Report

on

Heating Upgrade Options Towards Zero Carbon

at

St Nicholas's Church
Sydling Saint Nicholas
Dorchester
Dorset

Client

Parochial Parish Council
Church Lane
Sydling St Nicholas
Dorchester

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Report
Renewable Heating Options
St Nicholas's Church, Sydling St Nicholas

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INTRODUCTION

Scope of Report

A report was produced in March 2020 discussing heating improvement options based around adapting the existing Low Pressure Hot Water (LPHW) wet systems and various boiler configurations plus the provision of an 11kWp Photovoltaic (PV) electricity generation system to offset the carbon emissions of the oil-fired heating solution. The PV system outlined was a ground-mounted array located in the graveyard and down the hill from the church building in the hope that it would not detract from the Grade 1 Listed status of the church building.

The proposal has been rejected for the following reasons:

- The churchyard lies within the Dorset AONB,
- The churchyard lies within the village conservation area,
- The church site is listed Grade 1,
- The churchyard extension lies next to a bridleway,
- The Parish Council, when unofficially approached, said that they would object on the grounds of visual aspect.

Further to the above and after discussion with Mr Charles Hodgson, Church Warden, and Dr Erik Blakely of Low Carbon Dorset, this report is a response to their request for alternative low carbon solutions to heating the church along with budget costs for their implementation.

The Church of England, through General Synod, have voted to be carbon neutral by 2030.

This report records what was seen by the author during a site visit carried out on 16th April 2019. It uses the information collected during the visit to assess current utility supplies, heating arrangements, building construction, layout, fabric condition, building usage and the presence of anything that may be of value which could be vulnerable to damage by changing room temperatures.

Understanding the current church layout, the presence of fixed pews and plans for the future also assist in informing what options for heating are viable.

Because the report may be used as a "model" against which similar buildings could assess their suitability for adopting similar recommendations to those included herein, it is thought that elements of the previous report should be included in this report so that readers get a full understanding of the site specific arrangements, limitations and options previously considered. Much of the "Background" and "Heating Improvement Options" sections of the previous report have, therefore, been included in this document so that it is complete and meaningful to new readers. Budget costs have been updated to reflect current rates and fuel prices.

Terms of Reference

This report was commissioned on 2nd September 2021 under an instruction from Dorset Council (of which Low Carbon Dorset is a part). The instruction was based on our fee offer of 17th August 2021, ref PDC/FB2421/2.

Limits of Report

The information contained in this report relating to the existing services was gathered during a site visit to the church on 16th April 2019 where access was limited to ground floor areas only. The bell tower platform was not accessed during the visit.

No Record Drawings of the existing heating nor domestic water services installations were provided to the author because they do not exist.

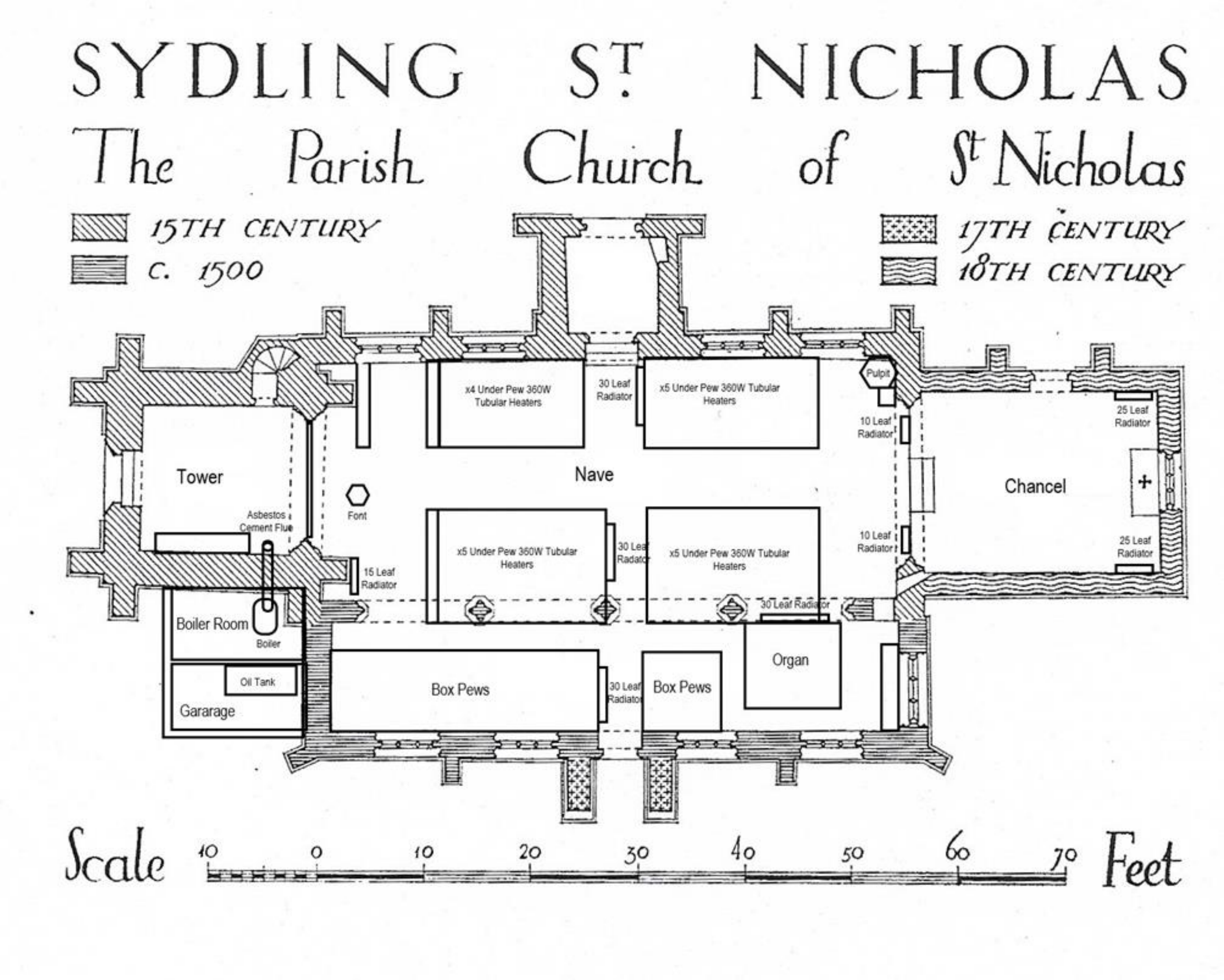
Only exposed, uncovered, and readily accessible building fabric, services and plant have been considered. Any concealed elements of the building services are included in this report as illustrated on the drawings in the appendices but with the caveat that further investigation is needed to confirm/disprove these "best guess" layouts. The condition of any hidden components cannot be assessed and it is not possible to say if they are free from defect or damage, or if they are suitable for re-deployment.

BACKGROUND

Structure

St Nicholas' Church, Sydling Saint Nicholas dates back in part to 1430 AD with much of the current building erected in the 15th century. It is an English Heritage Grade 1 Listed building and a number of the monuments inside the church are Grade 1 Listed. It is built with rubble-stone and flint walls, slated and lead roofs, and there is a graveyard on the west and south sides of the church building. The main access pathway which could be used for vehicular access runs from Church Lane. Internal floor finishes are a mixture of timber and stone slabs with slabs used in the tower and timber in the nave. A mixture of timber, stone slab and brick floor finishes are employed in the chancel. Stone slabs and clay tiled floor finishes have been used in the south aisle.

Pews are mainly fixed bench type in the nave with Box pews in the south aisle. All pews butt up to external walls. The arrangement is broadly as indicated in the below image.

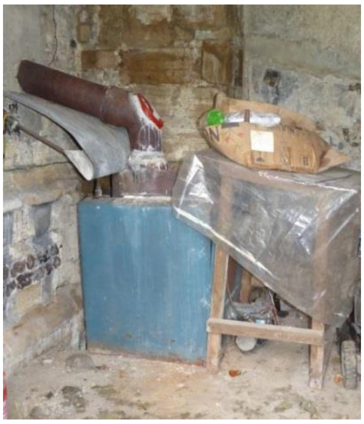


LPHW Heating

The remains of a low pressure hot water (LPHW) heating system is evident in the church with cast iron sectional radiators as indicated in the previuos drawing. Copper pipework extends from the radiators, disappears into the ground floor and is thought to link to flow and return pipes running in a floor duct below a cast iron grate along the central spine of the Nave. How this "spine" pipework links to the boiler in the boiler room is a guess but it is thought to be routed under the timber floor areas as these would have been the easiest to work with. Pipework distribution is general configured as a two-pipe system except for in the chancel where a single-pipe system with the pipe fixed to the wall at low level has been installed. The pipework is thought to have been installed about forty years ago, probably at the same time as the boiler. The pipework is "imperial size copper tube".

4-Column cast iron sectional radiators acted as the main heat emitters in the church. Radiators in the main body of the church were originally black but white radiators are used in the Chancel. The condition of paint finishes on the black radiators varies considerably but is generally poor. The white radiators have considerable paint damage. Radiators valves are all life expired.

The main run of heating flow and return pipework in the service duct in the Nave has attracted much dust, dirt and detritus over the years. It needs to be cleaned out. The duct is not continuous or complete. The pipework has closed cell thermal insulation applied to it but this is in poor condition and is not complete. Electric "twin and earth" cables also share the service duct.



An oil-fired Potterton cast iron sectional boiler, located in a modern, lean-to type housing on the southwest side of the church has been out of service since October 2017. It was fed from an oil storage tank located in an adjacent room. The oil tank appeared to be in reasonable condition but the boiler is beyond repair and out of service.

An asbestos flue extends from the boiler into the bell tower and runs up the bell tower to discharge the products of combustion out through the roof of the tower.

Assuming that the system was designed to operate at 82ºC and 70ºC flow and return temperatures respectively the output from the radiators has been calculated as 18.5kWatts. This is significantly less than the boiler output of 36 kWatts and goes a long way to explaining why the church heating was never satisfactory. The main heating pipework from the boiler to the central spine distribution appeared to be 22mm dia (without the benefit of measuring callipers). This would generally be considered too small for the boiler size but adequate for the radiators.

The existing system is an open-vented system with a galvanised steel feed and expansion tank located at high level within the lean-to building. A mains water pipe keeps the tank topped up.

A 2-channel timeclock controller located in the bell tower was used to control the on/off times of the boiler. A frost protection thermostat, located in the lean-to, could have overridden this to set the boiler to fire in cold weather. There is no other form of control present. Radiator valves, where present, are conventional manual valves.

