the centre of the town, and available space around the church, we do not consider this viable.

6.1.4 ELECTRIC BOILERS

The existing gas boilers could be replaced with direct electric boilers on a like for like basis. Due to their limited modulation we would suggest that at least 2 are provided.

The main advantages to such a solution are that there are no on-site emissions, no need for flues, and they are fairly cheap to buy and install. They also have the possibility of being linked with a green electricity tariff which can be used to achieve net zero carbon status, something which is currently limited with gas boilers without mostly carbon offsetting.

The main issues with this as a solution are:

- The significantly higher running costs. Heating bills can be expected to be at least 3 times higher than with mains gas due to the high price of electricity.
- The required size of incoming electricity supply, which will exceed 100A 3ph and may not be available in the area or may require significant and costly upgrades to the existing local electrical network.

The impact of the size of the incoming electrical supply on the surrounding network will not be known until an application is made, so this would be a risk moving forward with this option.

It is possible that electrical boilers may have a place as a short-term top-up for other more efficient systems.

6.1.5 AIR SOURCE HEAT PUMP

An air source heat pump (ASHP) is a device that absorbs heat from outside air and feeds it into a heating system by using a refrigeration process to 'upgrade' the heat to a usable temperature. Although ASHPs require electricity to run, they are seen as a low carbon technology as they only use about a third of the electricity when compared to direct electric heating, with the rest of the heat extracted from the air. The efficiency of a heat pump is calculated based on the electrical energy it consumes compared to the amount of heat it produces. As a heat pump produces more heat than it consumes in electricity, they have efficiencies over 100% (typically averaging 270% for an ASHP).

The improved efficiency results in the running costs being comparable with gas boilers (this varies as the price of gas and electricity fluctuate over time), whilst still achieving net-zero carbon status through the use of green electricity tariff.

It also results in a significant reduction in the required size of the incoming electricity supply reducing the cost of a potential upgrade, with the typically size church needing a 100A 3ph supply rather than much larger than this.

ASHPs can feed either LTHW systems (air-to-water) or direct expansion internal units (sometimes referred to as air-to-air systems). Air-to-water systems use water to distribute heat from the heat pump to the system similar to a boiler, while air-to-air systems use the refrigerant in the heat pump itself to deliver the heat.

The Factors when considering Air-to-Air Heat Pumps

There are several factors that need considering with air-to-air systems when it comes to heritage buildings:

- Refrigerant distribution pipework is generally smaller than the equivalent water distribution pipework, which can make running around the building easier. However due to the risk of leaks (see below), standard pipework jointing is not allowed and pipework is likely to need to be brazed, requiring hot works.

- The volume of refrigerant used in the system is much larger than for a traditional air-to-water system. Although refrigerants have got better in recent years, their Global Warming Potential (GWP) is still very high. Until this is improved further, we try to minimise the volumes of refrigerant used in our systems.

- The indoor units are not usually very attractive (they are typically designed for offices) and are sometimes difficult to locate and conceal.

- The indoor units use fans to circulate the air, so will produce some noise similar to a fan convector.

- The indoor units require more maintenance than a radiator system as there are more moving parts.

- If units need replacing in the future, it may be difficult to find replacements that match visually, as product lines are regularly replaced as new technology supersedes them.

- Maintaining and servicing the units can be more expensive than for a boiler system and can only be performed by a limited range of companies.

Figure 4: Indoor units for air-to-air systems

For the reasons listed above, if an air source system was to be considered for the church, we would recommend this is an air-to-water system.

<u>*Air-to-Water Heat Pumps*</u>

Figure 5: Domestic and commercial air source heat pumps (Mitsubishi Electric/Carrier)

Air source heat pumps (air-to-water) must be carefully designed when used for buildings with high space heating demands. Key considerations include:

- Location – a suitable external location in ‘free air’ is required for the heat exchangers to function correctly. Any enclosure must ensure that not only air flow is maintained but also has suitable access for maintenance. It is also important for the heat pump to be as close to the church as possible, as the further away it is, the longer the buried heating pipe run and greater the heat losses, lowering the efficiency. Any buried pipe route will need to consider any graves in the area and archaeology is likely to be involved. A unit of this size is likely to be around 2m x 1m in footprint and around 1.5m high.

- Noise – the fans and compressors within the units can be quite noisy and may cause disturbance to the surrounding area. Acoustic surrounds are available but increase the size of the units. With no acoustic treatment, sound levels of 65dB(A) at 3m is not uncommon. This can be reduced by providing attenuation to the fans, although this increases the unit size and cost.

- Power supply – the required electrical infrastructure and capacity needs to be available. A heat pump of this size will require a power supply of at least 100A 3ph, perhaps more if there are other high electrical demands in the church.

- Water flow temperature – The maximum water temperature generated by a heat pump is typically 50-60°C which is below the 80°C provided by a boiler. Modern buildings can usually cope with this reduction by having lower heat demands (by providing good insulation) and by providing more efficient modern radiators. However, historic buildings can struggle to get adequately heated by radiators with such a low surface temperature. The solution to this is usually to provide oversized radiators to compensate for the reduction, which can have a negative visual effect within the space, or to improve the thermal performance of the building (this was discussed in detail earlier in the report).

Underfloor heating can be used in conjunction with heat pumps to maximise their efficiency. Underfloor heating typically requires water temperatures around 40-55°C and, as such, providing this directly from the heat pump improves the heat pump efficiency and corresponding running costs. This is something that can be considered with the current proposals involving a new level access floor throughout the nave.

Air source heat pumps can be used in conjunction with a gas boiler which can top-up the heat from a heat pump when required and also provide backup heating in case the heat pump fails. This does, however, rely on a more complex control scheme and has all the disadvantages of a fossil fuel installation in terms of the need for carbon emissions, flue, etc.

In addition to the usual heating plant (expansion vessel, pump, etc.), a heat pump system will typically require a buffer vessel to prevent the heat pump cycling on and off too often. The intention would be for this equipment to be located somewhere within the church with the heat pump outside, however this will need further investigation and discussion with heat pump suppliers.

Advantages	Disadvantages
No on-site emissions, or boiler flue emissions	Significantly more expensive to install than a gas boiler solution
Efficient if run at the correct temperatures	Will decrease the heat output of radiators due to low water temperatures
Efficiency reduces the required size of incoming electrical supply and running costs compared to direct electric heating.	A suitable external location is required, that considers noise, proximity to church, and the buried pipework routes

Can be linked to a ‘green’ electricity tariff for net zero carbon target.	Requires annual servicing, and tends to have slightly shorter operational life than a boiler (10-15 years instead of 20-25 years)

6.1.6 GROUND SOURCE HEAT PUMP

Ground source heat pumps (GSHPs) work similarly to air source heat pumps (air-to-water), but extract heat from the ground rather than the air. This system has the advantage of sourcing heat from the more consistent ground temperature, which rarely drops below 10°C, therefore improving the efficiency of the heat pump.

GSHPs consist of an indoor unit and a ground loop. The ground loop is a long length of pipework that is buried underground. This may be orientated horizontally in an array or vertically in one or more boreholes.

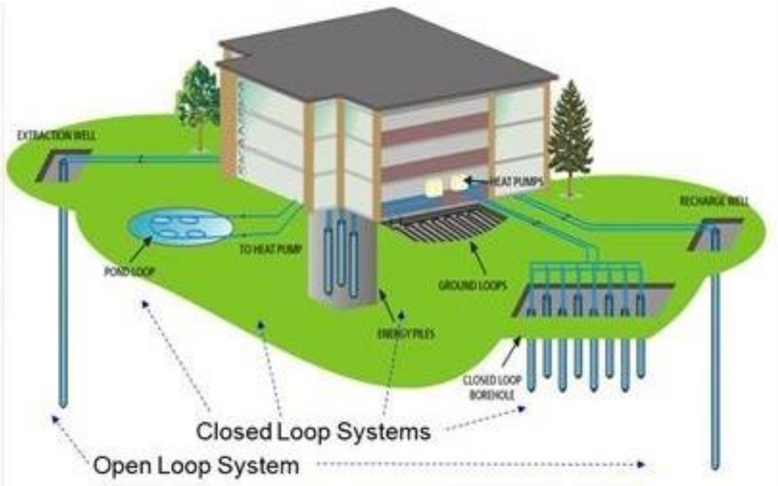


Figure 6: Types of ground source systems

With the town location, we would recommend that vertical boreholes are really the only option available to the church, and with the land that is not already taken by burials being limited, we see the only option for this would be to locate the boreholes outside of the churchyard probably within one of the fields to the south or east. We have also considered the gravel area to the west of the church, however advice from heat pump specialist installers would suggest this area would be too small to locate the number of boreholes required.

A borehole system would likely consist of multiple drilled holes around 100-150 m deep. Based on the estimated heat loads, around 12 boreholes would likely be required to heat the church, generally spaced at least 8m apart, depending on local ground conditions. If a ground source heat pump system is to be considered further, specialist advice should be sought to determine the exact number and depth of boreholes required.

Similar to air source heat pumps, it is likely that as a minimum a 100A 3ph electricity supply will be required, perhaps more if there are other high electricity demands.

The heat pump itself would need to be located inside. Due to the deterioration of the current equipment in the boiler room we would not recommend this is used to house expensive heat pump equipment due to the risk of reducing its lifespan. We would therefore suggest that the new heat pump would need to be placed in the vestry, with pipework to the boreholes run along the path to the north.

