

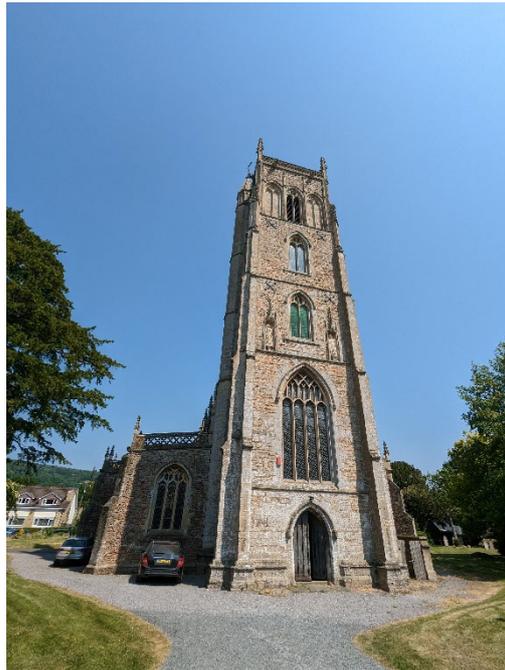
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**ST ANDREWS CHURCH, CHEDDAR**



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P1	First issue	SC	RDW	06.07.2023
P2	Options Updated	SC	RDW	10.07.2023
P3	Different Usage Profiles Added	SC/RDW	RDW	03/08/2023
P4	Option 5 Added	RDW	RDW	07/08/2023

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## 1.0 Introduction

The ESDP personnel involved in the inspection were:

Robin Woodger  
Steve Court

This report has been prepared for St Andrews Church (c/o Alex Coppock, Communion Architects, Studio 1, The Grange, Shelwick, Hereford HR1 3AW)

The Property Address is St Andrew's Church, Church Street, Cheddar BS27 3RF.

This report has been commissioned by the client to provide a recommended approach to the upgrade of the existing heating system with a view to meet the Church of England net zero carbon by 2030 target.

An initial meeting with the client and site survey were carried out on Wednesday 7th June. The weather was warm and sunny.

## 2.0 Scope of Survey & General Notes

The survey of the heating system was visual only. No testing or intrusive survey work was undertaken. We had access to below the floor at the point the pipework entered the church from the boiler room.

Unless specifically stated to the contrary within the report, the inspection did not cover those parts of the mechanical engineering services which were concealed or inaccessible, and as such, it is not possible to report that such are free from corrosion, infestation, deterioration, failure or other defects. Further defects of materials can develop subsequent to the survey. No functional or performance testing was conducted as part of the survey and this report does not therefore cover assessment of the operational performance of the mechanical and electrical services.

Within the report we have informed you accordingly of the extent of the examination that we have carried out, and if we are of the opinion that there is a material risk of defects or failure in areas we have not inspected, we have advised you of the potential risk which is subject to further investigation and review.

### *Exclusions and Qualifications*

Please be aware of the following exclusions and qualifications applicable to this survey and report:

- We have made no enquiries about contamination or other environmental dangers. If we suspect a problem, we will recommend further investigations.
- This survey is not an asbestos survey and will not identify asbestos within the building or associated with the building services. We may alert you to possible asbestos containing materials within the premises requiring further investigation, but you must carry out your own asbestos surveys and have an asbestos management plan as required under current legislation.
- We have not inspected heating services that are concealed or where access was not possible or not permitted.
- We have undertaken a visual examination of the heating installation only. This report comments on the condition of the heating installations in general terms only.
- No functional or performance testing was conducted as part of the survey.

### 3.0 Church background

The Church of St Andrew in Cheddar, Somerset dates from the 14th century and has been designated as a Grade I listed building. The church is in the parish of Cheddar and was restored in 1873 by William Butterfield. It contains a number of 15<sup>th</sup> century stained glass windows and an altar table dated 1631AD. The tower, which rises to 100ft, and dates from around 1423AD, contains a bell dating from 1759AD made by Thomas Bilbie of the Bilbie family.

### 4.0 Fabric heating Loss and heating system requirements

This section reviews the existing building fabric, air infiltration rate and usage pattern to calculate the required heat loss of the building. This can then be used to establish an alternative low/zero carbon approach to the heating strategy for the building.