Electric Heating

Electric tubular heaters are fixed under the seats of pews on both sides of the main aisle in the Nave. The combined heat output from all the tubular heaters equates to 7.6 kWatts. They appeared to be in reasonable condition. A separate timeclock is provided to control the on/off times of the under-pew heaters.

These heaters were used to supplement the LPHW heating system because it did not create a comfortable environment.

The 7.6 kWatt load equates to 33 Amps.

The power supply into the church is rated at 100 Amps, 230 Volts, 1 Phase.

Total Available Heat Input

The combined heat input of the original LTHW heating system and the supplementary electric tubular heaters is 26.1kWatts. This is less that most domestic installations.

Calculation tells us that the maximum internal temperature that could be achieved with the combined radiator and electric under-pew heaters would be 11.15^{o}C when it is -1^{o}C externally.

It is understood that the system used to be controlled to operate for about one hour before a service and for the duration of the service. It is understood from discussions at our meeting on site that the church neither felt warm nor comfortable, even with both heating systems running. This is not surprising.

HEATING IMPROVEMENT OPTIONS

Considerations

In considering any changes to the heating system in the church it is important that the following points are understood as they have a direct bearing on options that can be sensibly considered :

1. There are no plans for re-ordering the church
2. The existing pews will be remaining, fixed and butting up to the external walls
3. The proposals should not detract from the aesthetic of the building
4. The proposals will require the approval of Salisbury's DAC
5. There are no great art works in the church but it does have an organ and a number of Grade 2 Listed artefacts.
6. There is clear visual evidence of water penetration through the building fabric with significant green staining of walls and floor in the bell tower and South Aisle.
7. The church is off the grid for natural gas supplies
8. The existing electrical power supply is limited to 100 Amp, single phase.
9. Services generally take place for two weekly services, one of 45-75 minutes duration and the other of 30 minutes duration. There may be 2-3 weddings and funerals per year. Heating was historically used between October and April the following year. i.e. some 50 services per year.

There is evidence of deterioration of the building fabric in the bell tower and in the South Aisle, particularly behind the organ. It is due to damp penetration. The bell tower is especially vulnerable to driving rain from south westerly prevailing winds. It is also the oldest part of the church, is the tallest and has no heating in it. Regular redecoration does not take place in the bell tower because walls are bare stone and flint and the floor comprises flagstones.

Elsewhere, the evidence of damage to painted surfaces necessitates regular redecoration of the church and other remedial action.

Design Temperatures & Operating Strategy

For design heat loss calculation purposes an external temperature of -1^{o}C has been selected and an internal temperature of 20^{o}C. The external design condition does not represent the lowest temperature that will be experienced at the church but it should be sufficient for 95% of the time. Designing for the other 5% would incur a significant cost penalty well in excess of a 5% increase and is generally not considered to be desirable. The 20^{o}C internal design temperature is about as low a temperature as people are prepared to sit in for any length of time, reflecting the modern trend for higher internal temperatures and lighter clothing. It is also the Chartered Institution of Building Services Engineers (CIBSE) recommended temperature for churches.

Running a heating system from cold for only one hour before a service is not going to create a comfortable environment, regardless of the heat source, and especially when cast iron radiators are used. The cast iron radiations have a high water content and considerable thermal mass in themselves. It takes time to elevate the heating water circulation temperature to design levels before the radiators can actually start to deliver their design heat outputs. For a system of the size needed in this church it could take up to one hour before radiators start to deliver their design output. The system then needs time to elevate the temperatures of the air and the fabric as much as possible. If starting from -1ºC it could take four or five days to reach a stable, comfortable, temperature.

If a background heating level of 14ºC is maintained during the heating season it should only take two to three hours to elevate temperatures to 20ºC and achieve a comfortable environment without the risk of surface condensation because the internal surfaces would be above the dew point temperature of the air.

Allowing the heating system to operate continuously to try and maintain a steady internal temperature of about 14ºC would greatly assist in drying out the walls and actually stop the water penetrating all the way through the walls into the inside of the building. Energy costs would obviously rise but would be partially offset by reducing the need for redecoration and maintenance of the fabric of the building. Improved thermal comfort for people in the church would be a further benefit as the building fabric itself actually warms up to act like a giant storage heater. The radiant heating effect from this has a dramatic impact on people's perception of comfort. 14ºC would be our recommended set back temperature.

Because any new system will be able to raise temperatures relatively quickly to 20ºC the building will be subjected to less thermal stress if it is maintained at 14ºC most of the time as temperatures will only have to be elevated by 6ºC to get the building up to 20ºC. This is significantly less likely to cause any damage to the building fabric and the organ than rapidly increasing the temperature by 21ºC from -1ºC to 20ºC if the building is only heated for services. Heating for services only can actually cause surface condensation problems inside the building with the moisture in the warm air after the service condensing onto the cold surfaces of the building fabric. This is because the wall surface temperatures would be below the dew point temperature of the air.

Feedback

Following the submission of the original report a meeting was held on site and the Parochial Parish Council instructed the authors to consider the following :

1. Reducing the set back temperature from 14ºC of any heating system to reduce running costs.

2. Reducing the target space temperature from 20ºC of any heating system to reduce running costs.

There was also a requirement for some type of Renewable Energy to be considered. After some discussion it was agreed that Solar Photovoltaic would be the most appropriate system to be considered because it was felt that a system could be installed discretely in the church grounds at the bottom of the hill where the panels would be largely out of sight. This is the arrangement that was subsequently rejected for the reasons detailed in the introduction.

Wind turbine and ground source heat pumps were rejected because of the AONB and cemetery status of the land. Air source heat pumps were rejected because of the poor efficiencies available at that time. Richard Blackmore, Church Architect, expressed concern that heating the church would dry out the timbers and could cause shrinkage and significant structural problems. This was, at the time, deemed beyond the scope of this report but it is a factor that warrants serious consideration.

The above comments are typical of those received from many similar church groups and the response the author generally makes is that the system should be designed to deliver a comfortable space temperature of 20ºC because failure to do so may deter people from attending church services and any other use there may be for the church building. The system can be provided with controls that will allow choices of running hours, set back temperatures and occupancy temperatures. It can also have weather compensation control to reduce output temperatures as outside temperatures rise. Frost protection control must be provided regardless of whatever else is.

Budget Cost Basis

Budget costs provided below for fuel have assumed the above design temperatures and assume that 8ºC is maintained continuously from 31st September through to 31st May every year and that temperatures would be elevated to 20ºC for up to six hours per week. Fuel prices used and other factors employed in estimating running costs are :

- Boiler efficiency : 90%
- Direct electrical heating efficiency : 100%
- Heat Pump Seasonal SCOP : 2.89
- CO_2 per kWh grid electricity : 0.233 kg/kWh
- CO_2 per kWh oil : 0.293 kg/kWh
- Oil Specific Gravity : 0.835
- Oil – 63.20 p/litre
- Electricity – 29.35 p/kWh
- Oil calorific value : 45.5 MJ/kg

Where professional fees are included below they include for detailed design, preparation of tender drawings, specification, obtaining competitive tenders, reviewing tenders, administering the contract works on site, processing contractor valuations and the assumption of Principal Designer duties under

the CDM Regulations 2015 for health and safety. Refer to this link for details https://www.citb.co.uk/documents/cdm%20regs/industry-guidance-principal-designer.pdf.
DAC submission support is **not** included.

Heat Losses & Required Heat Input

Preliminary heat loss calculations indicate that heat losses from the building are in the order of 54kWatts. To allow for distribution losses and an element of intermittent heating operation a heat generator of at least 65kWatts is needed to provide an effective response time if heating is to be undertaken by radiators alone. This assumes that set back heating to at least 8°C is maintained during the heating season. If it is not, a larger heat generator will be needed.

Given the relatively short life expectancy of the existing under-pew electric heaters (up to 8 years) and the fact that any heat generating system installed now should survive for at least 20 years it is thought that the new heat generator should be sized at 65kW. Any retained electric heaters can offer some backup or booster facility.

These values are preliminary only and more detailed calculations will be needed to confirm them.

Energy Sources and Potential Electrical Supply Upgrade

As there is no natural gas supply nearby, it cannot be considered as a potential energy source.

Oil is generally cheaper than LPG and there is an oil tank already present on site.

The existing electrical supply is a single phase, 230 Volt, 100 Amp service and would not be sufficient to meet the heating needs of the church, equating to a total of 23kWatts. Enquiries made by Charles Hodgson have established that, because of the remote location of the church, the maximum size of a power supply that SSE Networks could offer as an upgrade would be a 3 phase 50kVA service. This equates to 50kWatts maximum load. This would have to serve lighting, water boiling, organ and small power as well as any heating. SSE Networks provided a budget cost for this upgrade in 2019 of £3,000. A further £1,800 should be allowed for metering, change of switchgear and testing to re-establish what is there now onto a three phase service.

Other Design Considerations

The Parish Church Council assume an environmental and health and safety obligation to remove the existing asbestos flue that served the defunct boiler. Any new boiler would need to adopt a different flue approach. This work must be undertaken whatever boiler replacement option is adopted.

Many church and public buildings insist on the use of Low Surface Temperature (LST) heating systems so that vulnerable people using the building are not at risk of scalding themselves on hot surfaces if, for whatever reason, they are unable to pull away from contact with the surface for a period of time. This generally means covering radiators and distribution pipework with casings to prevent direct contact with the hot surfaces. These covers reduce the heat output of the radiators and consequently greater wall areas are required to achieve the necessary heat output. The limited wall space available in this church will preclude the adoption of an LST system. There may also be aesthetic reasons why an LST system would not be desirable or acceptable to DAC.

There is no re-ordering work planned to be undertaken at St Nicholas' Church and it is assumed, therefore, that minimal building work is desirable and that pews will remain as they are. The current pew configuration leaves very limited perimeter wall space for the addition of new heat emitters.

Fan convector heaters can be a way of reducing the total length of wall required to be occupied by heat emitters because the fan forces air over the heat emitter and increases the amount of heat produced per metre length over and above what can be achieved by natural convection alone. These units require filters to reduce the dust dragged into the heat emitters and they require power supplies to drive the fans. This leads to increase maintenance as filters need to be changed and fans tend to become noisy over time. They do not tend to be of an aesthetic that would be in keeping with the church. The disadvantages are considered to outweigh the advantages and they should only be the choice of last resort.

If there was no imperative to move towards Zero Carbon it would make sense to replace the existing oil-fired boiler with a new one of the same or larger size because the high temperature output they can deliver without compromising their performance means that much of the existing distribution system could be reused. Changing from the original flow and return heating temperatures of 82/71^{o}C to 80/60^{o}C to obtain an increase in boiler efficiency would mean that there would be 12% less output from the existing radiators than there was. A couple of additional radiators could compensate for this shortfall. This arrangement is presented as Option 1 below and is a benchmark exercise because the arrangements does not deliver on the requirements of the brief. Appendix 1 illustrates the arrangement.