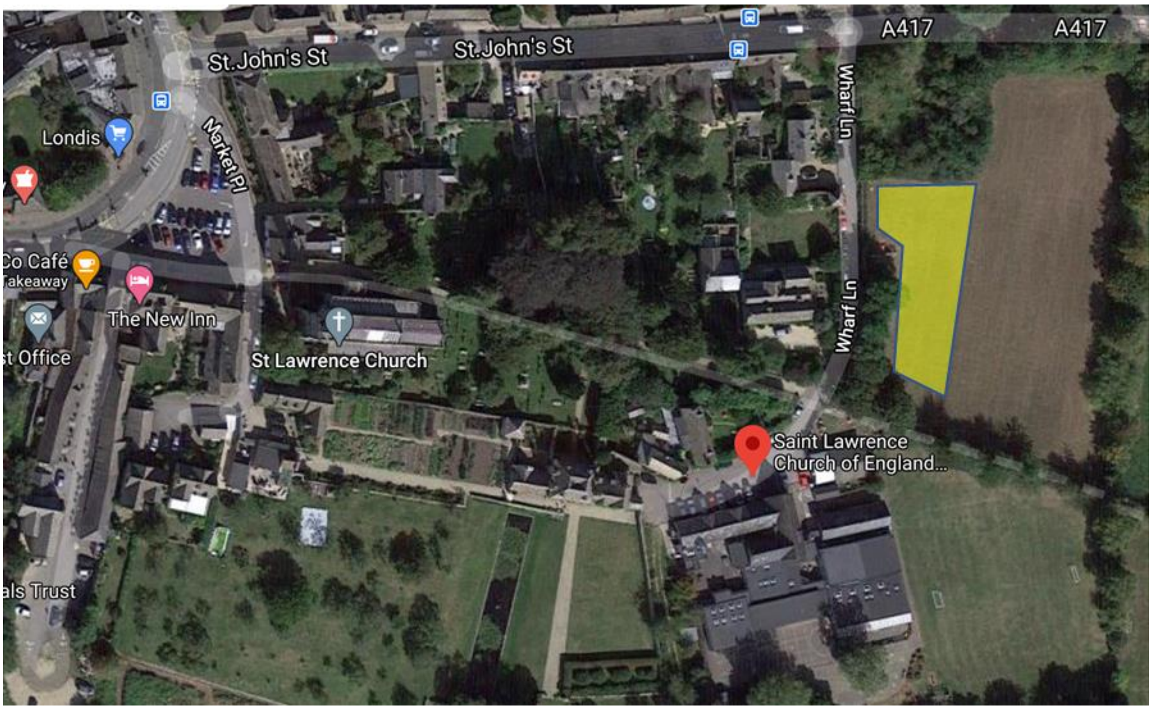


Figure 7: Yellow area indicated where boreholes could be located (subject to land ownership)

Figure 8: Ground source heat pump indoor unit (Kensa)

Advantages	Disadvantages
No on-site emissions, or boiler flue emissions	High capital costs, much higher than other options
Efficient if run at the correct temperatures	Suitable area of land is required for boreholes, with access required for drilling rig limiting options

Efficiency reduces the required size of incoming electrical supply and running costs compared to direct electric heating and air source heat pumps.	Will decrease the heat output of radiators due to low water temperatures, resulting in larger radiators being required
Can be linked to a 'green' electricity tariff for net zero carbon target.	Space is required for the internal unit(s) and associated equipment, along with buried pipework to the boreholes.

6.1.7 HIGH TEMPERATURE HEAT PUMPS

Heat pump technology is improving, particularly towards the increase use of CO_2 as a refrigerant. At the time of writing, options for commercial CO_2 heat pumps are limited, and their suitability for this application, likely efficiencies, issues with maintenance, availability of parts, and uplift in costs over a traditional heat pump is currently unclear. We are however in communication with the heat pump manufacturers and we would expect this technology to improve and become more mainstream over the next few decades.

The main advantage of using CO_2 as a refrigerant is that it can produce much hotter water temperatures than traditional refrigerant, therefore allowing it to be used as a straight swap from a gas boiler without impacting heat emitter outputs. It also has much lower global warming potential (GWP) and is therefore more environmentally friendly than traditional refrigerants.

We would suggest at the time of writing that this is considered as an option for future consideration, and we will update this as and when possible.

6.2 SUMMARY OF RELATIVE FUEL COSTS AND CARBON EMISSIONS

The below table gives an overall view of current fuel costs (per unit of fuel) and the corresponding relative heat cost after efficiencies of the technologies are taken into account, along with the typical carbon emissions for each option. This can be used to approximately illustrate the difference between the options. The relative running costs and carbon emissions have been compared to a new gas boiler installation. The figure for the CO_2 emissions for electricity is taken from SAP 10 (24th July 2018).

Fuel and heat cost data has been sourced from the Nottingham Energy Partnership website (https://nottenergy.com/our-services/resources/energy-cost-comparison) for July 2020, local variations may apply.

System	Fuel	Standard Fuel Cost (pence per unit)	Heat Cost (p/kWh) after boiler efficiency	Relative running costs compared to Gas Boiler	CO_2 emissions (kg of CO_2 per kWh) Relative carbon emissions compared to Gas Boiler
Gas Boiler	Mains Gas	4.28 p/kWh	4.75 (90% efficiency)	100%	Net zero carbon 'green' tariffs commercially available but most require significant carbon offsetting
Electric Boiler	Electricity	15.00 p/kWh	15.00 (100% efficiency)	316%	Net zero carbon 'green' tariffs commercially available, however amount bought directly from renewable energy generators varies greatly between suppliers
Biomass Boiler	Wood Pellets	26.33 p/kg	6.20 (90% efficiency)	130%	Depends on the sourcing and locality of the fuel, but typically seen as net-zero carbon if locally sourced
Air Source Heat Pump	Electricity	15.00 p/kWh	5.55 (270% efficiency)	116%	Net zero carbon 'green' tariffs commercially available, however amount bought directly from renewable energy generators varies greatly between suppliers
Ground Source Heat Pump	Electricity	15.00 p/kWh	4.28 (350% efficiency)	91%	Net zero carbon 'green' tariffs commercially available, however amount bought directly from renewable energy generators varies greatly between suppliers

We provide the following commentary on the figures above:

- We have estimated the electricity tariff, as the domestic tariff provided by the source above can make running costs for heat pumps unfairly high. If a heat pump option was to be pursued this may have an effect on what tariffs become available as a higher use user.
- Air source and ground source heat pump efficiencies are average seasonal efficiencies based on a typical installation.
- Biomass boiler systems have low carbon emissions; however, these are on-site rather than remote (the heat pump options have the advantage of no on-site emissions) and higher in other pollutants such as particulates. It also fails to take into account carbon emissions due to deliveries.
- The table shows that a ground source heat pump system is likely to have lower running costs than a gas boiler system, while air source heat pumps are slightly more expensive to run than gas. However, these assumptions are hugely dependant on the available electricity tariff. This may also change in the future depending on whether the Government implements measures to promote the use of electricity over gas.

6.3 RENEWABLE HEAT INCENTIVE

Heat pumps and biomass systems are currently covered by the Non-Domestic Renewable Heat Incentive (RHI) scheme, whereby applicants can claim money for each unit of heat generated from a low carbon technology. The purpose of the scheme is to allow the application to claim money during the operation of the technology, so that by the end of its operational life (20 years) the money claimed on the RHI equals roughly the initial capital cost uplift from installing the technology over a traditional oil or gas system.

Unfortunately, the scheme is officially due to end on the 31st March 2021 and it is unlikely that this project will be in the position to benefit from this by that date. It is not known yet what or if the scheme is to be replaced with anything. Initial consultations appear to suggest it is unlikely to be kept and may be replaced with a different scheme providing a one-off upfront grant instead of long-term tariff payments, and that this may be limited to £4,000 per installation. However, this is currently in consultation and may change over the coming months.

7. HEAT EMITTERS

7.1 HEAT EMITTERS FOR LTHW SYSTEMS

7.1.1 RADIATORS

Radiators are arguably the most typically used form of space heating within church spaces due to their flexibility in sizes and styles, with relatively high heat outputs when used with boilers. They are typically located around the perimeter of the church, but can also frequently be seen mounted at the back of pews behind the congregation.

We do not suggest the existing steel panels are fit for reuse, so any radiators for proposed options will be new and have the opportunity to be reselected to be more visually in keeping with the rest of the church.

For new radiators, there is a large variety of radiator styles available. The type of radiator chosen would affect the size/number of radiators required.

Cast iron radiators are commonly used in church refurbishments as they are seen as a more traditional design and can be painted or finished as required. However, they are usually significantly more expensive than more modern steel ribbed or flat faced radiators. Examples of both radiators are shown below.

Figure 9: L-R: MHS Clasico, Paladin Neo-Georgian, MHS Monoplan

There is not a significant output difference between the styles of radiators, and therefore the main considerations when choosing a type of radiator are visual appearance and cost.

7.1.2 UNDERFLOOR HEATING

The proposals include the provision of a new floor in the Nave. This opens the opportunity to provide underfloor heating within the new floor to improve the comfort levels within the centre of the church.

Underfloor heating can work very well within tall, poorly insulated buildings, as it provides heat directly beneath the occupants allowing the rest of the building to remain colder whilst still improving comfort. It also tends to reduce stratification and heat loss as a result.

The heat output from underfloor heating is limited by the maximum temperature of the floor. For timber this is normally around 27°C and for stone/brick around 30°C. The table below gives an approximate estimate of the heat output of underfloor heating with various internal temperatures:

Room Temperature	Maximum Heat Output	
	Timber Floor	Stone Floor
8°C (Minimum maintained temperature for fabric protection)	110 W/m²	180 W/m²
20°C (Recommended typical comfort temperature)	70 W/m²	105 W/m²

It can be seen that the heat output of the floor is much higher when the room temperature is lower. As a result, where underfloor heating is provided throughout much of the floor it is typically adequate for fabric protection without the need for further supplementary heating, and is normally acceptable on its own for comfort heating in all but the coldest periods where some additional heat may be required.

Underfloor heating has a slower warm-up time than that of a radiator system, as the system has to heat the floor itself before the heat is released into the room. It is however not correct to say that underfloor heating therefore requires permanent background heating in order to be functional, as underfloor heating can be used for intermittent heating the same as other forms of heating, it just takes a bit longer to get warm.

Unfortunately, some companies do have a tendency to push underfloor heating, particularly in combination with heat pumps, to run all the time at a background level. They do this in order to reduce the instantaneous heat demand and reduce the size of the heating system needed so that it can work with just underfloor heating, along with working with the reduced outputs and temperatures provided by the heat pump. It however does require the church to be permanently kept at a higher temperature which has knock on effects on energy use and ongoing bills.

The length of time it takes for an underfloor heating system to be switched on before it can be felt in the room is dependent on a number of variables, however we would initially suggest around 4°C/hour, resulting in around a 2.5-3 hour warm up period. A correctly sized radiator system may be around half this. However, cleaver controls such as optimised start can help with this, by calculating the required start time needed to get the building warm.