If budgets allowed greater comfort to be pursued, a larger boiler and additional radiators could be provided with pipework altered to suit. Flow and return temperatures of 80/60^{o}C would be the basis for sizing the radiators. The number of radiators required is significant and highlights how undersized the original system was. This system comprises Option 2 below and is illustrated in Appendix 2 as a benchmark of the amount of additional work needed to achieve comfort in the church.

The Zero Carbon target could steer the solution for heating the church towards an all-electric system comprising electric panel heaters instead of radiators. Procuring electricity from "green" suppliers could be seen to tick the box and deliver a zero carbon system. This is discussed as Option 3 below.

Moving to genuinely greener systems that actually get more energy out of the electricity used takes the conversation to heat pumps. As previously stated, air source heat pumps can only be considered because of the site's location. Developments in air source heat pumps mean that they now use refrigerants with low or zero Ozone Depleting Potential (ODP) and low Global Warming Potential (GWP) and come packaged to operate as air-to-water systems able to achieve seasonal coefficients of performance (SCOP) in the order of 3.5 (i.e. you get 3.5 kW of heat out for every 1.0 kW of electrical input). To deliver the promise of reasonable efficiency heat pumps cannot provide flow and return water temperatures of 80/70°C nor 85/60°C like modern boiler plant. Most work best with flow and return temperatures of 45/40°C but some can achieve 55/50°C without significant deterioration of performance. To do this they need to have a heat store / buffer vessel installed as part of the system to stop them cycling rapidly on/off at times of low demand and to smooth out their performance at high demand times by minimising auxiliary electrical input to defrost the coils in very cold weather.

Option 1 - Stay As Existing – Replace 36kW Boiler

It is not practicable to stay as per the existing arrangement because the boiler has failed and the flue cannot be re-used. A number of radiator valves are also likely to fail. As a minimum, therefore, the system would need to be drained down, flue removed and roof and wall made good, the distribution system would need to be thoroughly flushed out and chemically cleaned, the F&E tank replaced, radiator valves replaced and a replacement 36kWatt oil-fired boiler with a conventional or room-sealed flue would need to be installed. The under-pew electric heaters would need to be repaired / replaced where found to be faulty.

It must be said that if the existing system were allowed to run continuously for the heating season it would offer improved protection for the building fabric and greater comfort for people attending the church. Running costs would obviously rise but could, to some extent, be offset by reduced maintenance on the building fabric itself.

Pros	• Minimal capital expenditure • No impact on the layout of the church • No builders work associated with installing a replacement system except for new flue (through roof of lean-to building in south west corner, as far away from church stone walls as possible) and making good where existing flue is removed.

	• The heating is probably not run for long enough to cause any expansion and contraction in wood or other building elements. • Would help to protect the building fabric if run at set back temperatures for longer periods.
Cons	• No improvement in thermal comfort of people using the building over original installation. • Not able to achieve comfort throughout the heating season, even if run continuously. • Current usage pattern, with heating only used for the duration of a service creates a large swing in temperature for a short period and may contribute to surface condensation and deterioration of the building fabric. • Deterioration of building fabric due to moisture ingress through the external walls as evidenced in the south west walls and floors will continue. • Potentially ever-reducing numbers of congregation as people's comfort expectations are not met. • Oil storage tank may need replacing if it is not a bunded unit. • Risk of radiators failing when pressure tested • Does not assist with the Zero Carbon goal of CoE.
Capital Costs	£28,325 + VAT. Professional Fees : £5,720 + VAT. Assuming that works are undertaken from competitive quotations from "friendly" contractors without formal contracts.
Running Costs	Varies depending on hours of usage. Historically oil cost £250/yr and electricity cost £110/yr. Electricity bills have increased to c£455/yr since the boiler failure. These costs will have risen by approx. 50% due to current market price rises. Approximately £25.28 per hour for boiler system. £2.23 per hour for under-pew electric heaters. If boiler system is run continuously to maintain 8^{o}C and is also used in conjunction with the under-pew heaters to boost temperatures as much as possible : running costs become: £2,346.65 + VAT / year for fuel. £165 + VAT / year servicing

Life expectancy	20 years for boiler 10 years for pipework and radiators 5 years for pew heaters
Conclusion	No significant improvement in thermal comfort as the system can never meet the peak heat losses from the building as it is only sized to deliver about 50% of peak demand when operated as an intermittent system on its own. If used in conjunction with the electric heaters it can deliver about 65% of peak demands. If run continuously to maintain 14ºC and then boosted, with the aid of the electric heaters, to achieve as close to 20ºC as it can there would be a significant increase in comfort levels because the building fabric would assist as a "storage heater" towards the feeling of comfort. Fuel and boiler kept in lean-to extension, outside of the main church building for ease of access and maintenance and reduced fire risk. • Does not assist with the Zero Carbon goal of CoE.

Option 2 – 70kW Boiler & Radiator Heating

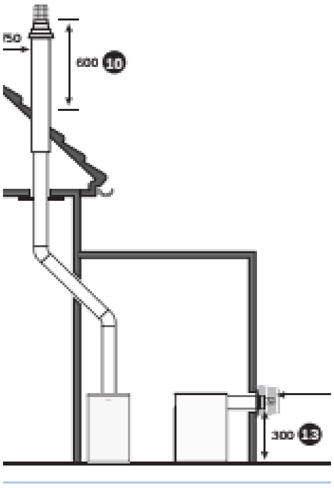
The most traditional method of heating churches is the use of wet low pressure hot water (LPHW) heating systems using radiators or fan convectors coupled to boilers with a pipework distribution system. These systems use natural gas, LPG or oil as the energy source.

There is no natural gas in the vicinity so it should not be considered as an option.

Oil is available and a tank exists and could be reused. LPG gas bulk storage vessels would be expensive to install. The positioning of LPG storage vessels is heavily regulated because of safety concerns and would need detailed consideration if it is to be considered further but having a direct line of sight between the storage vessel and the fuel delivery vehicle may be impractical. Providing a fenced exclusion zone around the vessel also makes it an unattractive proposition. Generally speaking LPG is about 20% more expensive per kWh of energy than oil. For these collective reasons LPG will not be considered further.

By default, oil is left as the only viable energy source for a wet heating system. However, further design will be needed to establish if the existing oil tank can be re-used or of it needs to be replaced by a bunded tank.

Installing a new 70kWatt oil-fired boiler in the existing boiler room with a new balanced flue running at high level from the boiler, through the oil tank room to discharge through the roof of the oil tank room at a minimum of 600mm above the roof would mean that the flue discharge would be 3.5m away from the South Aisle west wall and 4.5m away from the tower south wall. This is more than adequate for the products of combustion to be dispersed so as not to damage the stone work.



Inside the church the options are radiators and / or fan convectors. Radiators must always be the first choice if there is sufficient wall space to fit them because there are no moving parts so they need far less maintenance than fan convectors and they do not produce noise in the same way that fan convectors can do. They also have a radiant heat component which adds to comfort perception.

It would be good to reuse as much of the existing installation as possible because it should be more economic to do so and some of the copper pipework is not accessible. However, there is no guarantee that the radiators will not leak through their gaskets when tested and they do need painting. Internally they certainly need to be thoroughly power flushed to remove any build up of magnetite that could damage the new boiler and that would reduce heat output. A full refurbishment is recommended. Follow this link to get an idea of what this implies :https://www.youtube.com/watch?v=rEziPYaWaUk. However, budget costs for the full refurbishment suggest that it is not economical to do so because similar new radiators can be purchased for a similar cost.

Because existing radiators have a combined output of 18.5kWatts and because there is limited wall space available for more radiators it will be necessary for the existing 7.6kWatts of under-pew electrical heaters to be retained for use. This leaves a shortfall of 28kWatts which needs to be made up by more radiators. Quantifying the numbers of radiators required and where to locate them is for detailed design stage.

Establishing the correct type of radiator for the church is important now because prices vary hugely and if cast iron sectional radiators are required to match the existing there will be a significant impact on budget because they are amongst the most expensive products available per kWatt output. They are however, totally in keeping with the church and are unlikely to cause any objections from DAC or heritage organisations. They do not offer the quickest response times because of their inherent thermal bulk but have long life expectancy. New radiator valves will be thermostatic to offer some local control but will be aesthetically in keeping with the cast iron radiators.

Reference to the drawing in Appendix 2 shows our best guess for the existing installation layout and a layout that is thought to offer sufficient additional radiators to deliver the necessary heat input to the church. Pipework routes have been chosen to minimise the need for builders work and holes through walls.

Pros	• Improved temperatures and thermal comfort for occupants. • Good protection of the building fabric through extended running times of the LPHW heating system to maintain a steady "set back" temperature of 14°C or there abouts with boost facility to 20°C. • Easy to control. • Robust and well proven technology for heat generation and emission into the church. • Easily understood system for competent heating contractors to maintain. • No significant building work needed inside the church. • Responsive to changes in demand. • Aesthetically sympathetic solution similar to the system it replaces but this time using more efficient boiler, pumps, pipe distribution and controls and a greater number of radiators • Can re-use the existing oil storage tank (further to detailed investigation). • Can use existing floor ducts where practicable to do so for pipework distribution • Will provide a greater evenness of heat throughout the church.
Cons	• Need to locate a boiler flue at the south west corner of the lean-to extension building with the flue extending 600mm above the roof. • Need to agree flue discharge details with DAC. • Need to install pipework around the church to connect to radiators. Some will be surface fixed.

	• Some pipework will need to pass through timber members of pews that will need to be carefully cut out. • Disruptive to the church function whilst work is in progress. • The installation will not be a Low Surface Temperature installation. • Oil storage tank may need replacing if it is not a bunded unit. • Does not assist with the Zero Carbon goal of CoE.
Capital Costs	£78,650 + VAT Professional Fee estimate : £11,385 + VAT. Assuming that works are undertaken from competitive quotations from "friendly" contractors without formal contracts. Excluding architectural and structural engineering support if needed.
Running Costs	Varies depending on hours of usage. Approximately £37.88 per hour. £3,090.05 + VAT / year for fuel £150 + VAT / year servicing
Life expectancy	20 years for boiler and pump 30 years for internal pipework system and cast iron radiators. 5 years for retained electric tubular heaters
Conclusion	Good, robust system, easy to control and maintain using well proven technologies and involving minimal construction works. Very likely to be accepted by DAC. Fuel and boiler kept in lean-to extension, outside of the main church building for ease of access and maintenance and reduced fire risk. This system offers the possibility of retaining existing radiators for re-use if economically advantageous to have them refurbished rather than replaced with new radiators. This solution retains the under-pew electric tubular heaters for use. This system can deliver comfort and design temperatures – a perceptible improvement. Does not assist with the Zero Carbon goal of CoE.

Option 3 - Increase Electrical Heating

Upgrading the power supply to the church with the maximum sized 3-phase service available (50kWatt) and removing the redundant LPHW heating system (radiators, pipework, boiler, oil tank, etc) would be the starting point for this option. Adding more under-pew heating with tubular heaters fitted to the box pew seats would increase the total possible output from 7.6kW to 14.3kW. This leaves a significant shortfall from the 50kWatt to 70kWatt heat input that is needed depending on the control regime that is adopted.

Adding electric panel type heaters (generally only available in white) to replace existing cast iron radiators plus increasing numbers with wall-mounted panel heaters, where space is available, to deliver up to a full 50kWatts of connected heating would be the closest to the 70kWatt heating demand that could be achieved electrically. This would still be well short of what is required to meet comfort conditions by quite some margin, particularly if used intermittently. About 19 No 2kWatt electric panel heaters would be needed.

These heaters heat the air and have no radiant heating component to their output. Much of the hot heat will, therefore, rise to the roof through the natural buoyancy of warm air. As such they will accelerate the heat losses through the roof and occupants will not get the full benefit of the total energy input.

Pros	• Removal of oil storage tank from site • No impact on the layout of the church • Only minor builders work associated with wiring • Current usage pattern means that the environment is relatively stable within the church over any 24 hour period, with no great swings in temperature and humidity. Consequently, there is no significant expansion and contraction in wood or other building elements. The organ in particular benefits from this stable environment. • Quick response of system to demand. • Easy to control.
Cons	• Not able to achieve comfort throughout the heating season, even if run continuously because of limitation on available power supply.

	• Current usage pattern, with heating only used for the duration of a service, creates a large swing in temperature for a short period and may contribute to surface condensation and deterioration of the building fabric. • Continued deterioration of building fabric due to moisture ingress through the external walls as evidenced in the south-west walls of both side aisles. • People would expect a significant improvement because the heating system is supposed to be "upgraded" and they will quickly lose faith with it in the first winter because it does not deliver significant improvements in comfort. • Potentially ever-reducing numbers of congregation as people's comfort expectations are not met. • Heaters are not as robust as cast iron radiators. • Heaters are not sympathetic to the design of the church, being very modern and largely white. • Damage to walls and pews for wall mounting brackets and wiring. • Expensive to run per kWh output. • Does not assist with the Zero Carbon goal of CoE.
Capital Costs	£34,430 + VAT. Professional fee estimate : £7,205 + VAT. Assuming that works are undertaken from competitive quotations from "friendly" contractors without formal contracts.
Running Costs	Varies depending on hours of usage. Approximately £14.68 per hour. £11,375.43 + VAT / year for fuel. £0 + VAT / year servicing
Life expectancy	5 years for existing pew heaters 10 years for new panel heaters and pew heaters Will vary depending on usage.
Conclusion	Some improvement in thermal comfort but the system will still not meet the demand for heat at peak conditions as it would only be able to achieve 65 to 70% of maximum demand. Does not assist with the Zero Carbon goal of CoE.

OPTION 4 – HEAT PUMPS + LPHW HEATING

A rule of thumb used to be that electricity was 3 times the price of gas per kWh. For a heat pump to deliver the same amount of heat as a gas-fired boiler, for the same fuel cost, it would need to have a SCOP of at least 3. Energy prices, and gas prices in particular, are starting a period of great turbulence as global demand increases because of population growth, reduced reliance on coal and oil and dwindling gas supplies. Whilst electricity generation is globally still reliant on gas, there is a shift away from gas and other fossil fuels towards nuclear, hydroelectric, wind and solar photovoltaic generation. Within a short time the minimum SCOP of 3 "rule" will no longer apply and the focus will be exclusively on environment damage limitation.

The Church of England's Synod have decided that their estate should be carbon neutral by 2030. For that to be achieved action needs to start on the ground now. If replacing the heating system in St Nicholas's Church, Sydling St Nicholas is to be in the vanguard of this urgent drive it cannot replace the existing heat system with another oil-fired boiler as the heat source. For this site heat pumps offer the only viable alternative as a heat source.

There are two types of heat that could, theoretically, be employed on this site : air source heat pumps (ASHP) and ground source heat pumps (GSHP). ASHP's extract low grade heat from the air and convert and, through a process of compression and expansion, generate higher grade heat from it with a seasonal efficiency (SCOP) in the order of 3.25. GSHP's extract heat from the ground via a network of pipes laid in trenches about 1.2m below the ground or via boreholes that are typically 80+ m deep. GSHP's generally offer higher SCOP's because the temperature of the ground is higher than the air temperatures when the heat is most needed. SCOP values of 4.5 are not uncommon. GSHP's are not a practicable solution for this site because the land around the church is a graveyard and in an AONB.

ASHP performance has improved in recent years and manufacturers have been focusing on the development of air to water heat pumps using low ozone depleting potential (ODP) and low Global Warming Potential (GWP) refrigerants but they still struggle to improve the SCOP significantly. Notwithstanding this, the main problem lies with achieving the best efficiency practicable and this means limiting flow and return temperatures to be as low as possible. Temperatures as low as 40/35ºC can work reasonably well in modern, highly insulated, buildings. Temperatures of 45/40ºC are becoming normal as more manufacturers see the market opening up. Underfloor heating is a good distribution system to couple with heat pumps because it operates with flow and return temperatures of this order so as not to scald peoples' feet, etc. This option is not considered for St Nicholas' Church because there are no other works proposed for the building and underfloor heating would cause significant issues with building, door heights, box pews, covering of historic floors, etc. It should also be recorded that an underfloor heating system on its own, if installed throughout the whole footprint of the church, could only meet about 45% of the total heat demand. It would need to be supplemented by other heating. Underfloor heating is not pursued as an option for these reasons.

Option 2 and Appendix 2 illustrates how many radiators and how much surface area is needed to achieve a space temperature of 20ºC when it is -1ºC externally and flow and return temperatures to radiators are at 80/60ºC. Heat pumps operating at 55/50ºC flow and return temperatures means that the heat output available from radiators is 0.572 of what can be delivered with flow and return temperatures of 80/60ºC. However, there is no point looking for heat pumps that operate at higher temperatures because their efficiencies reduce excessively. This forces the focus to move to available wall space for heat emitters. Other considerations are where to locate the heat pump, how to address noise break out from the heat pump and control of the system.

Appendix 3 illustrates how many radiators would be required at 55/50ºC lower temperatures. To reduce the cost impact of the large number of radiators it is proposed that cast iron units are dropped and tubular steel units of similar appearance are adopted. To obtain the total output needed and to achieve more even heat distribution into the building under bench radiators are proposed to be installed under the box pew seats. These would be similar to the below image but without the timber seat fitted.

Tubular steel radiator suggested to replace the existing cast iron units. Alternative colours and valves are available.

If the number of radiators and their cost seem high, the only alternative would be to consider fan convector heaters.

It is worth noting that the option of operating ASHP's at 45/40ºC flow and return temperatures is not viable because the number of radiators that would be required cannot physically be accommodated in the space. This means that some potential efficiency gains in heat pump operation cannot be achieved.

If the radiators were changed to fan convectors it has been estimated that 16 of them would be required instead of the 33 radiators. Power wiring would be required to each fan convector for their fans and controls. Whilst greater heat output per metre length is available from fan convectors they prefer to operate with greater temperature differences than (10ºC +) between flow and return than heat pumps like and operate most efficiently at (5ºC). There would, consequently, be some loss of efficiency with fan convectors and they do introduce the risk of noise and greater maintenance costs for annual servicing, cleaning and filter changes.

Heat pumps use different refrigerants and some refrigerants are kinder than others to the planet and they may have other characteristics that need to be factored into the decision process. Preferred options for this project are :

ODP = 0, GWP = low as possible, Flammability = Low

Refrigerant	ODP	GWP	Flammability
R11	1	4000	High
R22	0.0550	1810	
R410A	0	2088	High
R407C	0	1770	Low
R32	0	675	Medium
R12134yf	0	4	Medium
R290	0	6.3	
R744 (CO_2)	0	1	Low

F-Gas legislative requirements have driven commercial development so that R410A, R407C and R32 are the choices currently available for products of the size, performance and usage type required for this project. Of these R32 would be preferred for its lower GWP value.

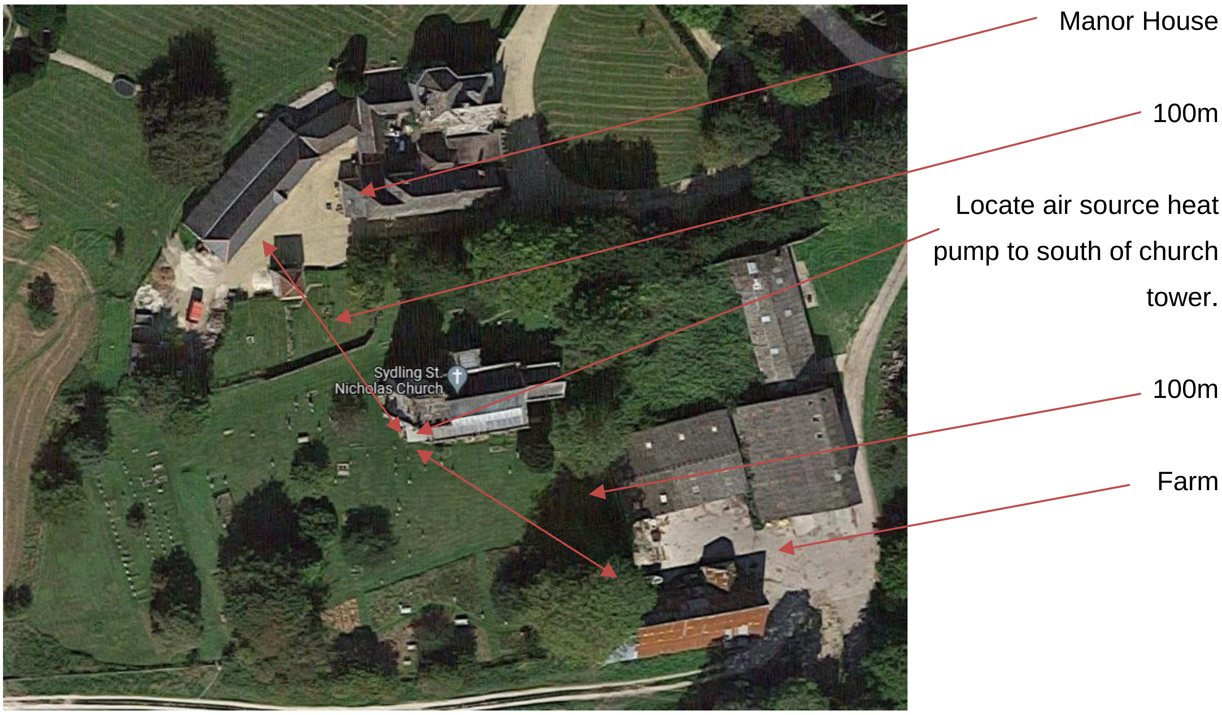
All ASHP's are designed to operate outside with free air movement around them to draw heat from and so that they can discharge the cooler air directly back into the atmosphere without risk of it causing damage to building fabric or short circuiting back into the "air inlet" side of the units. To a large extent, keeping the heat pumps outside buildings means that the flammability of the refrigerant is not a critical factor.