Development of floor details will need further discussion with the Architect. Breathability of the floor can be an issue when installing underfloor heating and this will need careful consideration.

The pipe has a ‘design life’ of 50 years, however would be expected to last much longer than this. The pipes are plastic composite, so there is nothing to rust of corrode over time.

Underfloor heating manifolds will need to be located in inconspicuous locations around the church to feed the floor pipe loops. These can either be located on walls, concealed within joinery or cupboards or, alternatively, be located under the floor with access panels above (although this is only if no other options can be found).

As mentioned in previous sections, underfloor heating is particularly suitable for heat pump systems as the water temperatures generated efficiently by the heat pump match those required to pump into the floor.

7.1.3 LTHW FAN CONVECTORS

Fan convectors can be used as an alternative to traditional radiators. These have the advantage of being fan assisted, therefore providing a higher heat output than a radiator of a similar size. As a result, they are commonly proposed within buildings with high heat losses such as factories, halls, etc, particularly where a fast response is desired.

We would assume the reason the existing fan coil units were installed when the existing heating system was designed was to provide the fast heating response. It is likely however that the performance of these old units has now reduced to the point where this is no longer the case.

Disadvantages of these units can include:

- Noise generation from the fans within the heater, particularly when in dusty environments. It is not rare for fan convectors to be switched off or switched to lower speeds during services.
- Increased maintenance of fan components.
- The lifespan of the unit is typically 10-15 years, at which point they are likely to either need a substantial refurbishment or replacement, compared to underfloor heating and radiators which are unlikely to require any maintenance for a much longer period.
- As the units heat the air directly, stratification within tall areas can be an issue and result in hot temperatures near the ceiling whilst providing significantly cooler areas at occupant level. This can be reduced by arranging the heaters to blow the warm air across the floor rather than out of the top of the unit, or by fitting destratification fans on the ceiling to blow the warm air back down.

Figure 10: Typical fan convector (Dunham Bush)

The units are generally white steel boxes, so it is common where visual appearance is important for them to be housed within timber casings with grilles provided at high and low level to match the grilles in the unit.

Fan convectors, being an emitter that only heats the air, are 100% convective with no radiant element and therefore can result in issues with the building fabric and sensitive finishes if not carefully controlled. This is due to the increased risk of condensation with warm air and cold surfaces. We would always recommend that in historic buildings where condensation, damp, or protecting the building fabric is an issue that a radiant form of heating is also included, for example, radiators or underfloor heating.

7.1.4 TRENCH HEATING

Trench heaters can be commonly seen within churches with cast iron decorative grilles above to be in keeping with the rest of the church. They most commonly consist of either bare or finned heating pipes run within the trench, with the heat driven out by convection. Fan assisted models are also available.

The output of the trench heaters are significantly affected by the depth of the trench and we would suggest a minimum depth of 150mm is required to get a good amount of heat output (shallower or deeper versions are available).

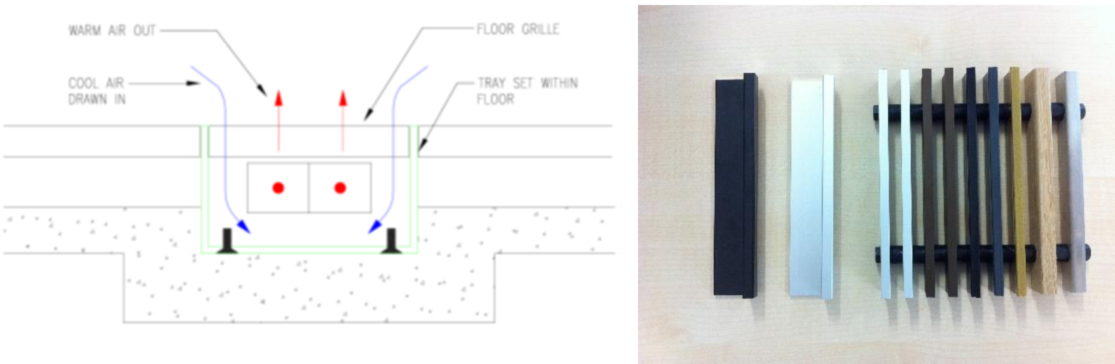


Figure 11: Typical detail for trench heaters and different types of top grille finish

The location of trench heaters will need to be carefully considered if the intention is to have a flexible seating plan, by either locating the trench heaters in locations away from the seating, or selecting suitable grilles that can support and won't get damaged by chair legs, etc.

We would recommend that fan assisted models are only used if no other options are available as they are susceptible to dust build-up and limited lifespan.

7.2 LOCAL ELECTRIC HEATING

Local electric heat emitters can be used as either an alternative to providing a low temperature hot water heating system or to supplement one.

The main advantage to this approach is the significant reduction in infrastructure required for this solution and, therefore corresponding reduction in installation costs. However, this is at the cost of lower levels of comfort, poor control of the internal environment and increased risk of deterioration of the building fabric due to damp and surface condensation.

Local electric heating can, and is, used successfully in many church buildings which are very infrequently used, with low levels of occupation, low expectations of comfort levels and no plans for future increased use in the community, and therefore cannot justify the installation and running costs of a full heating system.

Due to the local nature of the heating, we would recommend that these solutions should only be used as the main source of heating if conservation of the building fabric is deemed unimportant.

As the aspiration of increased utilisation of the church is a key part of the proposals, we do not recommend that local electric heating is the right way forward here, however we have included them for completeness of the report.

7.2.1 INFRARED OR PANEL RADIANT HEATERS

These are normally electric units and are quite often found within churches where other options have been found to be too difficult or expensive to install. They work by providing a very hot surface, which through radiant heat transfer can be directed at a particular location, normally the congregation. Radiant heating requires line-of-sight between the heater surface and the occupants, therefore only people directly under where the heater is pointed will feel the effects.

Figure 12: Left: Infrared radiant heaters installed at high level (SunSwitch)
Right: Brown-painted radiant panels installed on ceiling (Solray)

Radiant heaters do not significantly heat the air, so the air temperature will remain low. This means that the heat loss of the building is reduced, resulting in lower energy consumption.

As radiant heaters are directional and usually pointed towards the floor, the walls of the church will remain cold. This can mean that the risk of condensation, damp and mould increase, particularly during colder periods. Radiant heaters can also be considered to be uncomfortable to sit under by some occupants, as the high radiant heat combined with low air temperature can result in the sensation of lightly burning (like being in the midday summer sun).

7.2.2 UNDER-PEW HEATERS & HEATED PEW CUSHIONS

Both of these two technologies are available for use in churches that are retaining their pews in a fixed location, however as part of the proposals the pews are being removed and replaced primarily with flexible seating. We therefore have no investigated these any further.

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7.3 RELATIVE BENEFITS OF AVAILABLE HEATING OPTIONS

The below table aims to summarise the pros and cons of each option to aid future discussions on the way forward.

System	Pros	Cons
Radiators	- Relatively simple to integrate in comparison to other options. - Minimal intrusive works required as pipes can remain exposed. - Many different radiator styles available. - Cheaper than underfloor heating as less builder's work is required. - Some radiant heat provided which is beneficial to building fabric protection.	- Visual appearance can detract from the space if overly large. - If only radiators are used to provide space heating, these can get quite big and intrusive, especially if a heat pump is to be used. - Occupants near radiators will get greater benefit than those away from them – heating in the centre is limited. - Radiators present a scalding risk due to their high surface temperature (when used with a boiler).
Underfloor Heating	- Visually not noticeable. - Provides a balanced background heat over the area covered. - Provides heat where required directly under occupants particularly in the centre of the church. - Reduces stratification. - Gently warms the fabric of the building, which will help guard against future condensation issues. - Floor temperature will be limited to below 30°C (depending on floor finish), therefore no hot surfaces that could present a risk of burning.	- Disruption within the church during the works, although if a new floor is proposed anyway this is already the case. - Relatively low heat output unless installed throughout the church. - Warm-up time is slow, therefore better suited to providing constant background heat. - Some element of excavation can be required unless the underfloor heating can be incorporated within the new finish depth. - Depending on the required builder's work necessary, this can be an expensive option.

Fan Convectors	- High output heaters, therefore fewer are required. - Relatively simple to integrate. - Can be less expensive than radiators due to the lower number of heaters. - Low disruption within the church similar to radiators. - Can be boxed in within joinery, so long as air grilles are maintained. - Provides fast warm up time.	- The fans within the units can become noisy, particularly in dusty environments. They will likely need to be switched off during services. - Heaters need regular maintenance to keep fans running correctly, and have shorter lifespan. - Convective heat can result in stratification within the space, destratification fans are recommended to help with this. - Can cause condensation and cracking issues if poorly controlled.
Trench Heaters	- Discrete - When used along perimeters they can be used to combat downdraughts. - Can be used to get heat into areas where radiators/fan convectors are unable to reach.	- Require the floor depth to be able to fit. - Outputs tend to be quite low unless they are very large or fan assisted. - Location needs to be carefully considered as grilles can be an issue with narrow heels. - Stratification can be a problem if overused as they provide fully convective heat. - If the floor is not level, they can be difficult to fit in long lengths. - The fan assisted models can get quite dusty and this affects the lifespan of the unit. They can also become noisy and will likely need to be switched off during services.
Electric Radiant Heaters	- Relatively small and simple to integrate. - Provides instant heat. - Can be less expensive to install. - Cheap to run. - Low amount of disruption within the church and low amounts of builder’s work.	- Only heats occupants and surfaces where the heater is pointed, generally the church will be cold. - Heat can be considered uncomfortable, especially when too close or too far from the heaters. - Increased risk of cold surface temperatures, resulting in increased risk of condensation, damp and mould. - Incoming electrical supply may need upgrading.

8. HEATING RECOMMENDATIONS

8.1 SUMMARY OF REPORT

1. It is recommended, at the moment, that the proposals warrant a complete replacement of the existing heating system, due to its arrangement, age and condition, with the possible exception of the boilers and boiler shunt pumps.

2. We would recommend improving the control of the heating within the church so that it is intermittently heated using time and temperature controls. We understand permanent background heating is not wanted, with the exception of providing frost protection.

3. We would recommend that consideration is given to the installation of roof insulation sometime in the future, as this not only reduces heat loss and energy use, but also makes low and zero carbon heating options, such as heat pumps, more viable. However, we appreciate that this will not happen as part of this project and may be many decades away.

4. Either retaining the existing domestic gas boilers or providing a new commercial gas boiler would be one of the simplest installations, but would likely result in an increase in running costs as the church is heated better. We would recommend, due to evidence of corrosion and damp conditions inside the current boiler room, that the condition of the room is improved, or alternative location sought.

5. Net zero carbon with a natural gas solution relies on a green gas tariff, of which there are not many currently commercially available and most rely on carbon offsetting of the fossil fuel carbon emissions due to lack of bio-gas availability. The market would therefore suggest that the vast majority of buildings going forward will need to consider switching to an electric fuel source in order to meet net-zero carbon targets going forward to reduce the demand on bio-gas, although there could be some exceptions.

6. Direct electric boilers may not be viable due to the large incoming electrical supply required, and result in significantly higher running costs. It should be possible to install an air or ground source heat pump, helping to reduce both of these down to the equivalent of gas boilers. However these both require significant commitments and compromises to successfully implement. Due to the reduction in output of heat emitters as a result of the lower water temperatures produced, we would recommend that a heat pump solution is designed either with the consideration of additional/larger heat emitters, the use of top-up boilers to boost water temperature, destratification fans, run whilst keeping the church at a higher background temperature, or the addition of roof insulation at a later date, in order to offset this.

7. High temperature heat pumps are an emerging technology, which would remove the need for bigger heat emitters, however at the time of writing, these are expensive and operate at such poor efficiencies that they are not cost effective compared to gas boilers.

8. We do not currently recommend the use of radiant electric heating as the primary source of heating in the church due its proposed frequent and varied use and due to the increased risk of condensation and damp. Electric heating could also be used as a 'top-up' form of heat for the coldest parts of the year.

The heating system chosen will depend on the Church's priorities with regards to carbon emissions and available budget.

We have outlined three possible solutions below. These are just example options and there are a number of other solutions in between which could be possible. The aim of providing these options is to help understand what the priorities for the project are and, how a solution can be provided to meet these priorities within the scope and budget.

8.2 OPTION 1A – RETAIN EXISTING GAS BOILERS, WITH NEW RADIATOR AND FAN CONVECTOR SYSTEM

Option 1a, the lowest cost option, would be to retain the existing domestic gas boilers, and possibly the boiler shunt pumps, but to connect this to an entirely new LTHW heating system incorporating a mix of cast iron column radiators and fan convectors.

Please note that for all options the system will be converted to a pressurised system, and therefore there is no need for a feed and expansion tank or cold feed and expansion pipework.

We have proposed a mix of fan convectors and radiators to ensure that we provide some radiant heat into the church to help warm the building fabric and avoid drying out, whilst at the same time providing enough heat to warm the church to the required standard.

To do this we have proposed radiators and fan convectors around the perimeter of the nave. Unfortunately, due to high heat losses this does mean much of the wall is taken by heat emitters.

We have also proposed radiators positioned alongside the columns in order to get more heat into the centre of the church. These could be cast iron column radiators or vertical fan convectors, the latter may not be required on each column due to their increased output.

The existing boilers will remain in the existing boiler room with their current flue set up, although we would recommend conditions in the room are improved to increase the life of the equipment.

The existing boilers are currently slightly undersized, which would likely result in longer warm up times and the church struggling to stay warm during the coldest periods. We are therefore proposing that a 20kW electric boiler is provided adjacent to the boilers to assist the boilers during the coldest periods.

The dual heat sources will have an impact on the heating controls, making them more complex and complicated in order to provide this function.

Refer to heating diagram 1 for further details.

8.3 OPTION 1B – RETAIN EXISTING GAS BOILER, WITH UNDERFLOOR HEATING, PERIMETER TRENCH HEATERS AND CENTRAL RADIATORS/FAN CONVECTORS

Option 1B is the same as Option 1A in that it plans to retain the existing boilers, with top up electric boiler.

However instead of providing radiator and fan convectors which would take up a significant amount of wall space, this option is developed to free as much of the walls as possible by using underfloor heating and trench heaters.

Space heating is proposed to be predominantly provided by underfloor heating, with perimeter trench heaters on the north and south walls to avoid the need for perimeter radiators and keep the walls clear. We have not considered the location of cupboards and storage currently, and this will need to be considered.

We have based the trench heater sizes and lengths on passive natural convection units rather than fan assisted, for the much-improved life expectancy.

In order to adequately heat the church further heating is required and we have proposed the same radiators/fan convectors on the central columns as in Option 1, again to improve heating in the central space.

Refer to heating diagram 2 for further details.

8.4 OPTION 2 – NEW GAS BOILER WITH UNDERFLOOR HEATING, PERIMETER TRENCH HEATERS AND CENTRAL RADIATORS/FAN CONVECTORS

Option 2 assumes that it is decided that retaining the existing boilers takes on too much risk and instead proposes a new commercial boiler to provide the heat, located in the existing boiler room. Again, we would suggest the room conditions are improved in order to improve the life of the equipment.

The commercial boiler will require a different flueing arrangement, so we have proposed installing a new flue liner within the adjacent chimney.

The electric top-up boiler won’t be required as the boiler will be sized to provide the full heating allowance.

Heating in the space is the same as in Option 1B to free up wall space.

8.5 OPTION 3 – NEW AIR SOURCE HEAT PUMP WITH UNDERFLOOR HEATING, TRENCH HEATERS

Option 3 is an option to get the church off of mains gas. Instead of a gas boiler, heat will be provided by an air source heat pump located to the west of the church in a compound against the existing wall as part of the refurbishment of this area of the church yard. Buried heating pipework will be run below the proposed path into the existing boiler room.

In order to keep the heat pump efficiency as high as possible, water temperatures of the heating system will be kept low, no greater than 50°C. This will be adequate for most of the year, however during cold periods it is likely that this would not produce enough heat from the radiators, trench heaters and fan convectors to adequately heat the church. We therefore propose to keep the existing boilers and use them to raise the temperature in the circuit serving the radiators, trench heaters and/or fan convectors when needed to improve the heat output. If the existing boilers do not survive, or if a full off-gas solution is desired this function could be performed by a 20kW electric boiler same as proposed in Option 1, or an equivalent new small gas boiler.

The controls required to operate this will be more sophisticated than in the other options, due to the required integration of the heat pump.

Space heating for this option is proposed to be provided by underfloor heating and trench heaters the same as Option 2, however to remove the central radiators/fan convectors will have proposed an additional two rows of trench heaters to boost heating in the central area.

8.6 SUMMARY

<u>OPTION 1A – RETAIN EXISTING BOILER, NEW RADIATORS AND FAN CONVECTORS</u>

Estimate Budget Cost	£70,000 – 90,000
Estimate Energy Use	45,500kWh/year (30% more than current use)
Estimate Running Cost	£2,000-2,500/year
Estimate Carbon Emissions (if zero carbon tariff)	0kgCO2/year
Estimate Carbon Emissions (if standard tariff)	9,500kgCO2/year

<u>OPTION 1B – RETAIN EXISTING BOILER, UNDERFLOOR HEATING, TRENCH HEATERS AND CENTRAL RADIATORS/FAN CONVECTORS</u>

Estimate Budget Cost	£80,000 – 100,000
Estimate Energy Use	45,500kWh/year (30% more than current use)
Estimate Running Cost	£2,000-2,500/year
Estimate Carbon Emissions (if zero carbon tariff)	0kgCO2/year
Estimate Carbon Emissions (if standard tariff)	9,500kgCO2/year

<u>OPTION 2 – NEW BOILER, UNDERFLOOR HEATING, TRENCH HEATERS AND CENTRAL RADIATORS/FAN CONVECTORS</u>

Estimate Budget Cost	£100,000 – 120,000
Estimate Energy Use	40,500kWh/year (10% less than above assuming more efficient boiler)
Estimate Running Cost	£1,750-2,250/year
Estimate Carbon Emissions (if zero carbon tariff)	0kgCO2/year
Estimate Carbon Emissions (if standard tariff)	8,500kgCO2/year

OPTION 3 – AIR SOURCE HEAT PUMP, TOP UP BOILER (ELECTRIC/GAS), UNDERFLOOR HEATING AND TRENCH HEATERS

Estimate Budget Cost	£125,000 – 150,000
Estimate Energy Use	14,500kWh/year (assuming average CoP of 2.5)
Estimate Running Cost	£2,000-2,500/year
Estimate Carbon Emissions (if zero carbon tariff)	0kgCO2/year
Estimate Carbon Emissions (if standard tariff)	4,000kgCO2/year

9. ADDITIONAL HEATING CONSIDERATIONS

9.1 AIR CURTAINS

Part of the proposals include the provision of a new large glass lobby to the north door to reduce draughts. The lobby is large enough for it to be unlikely both doors will be open simultaneously unless a large number of people are entering or leaving simultaneously. This could be further reduced by the use of air curtains, however as the lobby is intended to have a glass 'lid' this may be difficult to incorporate.

We would suggest however it is given further consideration.

Figure 13: Horizontal and vertical air curtains from JS Air Curtains

9.2 DESTRATIFICATION FANS

A key issue often found in churches is the length of time it takes to bring the church up to temperature when heating up from cold.

Destratification fans may assist with this. One of the key issues with any radiator or fan coil unit system, particularly when combined with an uninsulated roof, is that the heat given off by the emitters stratifies and much is lost through the roof before ever being felt in the space. Destratification fans reduce this by using ceiling fans to gently direct the warm air back down into the occupied space. This helps to provide a more uniform temperature profile within the building.

The units require very little maintenance and normally have an operating life of 10-15 years. This is something we would also recommend is considered further.

Figure 14: Destratification fan by Airius. Fans can be powder coated any RAL colour to match ceiling

10. OTHER MECHANCIAL SERVICES

10.1 DOMESTIC WATER

Although the existing incoming water main into the vestry is relatively new and in good condition, it is in the wrong location for the proposed scheme. It is therefore proposed to relocated this so that the incoming water enters the building in the WCs, with a second incoming water main entering the kitchen.