Noise break out from heat pumps is an issue that needs to be addressed, particularly in remote rural setting and AONB. The compressors and fans that work together in ASHP's generate noise. Manufacturers are aware that noise can be problematic in urban and rural locations so they attempt to ameliorate the problem by designing in "Night Mode" settings which effectively reduce fan and compressor speeds to cut down on noise generation.

It is proposed that the outer part of the existing lean-to type building that currently houses the oil tank at St Nicholas Church be demolished, the roof covering adjusted and rain water guttering added to take rainwater run off from the remaining inner portion of the lean-to so that the retained concrete base can be used to sit the proposed heat pump unit onto.

Installing a 2.4m high hit-and-miss timber fence around the concrete base with access doors to get the ASHP in and out should provide both physical protection for the ASHP and allow air to pass freely through the fence and into the heat exchangers in the sides of the ASHP with colder air discharging vertically out the top of the secured enclosure. This location places the AHSP approximately 100m away from both the Manor House and the neighbouring farm. It also places the church tower between the Manor House and the ASHP. This should greatly reduce the risk of noise intrusion to these adjacent properties.

It is, nonetheless, a recommendation of this report that a professional Acoustician be engaged to advise on noise risks and mitigation measures (if required) once a final selection for the ASHP has been made.



Operation of a heat pump system requires a different mind set to what people are used to with gas or oil-fired boilers. ASHPs cannot deliver high outputs in small periods of time. They work better when run for extended periods at a steady rate. A heat store / buffer vessel would be connected to the system and the heat pump will need to raise its temperature to 55°C before water circulation around the radiator circuit commences (except when in frost protection mode when water will need to be circulated around the whole system).

The controls system that would be provided could allow the room temperature to be adjusted for occupancy periods and a separate set-back temperature selected to maintain the building for other periods. This would help to protect the building from rain penetration damage. It would also allow the internal fabric temperature of the building to rise towards the set-back temperature and this would greatly assist at improving the sensation of comfort in the church because radiant heat plays a significant part in how humans experience comfort.

Some drying out of the building would be a good thing but drying out roof timbers may lead to some problems over time particularly if there are underlying issues in terms of timber sizes or lengths already present. The benefit of driving rain ingress out and protecting the stone walls and internal decoration probably outweighs the timber shrinkage potential problems.

Pros	• Removal of oil storage tank from site with associated pollution and theft risks. • Removal of asbestos flue from site with associated H&S risk. • Moving towards a carbon neutral and sustainable heating solution. • No impact on the layout of the church • Can achieve 20ºC internal comfort temperatures. • New system can deliver real comfort to occupants and encourage people to use the church. Even heat throughout the church because of even distribution of radiators. • Main plant can be contained in external areas and plantrooms. • Being able to maintain a steady set-back temperature economically means that the environment is relatively stable within the church over any 24 hour period, with no great swings in temperature and humidity. Consequently, there is no significant expansion and contraction in wood or other building elements. The organ in particular benefits from this stable environment. • Thermostatic radiator valves can be used to control each radiator individually which could provide a simple way to have zone control over the system • Radiators are compatible with accepted cast iron type for this vintage of church building. • An all-electric solution offers the potential for further "greening" of the church's carbon footprint. Solar photovoltaic arrays could be installed to feed the system by generating electricity on site. • This option could become a flagship statement for the Church of England and be used as a benchmark installation for other churches to follow.

	• Future proofs site against potential zero carbon legislation.
Cons	• High capital cost • High running costs, but controllable. Running costs of other fuelled systems are likely to rise faster than electricity in the future. • Risk of noise breakout to surrounding area • Large number of radiators needed to deliver amount of heat input required to achieve design conditions and comfort.
Capital Costs	£174,000 + VAT. Professional fee estimate : £12,050 + VAT. Assuming that works are undertaken from competitive quotations from "friendly" contractors without formal contracts.
Running Costs	Varies depending on hours of usage. Approximately £5.41 per hour. £5,570.82 + VAT / year for fuel. (8°C set back, boosted for 8 hours/week to be at 20°C for 2 hour service) £300 + VAT / year servicing (£600 + VAT every second year.
Life expectancy	5 years for existing pew heaters 20 years for air source heat pump 20 years for radiators 30 years for pipework Will vary depending on usage.
Conclusion	Delivers comfortable space temperatures Highly controllable for time and temperature. Gets very close to zero carbon emissions for the heating system and could achieve this goal if coupled with sufficient amount of PV (approx.. 11kWp would be required).

Environmentally Friendly Enhancements

The installation of an ASHP reduces the church's carbon footprint relative to an oil-fired boiler installation by approximately 60% to 70%. It is possible to improve this further. Whilst the provision of a ground array of solar photovoltaic (PV) panels has been rejected, recent volatility in the energy markets and the impact of COVID-19 with its roots tied to environmental changes and growing populations there is a strong case for looking at the provision of some PV on the church roof. Salisbury and Gloucester

Cathedrals (both Grade 1 Listed buildings) both have PV installations on their roofs and DAC, the Church Synod and Historic England have a duty to look after not only the past but the future.

Mounting PV panels on the south aisle roof, clear of the parapet, offers approximately 35m^2 of surface area available for PV arrays. The pitch of the roof may not be the optimum for solar harvesting but it is not far off. The parapet would help to hide the panels from normal lines of sight and the system could deliver in the order of 5kW of output. This could be used to pre-heat the thermal store in the heating season or could be exported to the grid when not required by the church.

Refer to Appendix 4 for proposed locations of PV arrays.

The system would generate something in the order of 5,000 kWh/year of electricity with a resultant reduction in CO_2 output of 1,165 kg/year. Some of this will be in the sunnier months when demand for heating will be lower than in winter but there will still be benefits from heating the building in spring and autumn as well as on brighter winter days. Modern PV panels do not require bright sunlight to produce electricity, they work, albeit less efficiently, with overcast skies as well.

The electricity produced should be employed in the following order of priority to gain the maximum economic benefit from it:-

1. electric under-pew heating
2. immersion heater in a buffer vessel to feed the LPHW heating system
3. Export to grid

The 5kWp peak PV generation is less than the installed peak under-pew heating demand of 7.6kW. By providing a buffer vessel in the shed, as required for the efficient operation of the ASHP anyway, electric immersion heaters could utilise some of the surplus electricity to heat the water in the buffer vessel. This would serve as a pre-heater to the ASHP when it is called upon to raise space temperatures over and above what the under-pew heaters can achieve. By way of example : a 500 litre vessel could store 30 kWh of heat with a heat up period of 8 hours, using a 3.0kW immersion heater (assumed daylight period when demand for heat requires boiler top-up). Space constraints in the shed will dictate the amount of heat that can be stored and this is subject to detailed design.

To prevent the PV system from potentially wasting heat having to heat the buffer vessel when it is not up to temperature but when there is a demand for heating in the church, controls will be needed to effectively bypass the vessel. Exact details will be addressed in any detailed design development.

If the buffer vessel idea is not adopted, or if it is used but the vessel is up to its maximum temperature when the solar PV system is generating electricity there may be scope to store the electricity directly in storage cells or batteries such as the Tesla Powerwall 2, Powervault or similar energy store. This energy could then be used when the sun is not shining and/or demand for heat exceeds available PV generated instantaneous electricity.

By way of example: a Tesla Powerwall 2 can store a maximum of 13.5kWh and allows a peak 7.0kW draw off and 5.0kW continuous draw off. Typical fully installed costs for these units are £10,000. This need not be installed with everything else, it could be added later if funds permit and if sufficient space is available.

It would make more sense to install a hydraulic buffer vessel rather than a storage battery because the buffer vessel works well with heat peat pumps to smooth out demand and improve their operating efficiency so one should be installed as part of the hydraulic system anyway. Buffer vessels are also appreciably cheaper than battery stores for energy.

The difficulty in making a case for any sort of renewable technology that relies on daylight and the sun for heating a building is that peak performance of the system is inversely proportional to the demand for heating. However, if the goal is achieving Carbon Zero for the site, then PV can assist in doing this when coupled with ASHPs. Calculations suggest that an 11kWp PV installation would cancel out the carbon emissions of the ASHP heating system.

Budget costs for PV installations:

5kWp (south aisle roof)	£11,825 + VAT.
11kWp (ground array)	£23,100 + VAT (including trench + cable to church)
13.5kWh Battery Storage	£10,000 + VAT

CONCLUSIONS

The building fabric of the church is suffering from rain penetration on the western elevation and parts of the southern elevation and floor. This is damaging the fabric and some internal finishes. Extending the operating time of any heating system would help to dry out the fabric and may stop the rain achieving full penetration from outside. Any heating system should operate continuously to try and maintain a minimum internal temperature of 14ºC so that it is consistently above dew point. Heating systems should be able to rapidly boost the inside temperature to 20ºC for occupied periods.

However, in response to architectural concerns about excessively drying out the building fabric and parishioner concerns on running costs and the environmental impact of the various options it has been decided that base design conditions for comparison of options should be :

Outside design temperature ; -1ºC
Inside set back temperature : 8ºC
Inside occupancy temperature : 20ºC
Heat loss : 54kW
Intermittent heating plant output size 60kW if 8ºC set back temperature is maintained.
Intermittent heating plant output size : 70kW if building is unheated between occupied periods.

It is not practicable to adopt a low surface temperature heating installation in this church because of limited space available for heat emitters. It may not be aesthetically acceptable even if sufficient wall space was available.