As domestic hot water demand is low and infrequent, we would recommend this is provided by direct electric water heaters positioned close to the hot water outlets. This will be more efficient than producing the hot water centrally from the boiler/heat pump and requiring return loops.

10.2 DRAINAGE

New drainage will be required to both sides of the church to connect to new sanitaryware in the WCs and kitchen. Care will need to be taken to ensure that the drainage is adequately vented to avoid the pulling of traps.

10.3 MECHANICAL VENTILATION

The kitchen and WCs will both require local mechanical ventilation for removal of steam and odours. Discussions will be required with the Architect as to how best discharge these to outside. On previous projects we have ducted extract fans through the wall with new cast iron air brick terminals fitted to the outside. Both fans will be domestic in nature, with each WC requiring the equivalent of a 4" fan and the kitchen requiring the equivalent of a 6" fan. Examples of fans are below:

Figure 15: left: WC extract fan, right: kitchen extract fan

The incoming water main could be brought into the kitchen and WCs directly from outside with separate stop cocks. Alternatively, a single water main could be brought in buried through the west porch into the kitchen, and from there run buried to the WCs. Water mains under the building will need to be installed in continuous plastic pipe (no joints), sleeved along its whole length, and buried at sufficient depth to avoid warming.

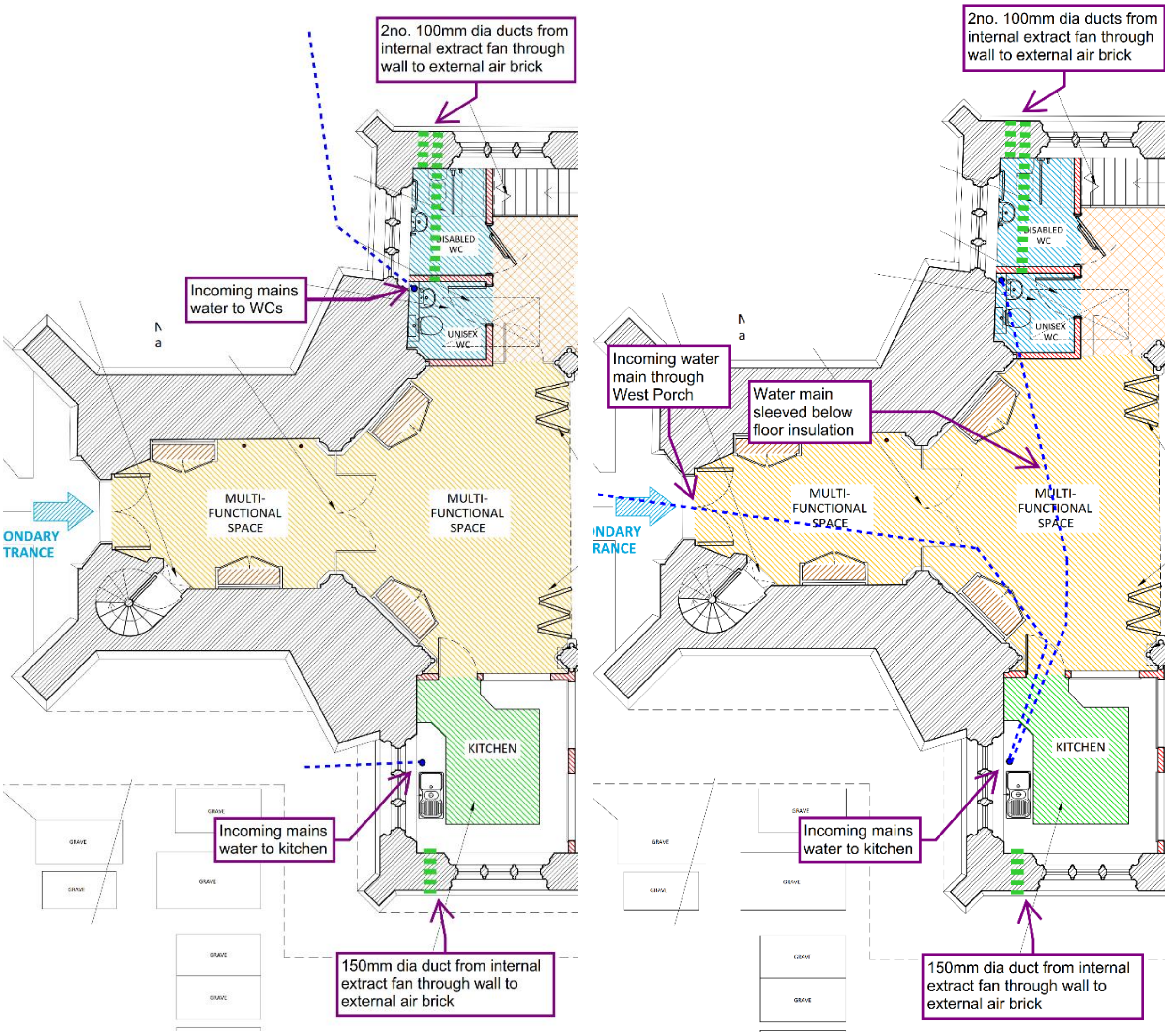

Figure 16: Ventilation and incoming domestic water options

11. EXISTING ELECTRICAL SERVICES

11.1 INCOMING ELECTRICAL SUPPLY

The Scottish & Southern Electrical power supply is routed via an overhead service cable from their network connections mounted on the side of the adjacent Church cottage. The cable enters the Church at high level adjacent to the west window of the north aisle where it then drops down internally into the electrical cupboard below. The supply is single phase 230Volt and the fuse holder states 100Amp rated, although it is possible a smaller rated fuselink is installed. The electricity meter is noted as being rated at 20-80A, therefore the fuselink rating should be 80A or lower (possibly 63A)? The fuselink cannot be accessed as it is within the sealed S&SE fused holder. The incoming supply arrangement appears to be in an acceptable condition for its age.

The earth arrangement is TT although this could not be fully verified without access to the rear of the electrical cupboard which would have required dismantling it, and no external electrode was identified (a requirement of a TT system).

11.2 ELECTRICAL DISTRIBUTION

All electrical distribution emanates from Church switchgear within the electrical cupboard referred to above, with the exception of some heating supplies and controls which are located in a matching cupboard at the west end of the south aisle.

The utility supply fused cut out is looped after the meter via terminal blocks into two Distribution boards and a supply to the heating controls. The Wylex Distribution Board contained miniature circuit breakers (mcb's) and residual current devices (rcd's) but has no circuit identification provided. The adjacent Crabtree Polestar Distribution Board contained miniature circuit breakers (mcb's) only and has board designation (Nave & Chancel Lighting) and circuit identification provided.

Whilst the two distributions boards are in reasonable condition and may have complied with the wiring regulations BS7671 at the time when they were installed, due to ongoing revisions to the standards, this is no longer the case. This is confirmed by the Periodic Test & Inspection report into the mains wiring installation, dated 2017 and witnessed on site, which classes the installation as 'Unsatisfactory'.

A sub-main cable is routed to the Organ area where the supply is terminated in a small distribution board that serves the Organ services and some local supplies. Power supplies are also routed, via an existing floor trench to the basement/cellar boiler room.

The heating controls and wiring appear to be the original installation from the 1960's.

11.3 WIRING

Wiring throughout appears typical of a Church installation with the last full rewire, believed to be from the 1960's, wiring type now mixed with alternative wiring types that have been added over the following years. There is evidence of:

MICC cabling, both with PVC sheath and bare. This appeared to be the system used on the last full rewire in the Church. As has already been noted in Project reports there has been some significant reaction between the copper insulation of the bare MICC cable and the wall plaster where surface mounted at low level around the perimeter of the Church, which has led to plasterwork breaking away. The cable at these locations has deteriorated and faults are already being experienced by the Church.

PVC Twin & Earth cabling. This is installed in several areas, principally used for extensions and adaptions since the original MICC cabling installation.

Prysmium FP200 or Firetuff – there are only a few instances of this type of cabling, which has been installed in the recent past and is in good condition

Where cabling has been added since the last full rewire this is generally surface mounted and fixed to stonework, with the originally sub-standard cabling, and at the foot of timber partition walls in an unsightly manner.

Accessories: sockets, light switches, etc., are predominantly surface mounted and those from the original installation are showing signs of age.

11.4 LIGHTING

The existing lighting is a combination of incandescent lamps and halogen spotlights, most of which are showing signs of age. Some spotlights appear to have been replaced with low energy equivalents, however none of the rest of the lighting appears to be low energy by current standards.

Some spotlights are located at the highest level on the Nave walls and maintenance of these is proving time consuming and costly to the church

Switching is generally provided by two multigang manual switches located within the electrical cupboard at the west end of the north aisle, one 15 gang and the other 8 gang. These switches are showing signs of age and gang identification is poor and worsening. Separate local manual switches are provided for the Vestry, Ringing Chamber, Bell Chamber and Boiler room.

Floodlighting is time controlled and can be activated upon request via a mobile communications link.

11.5 EMERGENCY LIGHTING

There is minimal emergency lighting currently installed, namely two illuminated exit signs. This does not appear to provide coverage in full compliance with BS5266. However, derogations from the standard may have been previously agreed due to confirmed evacuation procedures and the Listed status and historic nature of the building.

11.6 SMALL POWER

Small power provisions, namely 13A socket outlets, are minimal within the Church and plug in extension leads were noticed in a number of locations.

There is a dedicated supply to the Organ where dedicated switchgear and controls are located.

11.7 IT/DATA CONNECTIVITY

Currently only limited Wifi services are provided in the church by a repeater/booster with signal communications from the adjacent Parish Office.

11.8 AUDIO VISUAL SYSTEMS

A limited AudioVisual system is installed basically formed of hard of hearing induction loops, microphone facility and four high level speakers, all linked back to amplification equipment located loose on top of a timber cupboard at the west end of the north aisle. MTA were advised the speakers were approximately 40 years old.

11.9 INTRUDER ALARM

There is currently no intruder alarm system in the Church.

11.10 CCTV

The Church has a fully operational CCTV system consisting of 13 colour fixed lens cameras. Two of the cameras are located on the adjacent Church cottage, with roughly five internal cameras and six external cameras at the Church. The Church cameras are wired back to a controller/recorder sitting on top of cupboards at the west end of the north aisle. A cable is linked from this equipment to an external transmitter which sends picture transmissions wirelessly to a receiver mounted on the adjacent Church cottage.

The CCTV camera on the roof has a local alarm facility.

The system is remotely monitored and controlled, via wireless communications equipment, as was witnessed on the Church representative's (Richard Bell) mobile phone.

11.11 FIRE ALARM

There is currently no fire alarm system in the Church.

11.12 LIGHTNING PROTECTION

A full system of lightning protection air terminations, down conductors and earth rods are present.

MTA were advised that the Lightning Protection system is serviced annually as is the requirement under the British Standard.

12. ELECTRICAL SERVICES RECOMMENDATIONS

The following should be read in conjunction with the two copies of Chedburn Dudley As-Proposed layouts, overmarked with 'MTA small power distribution and general electrical services proposals' (1) and 'MTA Lighting proposals' (2), provided with this report.

12.1 ELECTRICITY SUPPLY

To assist in the understanding of power supply requirements MTA have included the tables below which show the base church power supply peak requirement plus the addition of electric heaters, aligned with new gas boiler(s), under 'Heating Options 1 and 2', and the base church power supply peak requirement plus the addition of two air source heat pumps, under 'Heating Option 3.

To further confirm the need for a new electricity supply it is requested the Church makes an enquiry to their Electricity Supplier for confirmation of the maximum capacity in kVA of their existing supply and the rating of the fuses fitted, as retaining a single phase supply remains a possible option.

If it were confirmed that 80A fuses were fitted then it might be feasible, with the diversity allowances shown in the table, that the peak load under Options 1 and 2 could remain below this rating, under the existing electricity supply. However, a risk would remain of an overload occurring at peak usage/occupancy/nightime/winter conditions. There is an option of providing a new small 3 phase supply (or new 100A single phase supply) if either of these Options were selected, and the existing supply was a) definitely required to be renewed as an underground service, or b) found to be below the required single phase load requirement.

The new electrical supply could be brought in through the north porch as indicated on the general electrical proposals diagram, or alternatively through the west porch.

An upgrade of the existing 60/80A single phase 230V supply to an incoming 80/100A 3 phase 400V supply would be necessary to provide adequate capacity to incorporate the proposed heating option 3 and enhanced usage of the Church, subject to final design.

	HEATING OPTIONS 1 AND 2					
	Element	Sqm	Watt/sq /m	Watts		
Base load	Internal lighting	302	10	3020		
	Floodlighting			1600		
	General Small Power (excl any heating)	302	8	2416		
	Organ			1000		
	Urn/Water heater			3000		
Heating	electric heater in vestry			2000		
	electric heaters in the two WCs (2kW total)			2000		
	2kW electric heater in ringing chamber			2000		
				17036	Watts	
	adjustment for power factor			0.85		
	Total VA			20042.35	VA	
	diversity reduction allowance		15%	17036	VA	
	peak electrical load			17.04	kVA	
				74.07	Amps single phase	
				24.58	Amps three phase	

	HEATING OPTION 3					
	Element	Sqm	Watt/sq m	Watts		
Base load	Internal lighting	302	10	3020		
	Floodlighting			1600		
	General Small Power (excl any heating)	302	8	2416		
	Organ			1000		
	Urn/Water heater			3000		
Heating	electric heater in vestry			2000		
	electric heaters in the two WCs (2kW total)			2000		
	2kW electric heater in ringing chamber			2000		
	Heat Pump x 2 (three phase)			30400		
				47436	Watts	
	adjustment for power factor			0.85		
	Total VA			55807.06	VA	
	diversity reduction allowance (excl Heat Pumps)		15%	52800.71	VA	
	peak electrical load			52.80	kVA	
				229.57	Amps single phase (n/a)	
				76.19	Amps three phase	

The PCC has expressed a wish to remove the rather unsightly existing overhead electricity supply cable under this project and as there is proposed resurfacing/groundworks to Shelley's Walk and to the ground floor in the North Porch, there is an ideal opportunity to bury a new supply cable along this route and into a new supply termination, fused head and metering position just inside the new glazed inner lobby. Suggested locations for the termination position are shown on the sketch mark-ups attached. Indicative space needed for S&SE's incoming supply fused termination head and metering is as follows:

Single Phase supply – 800 x 800mm wall space
Three phase supply – 1000 wide x 1200mm high wall space

With the existing supply being single phase it becomes a more challenging exercise in procuring a three phase supply, which will be totally dependent on Scottish & Southern Electricity's three phase availability and physical cabling network in the area. However, with the Church being town centre located there it is much more likely that a supply connection is available nearby, as opposed to if the Church were in a remote location. It is recommended that a supply application is made to S&SE early in the next stage of the Project, in order that a proposal, cost and any implications can be raised. A reliable indicative budget cost is not possible without this application.

12.2 ELECTRICAL DISTRIBUTION

The existing distribution boards and switchgear are not suitable for reuse, due to age, condition, obsolescence and non-compliance, as highlighted within the unsatisfactory overall rating on the 2017 Periodic Test & Inspection Certificate. They are also located in an area designated for a new WC under the proposed Project plan. It is therefore proposed to provide new distribution switchgear, suitable for the proposed three phase supply in a new location, and to comply with the 18th Edition Wiring Regulations.

It would not appear possible to locate the new distribution switchgear at the same proposed location as the new S&SE supply termination due to available space and it is therefore proposed to site the distribution switchgear behind the relocated Chancel screen up on the new proposed Gallery level. There would appear a relatively straightforward cabling route from the SSE termination head up to the Gallery, via the new raised floor and potential to conceal the rising cabling within a proposed storage cupboard, as shown on the sketch mark-ups attached, or within the new WC construction.

A new 100A rated 12way three phase distribution board is proposed to be installed at this location (dimensions 724 high x 440mm wide, plus 2No AFDD enclosures at 564 high x 440 mm wide each). This will provide supplies to the Organ area and basement boiler room, replacing the obsolete items of switchgear, as well as providing final circuits to all other small power and AudioVisual installations, including the Kitchen, Office and Tower. The distribution board will also provide the mains supply to the proposed Lighting Control Panel (approx. dims 800mm high x 600mm wide x 120mm deep) also in this position.

The small 4 way distribution board located in, and serving, the Organ area should be replaced as its poor condition was highlighted in the 2017 electrical installation report (dims 254 high x 292mm wide, plus 1No AFDD enclosures at 254 high x 440 mm wide).

Additional electrical distribution will need to be provided to suit the final heating option, such as a small Distribution Board in the basement/cellar.

Distribution boards shall be provided in a way that allows separate metering of lighting and power loads in order to comply with energy efficiency targets contained in Part L of the building regulations.

Circuit protective devices shall be included to provide RCD protection of all circuits. Surge protection devices shall be provided at the incoming cable positions to protect the installation from fire risks from transient voltages and downstream devices to protect the electrical and AV installations.

Arc Fault Detection Devices (AFDDs)

AFDDs are recommended by the 18th Edition of the Wiring Regulations. These are an additional safety component added to the standard circuit breaker/RCD for each final circuit, and do add a cost and space implication. Inclusion of AFDDs are recommended within BS7671. A detailed explanation of these can be found in Section 15 Appendix A.

12.3 WIRING

With the proposed extensive modifications to the building layout and requirement for new switchgear location, combined with the unsatisfactory condition of much of the existing installation, it is recommended that a full mains cabling rewire is provided within the reordering project at the Church. This should include rewiring of the tower spiral staircase and tower in general. It may however be feasible to retain the local Organ services wiring, which emanate from a local distribution board in the organ area, although it is noted there is much unsightly surface mounted cabling in the area and this will depend on final agreed use of the space around the Organ.

All new cabling will be provided with low smoke zero halogen sheaths. New cable routes will be coordinated with the new layout and the existing structure, taking particular advantage of the new flooring being installed throughout much of the Church. This will reduce the extent of visible surface mounted cabling, which will be concealed where possible, however, given the historic and listed nature of the structure, walls and finishes surface fixed cabling, sockets and other electrical accessories will be required in certain instances.

The new mezannine balcony will also be fully utilised to route and conceal new cabling, as will the existing raised timber flooring on either side of the choir/chancel.

12.4 ACCESSIBILITY

Accessories, light switches, sockets, etc., will be provided in colour contrasting finishes and at mounting heights to comply with Part M of the Building Regulations.

12.5 LIGHTING

With the proposed extensive modifications to the building layout, combined with the generally aged and inefficient condition of the existing internal lighting, it is recommended to provide new lighting via low energy luminaires throughout within the reordering project at the Church. This would include the basement boiler room, ringing chamber, bell chamber and tower.

Emergency lighting should be provided throughout the building, replacing existing, to comply with BS 5266, but this will also follow the requirements given in the Church's recently undertaken Fire Risk Assessment.

<u>Lighting Strategy:</u>

General lighting in the nave and aisles would be achieved with wide angle spot/flood lights mounted at wall plate level to give an average illuminance of 200lux dimmable to suit various uses of the space. We would propose to utilise small/discrete units in a white finish which can be easily concealed against the light coloured walls and stone wall plate.

Points of emphasis would be created using a similarly styled luminaire with tailored beam width and output to illuminate areas like the altar, font, pulpit, memorials, carvings etc. Specifically designed luminaires would be proposed to provide subtle and appropriate uplighting to the stained glass windows and clerestory windows, and possibly an element of uplighting grazing the wooden beam details of the roof. This requires only a small amount of light so a very small luminaire can be used and is therefore easily concealed.

It is also intended to provide some feature uplighting to the main columns in the Nave, utilising small recessed LED uplighters, installed and wired within the new floor construction. Angled beams and built in glare shields can be incorporated to avoid unacceptable glare to visitors. This proposal may also be utilised to enhance the 'welcome' lighting within the new glazed inner lobby.

Lighting within the multi-functional spaces will incorporate luminaires with both a functional and decorative design, predominantly ceiling/soffit mounted to avoid surface mounted cable drops. There is a wide variety of styles available for these areas, be it traditional, classic or a more contemporary design, and a number of options would be put forward to the Church and Architect during the design stage.