The installed/failed heating boiler was 36kW although the combined radiator output would have been 18.5kW. The system, when used in conjunction with the under-pew electric heaters could only hope to achieve 11.15ºC at -1ºC externally. See Appendix 1 for current layout.

A 70kW oil-fired boiler could meet the requirements of thermal comfort in the building but falls foul of the zero carbon emission requirement. If lowest capital cost for a system that can deliver good control of temperatures is the prime concern a 70kWatt oil-fired boiler connected to an increased number of radiators via a largely new LPHW pipework distribution system is the preferred solution because it can deliver the amount of heat needed using a reliable and robust technology. It can be used either for continuous or intermittent operation assuming at least a 3 hour preheat time before services. It could re-employ the existing oil tank and allow the existing asbestos flue to be removed. A new boiler flue could run through the roof of the lean-to building far enough away from the stonework of the church not to present a hazard to it. Lifting some floorboards will be necessary to establish routes for new pipework but this should be minimal. See Appendix 2 drawing for proposed layout.

The type of radiators chosen for use in the building needs careful consideration because of the aesthetic and budgetary impact. Rather that employing cast iron column radiators as per the existing it would be more economic to use tubular steel column radiators that appear similar but cost less and have achieved DAC approval on similar schemes.

The existing electric under-pew tubular heating system delivers 7.6kWatts of heat into the church. The existing under-pew electric tubular heaters should be retained to supplement any heating system that is adopted. Damaged or failed units should be replaced.

The maximum amount of direct electric heating that the existing power supply could support would be 23kWatts. Maximising the use of direct electric heating cannot achieve the desired internal temperature even if the biggest available power supply upgrade (50kWatt) is brought into the church. An all-electric heating solution also fails to meet the zero carbon emissions requirement.

Low grade heat from heat pumps could produce sufficient heat to meet peak demand. Flow and return temperatures of 55°C/50°C would be as low as could be accepted because of the large number of radiators that would be required to offset heat losses using these temperatures. Underfloor heating has been ruled out because no other changes are planned for the church to warrant the upheaval and cost associated with changing the floor. Tubular steel radiators should be adopted and sufficient space is available for them as demonstrated in the Appendix 3 drawing. The system should be designed to operate without reliance on the electric under-pew heaters because they have a relatively short life expectancy.

The ASHP system will require the electrical power supply to the church to be increased to the 50kVA, 3 phase service that is locally available because heat pumps of this size require 3-phase power supplies and because there is insufficient power available at present.

The ASHP should be provided with a buffer vessel / heat store to maximise the efficiency of the plant.

The heat pump system offers the nearest that can be achieved to zero carbon without some on-site power generation.

If low carbon emissions are the primary focus in the decision making then the provision of a PV system coupled to buffer vessel immersion heaters and an ASHP must be the preferred option. Zero carbon emissions can only be achieved if more PV than can be accommodated on the South Aisle roof is installed. Appendix 4 illustrates two options. Using the South Aisle and/or main roof would be subject to approval by an architect and a structural engineers on technical grounds.

It is estimated that an 11kWp PV system coupled with the ASHP heating would render the site Zero Carbon and meet the Church of England's target.

The impact of the set point for the temperature inside the church has a very significant bearing on the fuel consumption and CO_2 emissions.

Cost Comparison Summary

A summary of cost information for the above options follows. All costs will be subject to the addition of VAT. These costs are for maintaining the church at 8ºC minimum during the heating season and boosting temperature to 20ºC for occupied periods (6 hours/week).

The following observations have been based upon analysis of the information provided in the table on the following page.

1. Option 4, the ASHP system, achieves nearly 500% reduction in carbon emissions over Option 2 which is the only other option that can deliver 20ºC internal occupancy temperatures at peak times.
2. The addition of 5kWp PV installation reduces the carbon emissions generated by the ASHP solution by 40%.
3. If the site is to have zero carbon emissions it must use a combination of air source heat pumps and solar PV to achieve that goal. The amount of PV will need to be greater than the South Aisle can support on its own.
4. The longer the heating system is run on an annual basis the greater the significance of the carbon emissions from them will be on the environment.

* Acoustician, Architect and Structural Engineers fees may need to be added to these sums. Assume an additional £7,500 + VAT for budgetary purposes.

Option	System	Capital Cost	Running Cost	Annual CO_2 Emissions	Fees*
			Per year	kg	
1	Replace 36kW Boiler, retain existing radiators and under-pew heaters to maintain 11.15°C inside occupancy temperature and 8°C set-back temperature	£28,325	£2,346.65	10,138	£5,720
2	Remove existing, upgrade existing system with a 70kW Oil-Fired Boiler + new Radiators, replace much of the pipework to maintain 20°C inside occupancy temperature and 8°C set-back temperature	£78,650	£3,090	14,618	£11,385
3	Remove LPHW heating, increase power supply size, retain under-pew heaters and add electric panel heaters to maximum capability of supply to maintain 18.5°C inside occupancy temperature and 8°C set-back temperature	£34,430	£11,375	9,196	£7,205
4	Remove existing, upgrade power supply, install air source heat pump and new LPHW radiator system capable of maintaining 20°C inside occupancy temperature and 8°C set-back temperature	£173,810	£5,571	2,928	£12,050
	Enhancements				
5	Install 5kWp Roof mounted PV on South Aisle roof	£11,825	- £1,467 saving	1,165	£850
6	Install 11kWp Ground mounted array of PV at south west lower end of site	£23,100	- £3,129 saving	6,180	£1,050

RECOMMENDATIONS

Removal of the existing asbestos flue should be undertaken regardless of which design solution is adopted.

Replace the existing 100A 230 Volt, 1 Phase electrical supply to the church with the maximum available at 50kVA, 400Volts, 3 phase to allow an all-electrical heating system to be installed in place of oil-fired boilers as they cannot deliver a Zero Carbon solution.

Extending the operational running hours of any heating system in the church should be a priority to help protect the building fabric and to limit large swings in temperature that arise when systems are used intermittently. This also reduces the risk of surface condensation forming on internal building fabric.

It is desirable to maintain a steady internal temperature of 14°C as a set-back temperature ideally but 8°C would be better than nothing to help protect the building fabric and to allow shorter pre-heat times to 20°C for occupied periods.

A 65kW air source heat pump coupled to tubular steel column radiators operating at flow and return temperatures of 55°C/50°C respectively should be adopted because it is deliverable and would have lower carbon emissions than any other viable option. It should be provided with a heat store/buffer vessel to optimise efficiency and to enable it to harness the electrical output of a PV system that could be either installed at the outset or as a future date to render the site Carbon Zero.

An Acoustician should be engaged early on in the detailed design stage to establish if noise generated by an ASHP will be problematic and what, if any, mitigating measures could be adopted to address any concerns.

The amount of PV needed to achieve Carbon Zero needs further investigation based on using the most efficient panels and optimisers but it may be that the South Aisle roof does not provide a large enough useful surface area on its own. Architectural and structural engineering advice should be sought of the suitability of any roof.

To reduce the environmental impact of heating the church it is recommended that a solar PV system is installed and operated so that it serves electrical demand in the following sequence to gain best advantage from the installation:

1. electric under-pew heating (whilst it remains operational)
2. immersion heater(s) in a buffer vessel to feed the LPHW heating system
3. battery store surplus (if battery is installed)

4. Export to grid

It is unlikely that a battery energy storage unit would be economically justifiable if an hydronic heat store with immersion heaters is installed.

Existing pipework needs to be replaced because of the increased pipework sizes dictated by the lower flow and return temperatures. New pipework should be heavy grade screwed black iron because it is robust and does not attract criminal intent the same way copper does. It also does not require naked flames to be employed for jointing. This should reduce the fire risk to the building.

A simple controls system should be employed to encourage sensible use and ease of boosting internal temperatures. The system should also have safety features such as frost protection incorporated in case they are ever needed.

Early dialogue with DAC advisors on the preferred design solution should avoid the risk of abortive design work. Similarly Planning considerations may need to be addressed in light of the PV requirement.

Budget costs for Option 4 are :

- Capital Cost : £173,810
- Professional Fees : £12,050 + acoustician + architect + structural engineer.
- Running Costs : £5,571 / year
- Carbon emissions : (2,928 kg CO_2/year – useful PV on-site generated electricity)
- Life expectancy :20 years PV, heat pumps and pumps, 30 years pipework and radiators, 10 years PV inverter.

All above budget costs will be subject to the addition of VAT.

APPENDIX 1

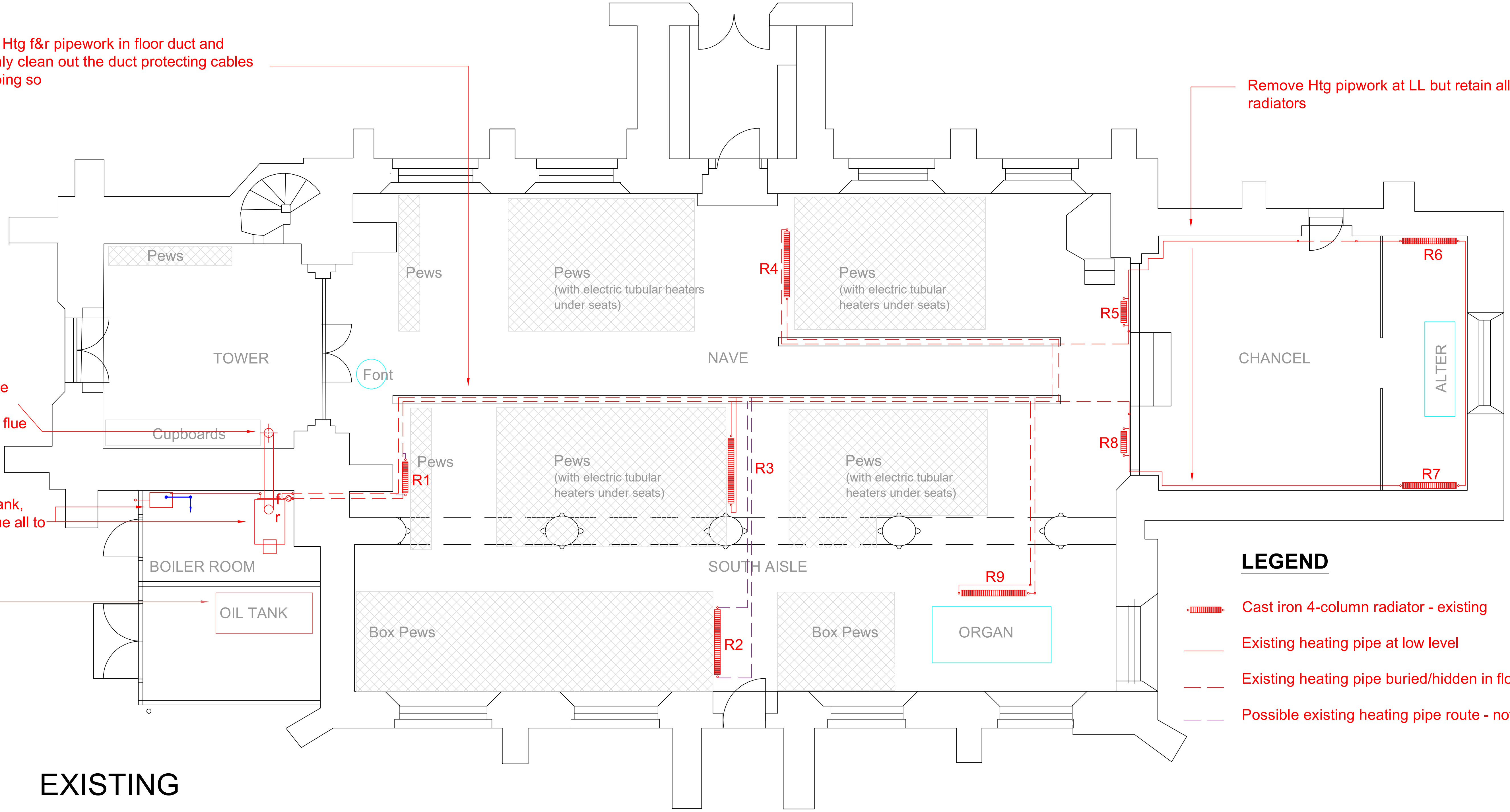
Drawing 835/M/01/P2 – Existing Heating Layout