Access lighting is also proposed for the new Shelley's Walk with a number of style options to be agreed with the Church and project Architect, ie ground recessed uplights, bollard lights.

It is recommended all lighting in open Church areas is provided with 3000K colour temperature (warm white) lamps/luminaires, which is known to enhance historic stonework and timber features aswell as providing a more comfortable ambience. The Office and Kitchen may benefit from a colder light, more daylight in effect, at 4000K colour temperature.

All new luminaires will have LED lamp source, which provides maximum efficiency and reduces maintenance time and cost. Location of LED Drivers/Transformers, which are often remote from the luminaire, will need attention and coordination during the design stage, to ensure they are concealed as best as possible but remain accessible.

Lighting design will be undertaken at a later stage but for Feasibility Study the following suggested luminaires and spreadsheet can be used as an indicative guide for the intended scheme:

Illuma Pro-Spot: (Type A)
Proposed spot/flood- light used for general lighting throughout, discretely mounted at high level. Dimmable and with adjustable beam angle
Approx. 95mm Diameter.

LightGraphix LD56 (Type B)
Recessed floor uplighter, at foot of stone columns, walls
Available with a choice of beam angles and LED colours, as well as a new optional glare shield.
52mm overall diameter, 42mm recess depth

Light Graphix Micro Spotlight: (Type C)
Proposed uplighter, used to illuminate roof beams
Approx. 35mm diameter

Simes Mini-Shape (Type D) and Shape (Type E)
Specific luminaires for window surround illumination
Mini-Shape 87 x 71 x 37mm, Shape 150 x 90 x 40mm

Thorlux Lighting – Jubilee range (Type F). Shallow profile surface mounted LED luminaires with co-extruded 'Satin-Glo' polycarbonate controller

Concord/Sylvannia Lighting – Cassini Planar (Type G), Ambient and decorative 400mm diameter LED bulkhead luminaire with halo backlight and white or silver surround

Collingwood Ltg – bespoke LED bollard in oak (Type H). 3 colours available. Recess mounted with 735mm exposed above ground. External path/access lighting option

Collingwood Ltg – LED recessed ground light (Type J), IP67 stainless steel
85mm dia. External path/access lighting option

Thorlux Lighting – Thoroproof range (Type K). IP65 LED luminaires with injection moulded polycarbonate body and frosted prismatic polycarbonate cover, both fire-retardant.

	Type A	Type B	Type C	Type D	Type E	Type F	Type G	emergency ltg provision	Type H	Type J	Type K	Lamp colour temperature	Average lux level on floor	dimmable
Norch Porch							1					warm white	150	no
New Glazed Inner Lobby							4	yes				warm white	300	yes
North Aisle	3	4		2								warm white	200	yes
Organ	2											warm white	300	no
Nave	8	6	8					yes				warm white	200	yes
South Aisle	4	4		2								warm white	200	yes
Piano Area	1			2								warm white	200	yes
Chancel	4											warm white	500	yes
Sanctuary	4			1	1							warm white	500	yes
Office						2						daylight	350	no
Kitchen						2						daylight	300	no
Disabled WC							1	yes				daylight	150	no
Unisex WC							1	yes				daylight	150	no
Grd floor M/F space (large)		2					4	yes				warm white	300	yes
Grd floor M/F space (small)							2	yes				warm white	300	no
Gallery	2		2				1	yes				warm white	150	yes
1st floor M/F space				1			2	yes				warm white	300	no
Electrical Switchgear location							1	yes				daylight	300	no
Boiler/Plantroom						1		yes				daylight	300	no
Shelley's Walk pathway									6	8		warm white	20	no
Churchyard Maintenance Building											1	daylight	150	no

It is proposed to retain the existing external floodlights at ground level and at the tower walkway, as these are believed to be of LED source and in good working condition.

12.6 LIGHTING CONTROLS

Due to the ageing and overly complicated existing manual light switching, combined with the introduction of additional specific areas under the reordering proposals, it is proposed to provide a lighting control system with scene setting controls to provide overall control of the main lighting in the church. A push of a button can recall any one of a number of pre-set scenes. The main system controls and components would be mounted within a Lighting Control Panel, which is proposed to be mounted adjacent to the new Electrical Distribution Board at Gallery level.

This would be augmented with local controls to automatically bring on lighting in the entrance areas, such as using PIR sensors, and manual switching to kitchen, office and some multi-functional areas, all linked to the lighting control system.

Controls and scenes can be programmed as desired and activated from as many positions as required either by a switch or numbered buttons or a digital touchscreen.

The lighting control system can incorporate time controllers, override facilities and dusk/dawn sensors and so is ideal to also control the proposed external access path lighting, and existing floodlighting, if required.

It would additionally be possible to control the system from an App on a phone or similar. This would require the provision of a small router, discretely positioned, linked either by cable or wirelessly, to the Lighting Control Panel.

Figure 17: Typical Lighting Controls Examples from Mode Lighting

MTA have recently specified a Mode Lighting control system at two churches, and we would recommend seeking a proposal from them during the design stage. Mode Lightings full range and details can be found on the following website: http://www.modelighting.com/. Their 'eDIN+' system would be the initial proposal here.

12.7 GENERAL POWER SUPPLIES

The following existing and/or proposed supplies will need to be incorporated within the proposed rewire and reordering project:

- Clock mechanism in the Tower
- Organ
- Projector locations

- Kitchen 'domestic' based appliances (small cooker, dishwasher, water heater, coffee/tea urn, microwave oven)

A full new provision of 13A socket outlets is proposed to avoid the use of socket adaptors and trailing leads, as existing, and to meet the requirements of the new reordering layout. This will include new replacement provisions to the bell chamber and tower.

To avoid or limit the fitting of sockets on walls it is intended to utilise the proposed new floor construction to install recessed floor outlet boxes where required along walls and adjacent stone columns. These would sit over or adjacent the buried/recessed wireways that are proposed within the flooring. Two compartment floor boxes shall be considered where data or AudioVisual outlets are required at the same locations as 13A mains sockets. Smaller hinged flap floor sockets can be utilised where only 13A mains power is required.

It may be possible to retain outgoing supply wiring, serving the Organ, although this would need some adaption as a new small distribution board would be required in the area.

The recent Fire Risk Assessment undertaken has noted that Portable Appliance Testing is overdue and it is recommended this is implemented and managed outside of the proposed reordering project

12.8 IT/DATA CONNECTIVITY

To fully service the proposed reordered church with appropriate and reliable IT/Data connectivity it is intended, as advised by the church, to install a new fibre communications cable into the proposed new Parish Office (current Vestry). This would be subject to an application and proposal from an external internet service provider. The proposed incoming cable route would preferably be buried along Shelley's Walk from the Market Place, taking advantage of and in coordination with the proposed new path and DDA access ramp construction.

Data cabling to hard wired data socket outlets and/or Wifi access points around the church, to suit the reordered layout, CCTV and AudioVisual requirements, would be extended from the router in the Office. Wifi boosters will be considered where this reduces cabling requirements between the office and the main church areas. Liaison/involvement of a specialist Data/Communications company will be required to progress/complete this element of the project.

12.9 AUDIO VISUAL INSTALLATION

The Church have expressed an intention to enhance and update the current basic Audio Visual installation within the reordering project at the Church. It is proposed that a complete new installation is provided, consisting of new central controls and amplifiers, full range speakers and hard wired and radio linked microphone points, coordinated with the proposed hard of hearing induction loop installation. The central equipment location will need to be well ventilated and allow approximately 500 x 500 x 800mm high secure accessible installation space, preferably at ground floor level where direct access to wiring routes in the new floor construction is available.

It is considered provisions for Projectors and Screens, together with required IT connectivity and mains power supplies should be provided at high level in all three ‘Multi Function Spaces’

Should the Church require specific stage/performance lighting facility, the following would be proposed. A new powered lighting gantry to include 2no 10 way lighting bars internally wired for power and DMX for theatre lighting, installed on the Nave high level wall plates. Controls can be stand alone or linked to the proposed church lighting control system However, the exact connections will need to be coordinated with the Client’s AV specialist. This can be provided with a manual or powered hoist if desired.

Liaison/involvement of a specialist Audio Visual company will be required to progress/complete this element of the project.

12.10 INDUCTION LOOPS

It is proposed to renew the existing hard of hearing induction loop installation, with tape/cabling being routed via the new raised floor construction. The main equipment would be incorporated within the Audio Visual control equipment and location

12.11 INTRUDER ALARM

It is understood the Church require an Intruder Alarm system to be incorporated within the reordering project at the Church. The required Grade of system will need to be advised by the church, under BS EN50131, which should include whether remote monitoring is required and a Police response.

The system will likely include a wall mounted accessible control panel, say 800 x 400mm, one or two entry/exit keypads, room/area dual technology sensors/detectors, door and window contacts. A wireless system could be considered but this is subject to the Grade of system required.

Within Project Inspire reports received there is a reference to ‘Construction of a small building in the southwest of the churchyard for mowers etc’ within the scheme. The church will need to confirm if it is intended to extend intruder alarms, small power and lighting to this building.

12.12 CCTV SYSTEM

It is suggested and recommended that the existing CCTV system is adapted and enhanced to meet the church’s security requirements within the proposed reordered layout at the church.

The intention is that the current system cameras and any new required cameras will need to be wired back to control and recording equipment in the new church office, where it would be linked to the new communications router to allow external transmissions and monitoring. Wifi boosters will be considered where this reduces cabling requirements between the office and the main church areas.

Liaison/involvement of a specialist CCTV company will be required to progress/complete this element of the project.

12.13 FIRE ALARM

It is understood the Church require a Fire Alarm system to be incorporated within the reordering project at the Church. This has also been recommended within the Church's recently undertaken Fire Risk Assessment. It is noted the required Category of Fire Alarm system has not been referred in the FRA and this will be necessary prior to undertaking any system design.

It is therefore recommended that a fire alarm system is provided within the reordering project, to cover the main body of Church and also the boiler room and tower, subject to Category required

The system would incorporate a control panel, manual breakglass points, automatic detectors and sounders. Wireless systems should be considered and also beam detectors to cover the high roof area over the Nave.