Notes

1. These drawings may not be entirely accurate.
2. These drawings should not be used as design or tender drawings, they are intended only to illustrate design intent for DAC submission for approval in principle and to foster an understanding of what is proposed by Option 4.
3. Worldwise Limited do not give permission for these drawings to be used for any purpose other than the above and they do not take any responsibility should the drawings be used for any reason other than the above.
4. Copyright of the design intent illustrated by the drawings rests in perpetuity with Worldwise Limited.

NOTES

1. All dimensions to be checked on site.
2. If in doubt; please ask.
3. All pipework routes need to be verified on site.



Remove Htg f&r pipework in floor duct and thoroughly clean out the duct protecting cables whilst doing so

Remove Htg pipwork at LL but retain all radiators

Remove mass concrete shoulder pad currently supporting the vertical flue

Feed and expansion tank, boiler and asbestos flue all to be removed

Retain oil tank

EXISTING

LEGEND

▥ Cast iron 4-column radiator - existing

——— Existing heating pipe at low level

— — Existing heating pipe buried/hidden in floor duct

— — Possible existing heating pipe route - not verified

Revision	Date	Description	By
P1	24.05.19	First issue for feasibility report	pdc
P2	10.10.21	Updated for new feasibility report	pdc

Project
Heating System Upgrade
St Mary's Church
Sydling St Nicholas
Dorset

Title
EXISTING HEATING LAYOUT

Date
23.05.2019

Scale
1 : 100 @ A3

Drg. No.
835 / M / 01

Rev.
P2

worldwise

APPENDIX 2

Drawing 835/M/02/P1 – Proposed Oil-fired Heating Layout with Boiler F&R Temperatures of 80ºC/60ºC

Notes

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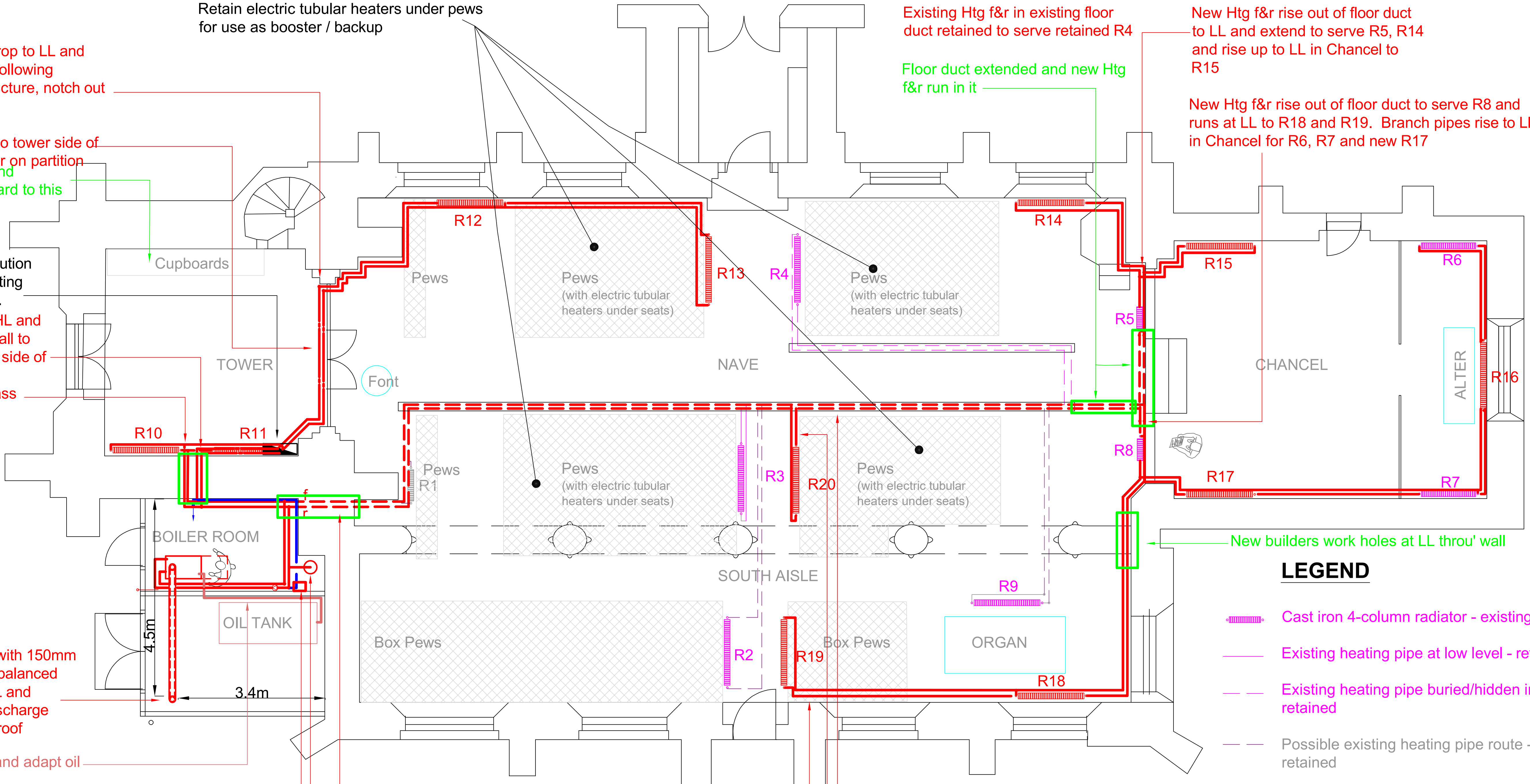

Retain electric tubular heaters under pews for use as booster / backup

Htg f&r pipes drop to LL and extend to R12 following contours of structure, notch out pews to suit.

HL pipes fixed to tower side of timber cross bar on partition

Remove pew and relocate cupboard to this side of tower

Electrical distribution boards and heating controls on wall.

Htg f&r rise to HL and pass through wall to extend to other side of tower.

Htg f&r at LL pass through wall to connect to LL radiators.

Oil-fired boiler with 150mm OD concentric balanced flue rising to HL and extending to discharge 600mm above roof

Retain oil tank and adapt oil lines to suit

Existing Htg f&r in existing floor duct retained to serve retained R4

Floor duct extended and new Htg f&r run in it

New Htg f&r rise out of floor duct to LL and extend to serve R5, R14 and rise up to LL in Chancel to R15

New Htg f&r rise out of floor duct to serve R8 and runs at LL to R18 and R19. Branch pipes rise to LL in Chancel for R6, R7 and new R17

New builders work holes at LL throu' wall

New htg f&r to re-use existing floor void /break out and make good as necessary for larger pipes

Expansion vessel on ground.

Pressurisation unit on wall with mains water feed.

New Htg f&r in existing floor duct

New Htg f&r in new floor duct to R20

New Htg f&r at LL to new radiators - notch out pews to suit

PROPOSED

LEGEND

- ▥ Cast iron 4-column radiator - existing, retained
- — Existing heating pipe at low level - retained
- – – Existing heating pipe buried/hidden in floor duct - retained
- – – Possible existing heating pipe route - not verified - retained
- — New pipework
- ▥ Cast iron 4-column radiator - new
- ☐ Builders work required through stonework / flooring

Revision	Date	Description	By
P1	24.05.19	First issue for feasibility report	pdc
P2	10.10.21	Amended for revised feasibility report	pdc

Project
Heating System Upgrade
St Mary's Church
Sydling St Nicholas
Dorset

Title
PROPOSED OIL-FIRED HEATING LAYOUT WITH BOILER F&R TEMPERATURES OF 80°C / 60°C

Date
24.05.2019

Scale
1 : 100 @ A3

Drg. No.
835 / M / 02

Rev.
P2

worldwise

APPENDIX 3

Drawing 835/M/03/P1 – Proposed ASHP Heating with Radiators Needed at F&R Temps of 55ºC/50ºC and Likely Pipework Routes

Notes

1. These drawings may not be entirely accurate.
2. These drawings should not be used as design or tender drawings, they are intended only to illustrate design intent for DAC submission for approval in principle and to foster an understanding of what is proposed by Option 4.
3. Worldwise Limited do not give permission for these drawings to be used for any purpose other than the above and they do not take any responsibility should the drawings be used for any reason other than the above.
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AIR TO WATER HEAT PUMP