It is recommended that the Fire Alarm system is provided with a remote monitoring system linked to an Alarm Receiving Centre (ARC). The existing roof alarm monitoring system will be considered and reviewed as a possible alternative method of remote monitoring the fire alarm system, however, this will be subject to compliance with the required Category of Fire Alarm system required

12.14DISABLED WC ALARM

To meet the DDA requirements where a compliant Disabled WC is being provided it will be necessary to install a standard Part M compliant WC alarm system. This consists of a power supply, pull cord, reset button and overdoor audio/visual alarm unit. If required the alarm can be signalled, via cable, to a remote location, ie the office.

12.15LIGHTNING PROTECTION

The existing lightning protection shall be augmented by the provision of surge suppression devices provided as part of the proposed distribution equipment upgrade and the installation shall be connected to the main earth terminal, proposed in a new location.

13. PHOTOVOLTAIC SOLAR PANELS

Photovolatic (PV) panels, or solar panels, are often used to generate electricity using solar power, which can reduce energy bills and net carbon emissions.

Due to the removal of the feed-in tariff in 2019, the most cost-effective solar panel installation would be sized to ensure that as much of the electricity generated by the panels is used within the church itself and not exported to the grid. This can significantly limit the size of the installation, as the church's electricity use during a typical summer week when the solar panels are producing their most is low, particularly with the use of low energy lighting. We would also recommend that for this approach the installation is provided with battery storage sized in order to ensure the PV generation over a typical week is stored for it to be used when required during that week.

For the size of church and likely summer electricity demand, we would suggest the size of installation is limited to around 2-3 standard solar panels (500-750W(e) peak) with a 5-10 kWh(e) battery. This would generate around 800kWh per year (compared to the recorded approx. 4000kWh use therefore providing approximately 20% of the annual electricity demand), and offer around £100 per year energy savings, with a capital cost of around £2,000 with an extra £5,000 for the battery.

The alternative approach is to provide as many solar panels as possible in order to maximise the amount of electricity generated. Most of this electricity will be exported, and provide little financial benefit, but could be used to 'offset' carbon emissions during other times of the year when the solar panels are generating much less that the consumption.

The Smart Export Guarantee is an obligation set by the Government for electricity suppliers to make payments for electricity exported to the grid using low-carbon generation, providing certain criteria are met. It came in to force in January 2020. It is up to the electricity suppliers to set tariffs, so they vary widely between suppliers, but you could expect to be paid around 2-5p/kWh generated.

The south aisle roof is available for the installation of solar panels and we would suggest that a total of 9 panels (2250W(e) peak) could be located on this roof producing around 3000kWh per year. The savings are difficult to calculate as it is likely that generated electricity will be mostly exported, but assuming 10% utilisation on site suggests around £40 per year in savings and £100 in export income, with a capital cost of around £5,000.

We understand that there are a number of challenges with integrating solar PV panels onto church buildings, not only from Dioceses level, but also Planning and Listed Building Consent. However, the number of example installation are increasing over time as part of the move towards net zero carbon. It should however be noted that whichever approach is taken for PV going forward, it is unlikely to ever pay for itself in energy savings within its typical expected lifespan. It will also only contribute a proportion of the church's electricity needs, with the rest requiring to be supplied from a green tariff, particularly if a heating technology with an electric fuel source is selected which could push electricity use closer to 15,000kWh per year.

13.1 SUMMARY

Estimated Annual Electricity Use	4,000kWh
Estimate Carbon Emissions (if zero carbon tariff)	0kgCO2/year
Estimate Carbon Emissions (if standard tariff)	1,150kgCO2/year
Estimate annual electricity use with heat pump heating	20,000kWh
Estimate Carbon Emissions (if zero carbon tariff)	0kgCO2/year
Estimate Carbon Emissions (if standard tariff)	5,750kgCO2/year

	Number of panels	Electricity generated (kWh/year)	Reduction in carbon emissions (kgCO2/year)	Cost	Annual saving (£/year)
Use on Site Option	3	800	250	£2,000 + £5,000 battery	£100/year
Export Option	9	3000	850	£5,000	£40/year + £100/year export

14. BUDGET COSTS

We would suggest the following would be an appropriate approximate budget allowance for the different elements discussed in the report above:

14.1 MECHANICAL SERVICES

Refer to summary for heating option budget costs.

Gas boiler and controls	£20,000 - 30,000
OR	
Air source heat pump system	£50,000 – 75,000
OR	
Ground source heat pump system	£80,000 – 150,000
Additional works to line existing chimney for boiler option *(only required if existing boiler room used)*	£10,000
Underfloor heating, radiators and pipework	£60,000 - 80,000
Domestic hot and cold water	£5,000
Internal foul drainage *(does not include below ground drainage or civils works)*	£5,000
Mechanical ventilation	£5,000

The above figures do not include allowances for the following:

- Any thermal improvements, such as roof insulation.
- Builder's work in connection or finishes, which could vary significantly depending on the proposed solution.

14.2 ELECTRICAL SERVICES

New Incoming 3 phase electricity supply & metering	£20,000*
Replace/Upgrade distribution boards & switchgear	£5,000 - £10,000
Replace/rewire small power supplies	£10,000 - £15,000
Provision of new lighting	£25,000 - £30,000
Lighting controls	£5,000 – £10,000
Audio Visual installation (Music/Public Address/Sound)	£10,000 - £15,000
Audio Visual (Visual projections)	£3,000 - £5,000
Fire alarm system	£10,000 -15,000

Intruder Alarm system	£6,000 - £8,000
IT/Data requirements	£5,000 - £10,000
Stage lighting gantry	£2,000 – £8,000
Total	£81,000 – £126,000 Excl Incoming supply

The above figures will rely heavily on the final scope for each element and do not include Builder's work in connection or finishes, which could vary significantly depending on the proposed solution.

* Denotes totally subject to further enquiry with the Utility company, nominal figure only included

14.3 OTHER SERVICES

PV Solar Panels	£5,000 – 10,000 *(depends on approach)*

The above figures do not include allowances for the following:

- Builder's work in connection or roof works

Please note that these are budget allowances only, provided to assist decision making and have been estimated using a number of assumptions. They therefore should not be used as an accurate costing of the works and are subject to change, depending on the development and complexity of the mechanical services design. The budget costs above also exclude allowance for VAT and professional fees.

We would recommend professional cost advice is sought for any further cost guidance.

15. APPENDIX A – EXPLANATION OF ARC FAULT DETECTION DEVICES

15.1 BS 7671:2018 REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

The purpose of this brief report is to highlight the major changes incorporated into BS 7671:2018

It should be noted that, although the detailed design of the replacement of the electrical installation, initially took place in March 2018, the current revision BS 7671:2018 Requirements for Electrical Installations, IET Wiring Regulations (Eighteenth Edition) was published in July 2018 and came into force on 1st January 2019.
The current regulations stipulate that all installations designed after 1st January 2019 should comply with BS 7671:2018. As there has been such a delay in undertaking the works on site we strongly recommend that the new electrical installation should be installed in line with current standards and should therefore be redesigned and installed in accordance BS 7671:2018 Requirements for Electrical Installations, IET Wiring Regulations Eighteenth Edition.

Our interpretation of the main changes introduced by the 18th Edition are summarised below.

There are approximately a thousand smaller changes which are basically "bringing the regulations up to date"

The Five major changes are as follows:

15.1.1 Arc Fault Detection Device (AFDD),

These devices are now recommended for a number of locations, two of which are places where people sleep and historic buildings. This will increase cost of electrical installations as an AFDD is recommended on each circuit.

At present, AFDDs are still a relatively new product within the UK electrical market and as such the number of devices commercially available is low, although we understand that manufactures are likely to be launching new devices in the coming months.
The budget cost for an AFDD is in the region of £240 per device compared to £5 to £10 for an MCB and £30 to £50 for and RCD/RCBO.
It is anticipated the cost of these will come down but this may take 2 or 3 years.

In addition, distribution board enclosures required to house the devices, and the devices themselves are physically much larger than a 'standard' distribution board enclosure.

AFDDs need to be provided in addition to overcurrent and residual current protective devices and therefore take up additional space within distribution boards.

The majority of AFDDs currently available are "two module" devices rather than "single module" (MCBs and RCDs tend to be single module) meaning they are 36mm wide rather than 18mm wide meaning that distribution enclosures will need to be larger.

Currently AFDD's are not required fitted onto three phase circuits (the technology simply does not exists). AFDDs fitted to single phase circuits derived from three phase distribution boards will therefore need to be installed in an additional enclosures adjacent to the board.

Our initial estimate is that this is likely to result in distribution cupboards etc. needing to be somewhere between 2.5 & 3 times larger than currently needed.

It should be noted that provision of AFDDs is only a ***recommendation*** at the moment. Regulation 421.1.7 (a new clause for 18th edition) states

> *"arc fault detection devices conforming to BS EN 62606 are recommended as a means of providing additional protection against fire caused in AC final circuits.*
> *If used, an AFDD shall be placed at the origin of the circuit to be protected.*
> *NOTE: Examples of where such devices can be used include:*
> *i. Premises with sleeping accommodation*
> *ii. Locations with a risk of fire due to the nature of processed or stored materials*
> *iii. Locations with combustible construction materials*
> *iv. Fire propagating structures*
> *v. Locations with endangering of irreplaceable goods"*

We would suggest that St Lawrence Church, Lechlade falls into the

- third category given the amount of timber used in the roof construction
- fourth category, again due to the timber construction
- fifth category given the listed nature and contents within the building

May fall into the second category depending on material stored.

AFFDs are protective devices that are designed to reduce the risk of fire caused by faulty electrical installations.

"About one-third of all fires caused by electricity are attributed to hazardous arcing faults. Particular mention is to be made to serial arcing faults. Residual current protective devices (RCDs) and miniature circuit breakers (MCBs) are not designed to detect and safely disconnect serial arcing faults and do not offer adequate protection in such cases: for example damaged wire insulations, crushed or broken cables, bent connectors, loose contacts, or even defective electrical devices. The resulting electrical arcing faults can cause cable insulation to ignite, leading to a cable or even building fire."
(Source https://www.siemens.com/global/en/home/products/energy/low voltage/components/sentron-protection-devices/arc-fault-detection-devices.html)