NOTES

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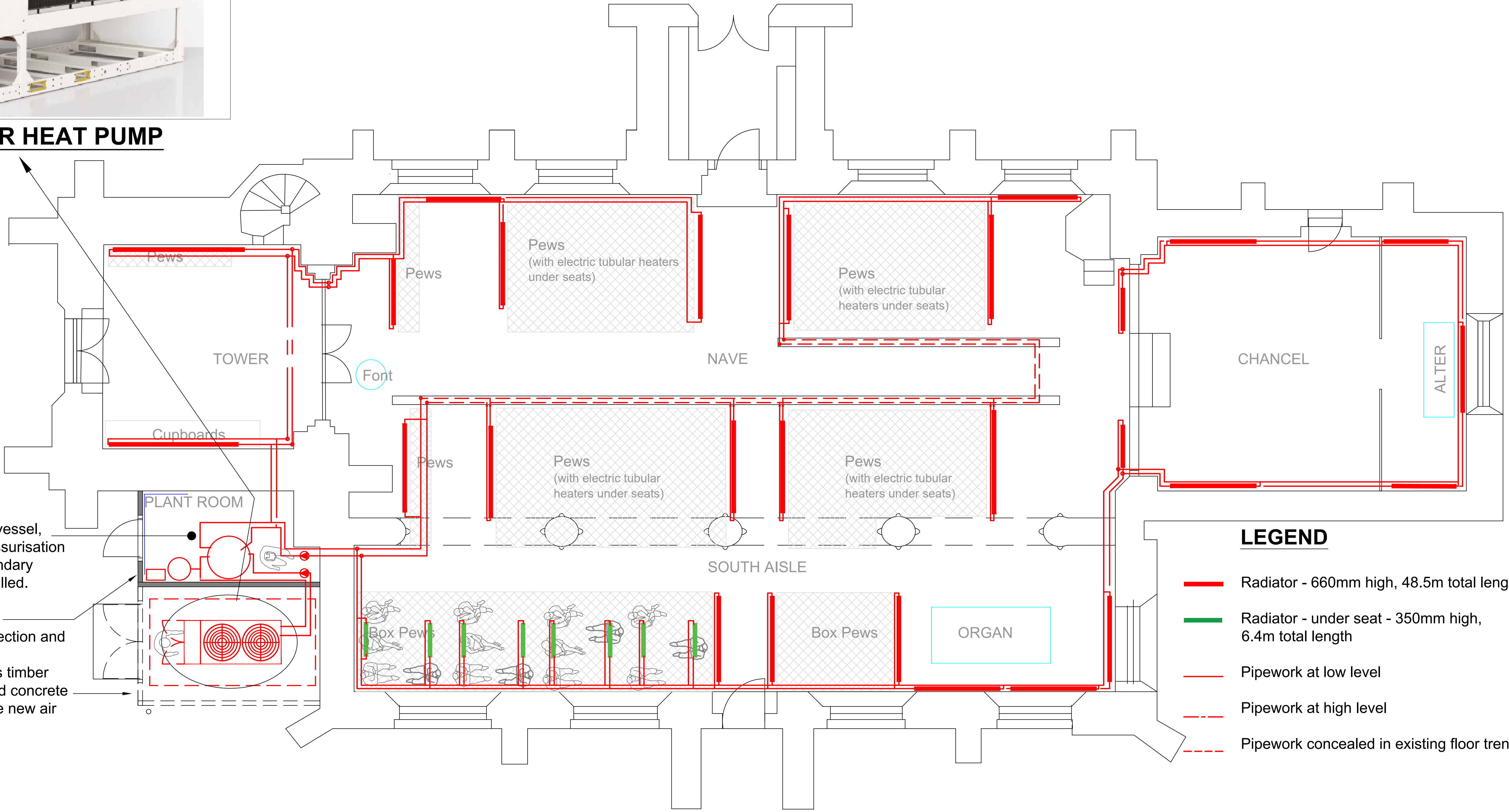

Old boiler removed.
New heat store/buffer vessel, expansion vessel, pressurisation unit, primary and secondary circulating pumps installed.

Existing walls retained.
Roof of lean-to outer section and walls removed.
2.4m High hit-and-miss timber fencing around retained concrete base provided to house new air source heat pump

LEGEND

🟥	Radiator - 660mm high, 48.5m total length
🟩	Radiator - under seat - 350mm high, 6.4m total length
—	Pipework at low level
-·-	Pipework at high level
- - -	Pipework concealed in existing floor trench

Revision	Date	Description	By
P1	12.10.21	First issue for feasibility report	pdc

Project
Heating System Upgrade
St Nicholas's Church
Sydling St Nicholas
Dorset

Title
PROPOSED ASHP HEATING WITH RADIATORS NEEDED AT F&R TEMPS = 55°C/50°C + LIKELY PIPEWORK ROUTES

Date
05.10.2021

Scale
1 : 100 @ A3

Drg. No.
835 / M / 03

Rev.
P1

APPENDIX 4

Drawing 835/M/04/P1 – Site Plan
PV System Options

Notes

1. These drawings may not be entirely accurate.
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NOTES

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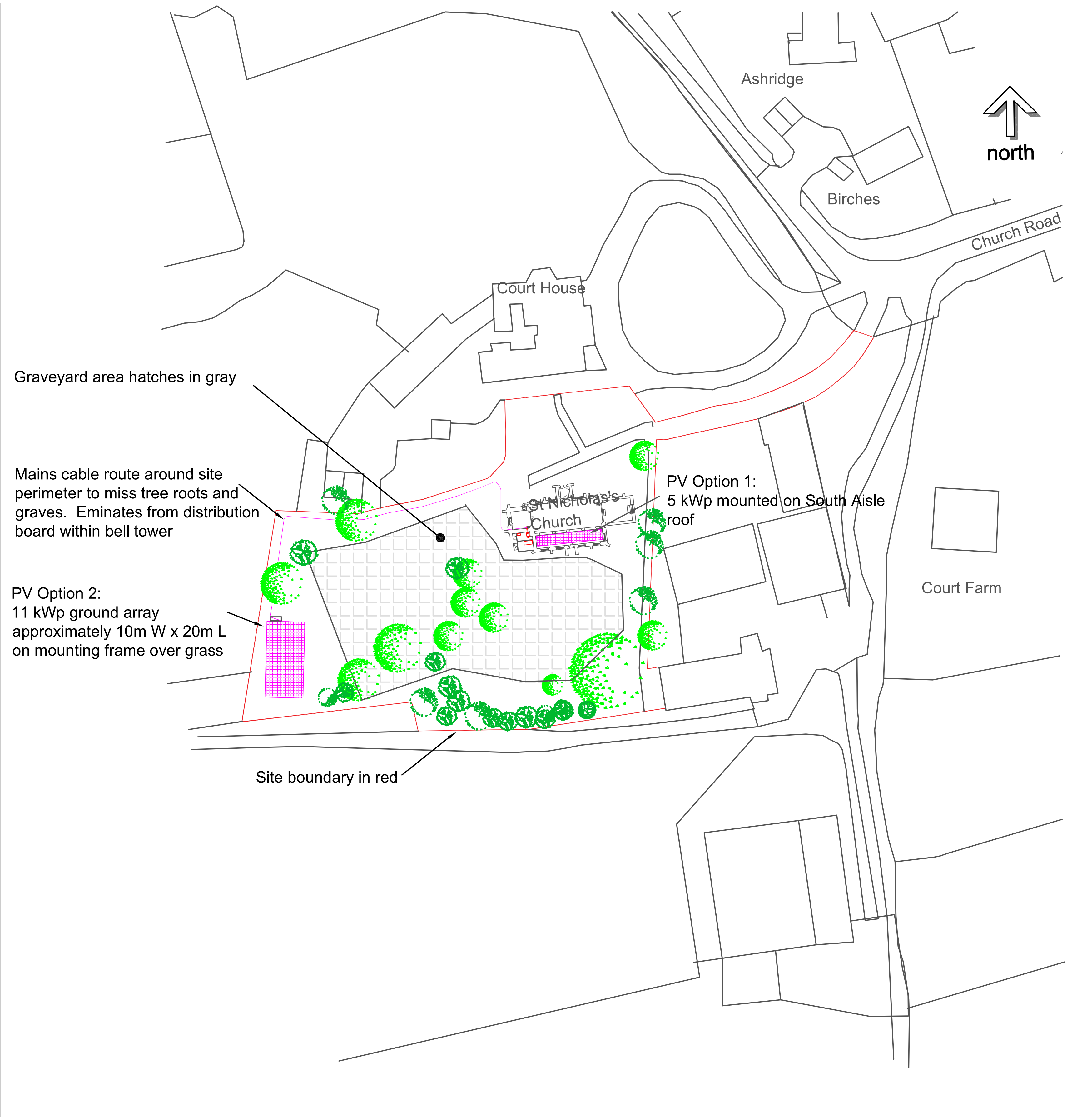

Revision	Date	Description	By
P1	10.10.21	First issue for feasibility report	pc

Project
Heating System Replacement
St Nicholas's Church, Sydling St Nicholas, Dorset

Title
Site Plan
PV SYSTEM OPTIONS

Date
10.10.21

Scale
1 : 1250 @ A3

Drg. No.
835 / M / 04

Rev.
P1

APPENDIX 5

Glossary

Glossary

ODP	**Ozone Depletion Potential** of a chemical compound is the relative amount of degradation it can cause to the ozone layer
GWP	**Global Warming Potential** is a measure of how much a given mass of a gas contributes to global warming. *GWP* is a relative scale which compares the amount of heat trapped by greenhouse gas to the amount of heat trapped in the same mass of Carbon Dioxide. The *GWP* of Carbon Dioxide is by definition *1*. Be aware that GWPs are highly controversial.
AONB	An **Area of Outstanding Natural Beauty** (AONB) is land protected by the Countryside and Rights of Way Act 2000 (CROW Act). It protects the land to conserve and enhance its natural beauty. There are 46 AONB in the whole of the UK.
ASHP	**An air source heat pump** (ASHP) is a reversible heat pump which uses the outside air as a heat source when in heating mode, or as a heat sink when in cooling mode, using the same vapor-compression refrigeration process and same external heat exchanger with a fan as used by air conditioners.
PV	**Photovoltaic** is the term used to describes the production of voltage / electricity when a body is exposed to radiant energy, especially daylight.
COP	**Coefficient of Performance** is a measure of the efficiency of a heat pump. It is the term used to describe the ratio of useful heat output or removal by a heat pump and the work or power supplied to the compressor in the heat pump.
SCOP	**Seasonal Coefficient of Performance** is a new way of measuring the true energy efficiency of heating appliances, over an entire year. This new measure gives a more realistic indication of the energy efficiency and environmental impact of a system.
EER	The **Energy Efficiency Ratio** of a piece of heating or cooling equipment is the ratio of the heat output (measured in kW) to the power input (measured in watt-hour) whilst the system is in operation. The higher the ratio of an air conditioning unit compared with other systems, the more efficient it is.
SEER	**Seasonal Energy Efficiency Rating** is a new way of measuring the true energy efficiency of cooling appliances, over an entire year. This new

	measure gives a more realistic indication of the energy efficiency and environmental impact of a system.
Dew point temperature	The **dew point** is the atmospheric temperature (varying according to pressure and humidity) below which water droplets begin to condense and dew can form.