#### Heat loss assessment

To establish the heat load required we have calculated the heat loss based on the following building fabric assumptions using CIBSE guidance;

<i>Building Element</i>	<i>Assumed make up</i>	<i>'U' Value</i>
External Wall (900mm Thick)	Solid Stone	1.15
External Wall (700mm Thick)	Solid Stone	1.4
Roof	Ornate timber ceiling, uninsulated void, timber sheeting with lead external finish.	0.6
Window	Single Glazed	5.5
Doors	Solid Oak	1.8
Floor – Timber below Pews	Timber deck, 400mm void, rammed Earth with brick build edges where it meets the solid floor below the tiled and stone floors.	0.6
Floor – Solid Stone	Flagstone bedded directly onto rammed earth	0.6
Floor - Tiled flooring	Tiles laid on thin bed of mortar directly onto rammed earth	0.6

An Air infiltration rate of 0.25 and a usage pattern of approximately 16 hours a week have been estimated.

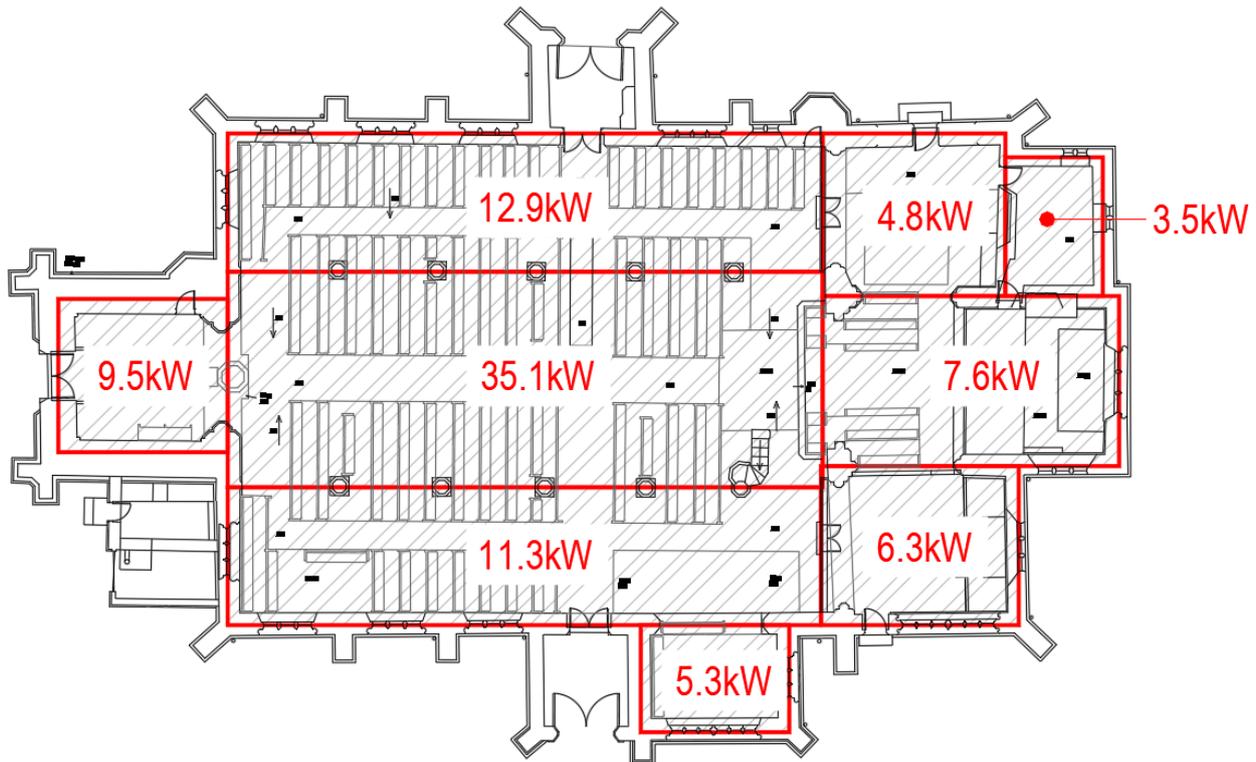
The heating loads have been split into two categories, one for building fabric protection which will maintain a minimum temperature of 10°C within the church during the heating season (October to April) and the second is for when the church is occupied, raising the temperature to 18°C. Based on available weather data, the external design temperature has been set to -4°C.

This strategy has been implemented due to the current limited usage of the church, with the aim to make the system as efficient as possible while preserving the building fabric.

Using the information above, the following steady state loads have been established;

<i>Heating Stage</i>	<i>Temperature range</i>	<i>Steady State Heating Load</i>
Fabric Protection	-4°C to +10°C	61.3kW
In Use boost	+12°C to +18°C	35.0kW
Total	-4°C to +18°C	96.3kW

The image below shows pictorially the breakdown of the heat loss assessment based on heating the church from -4°C to 18°C.



## 5.0 Existing Heating System installation

The observations from the survey of the heating system are contained within this section.

It was noted during the colder months, the existing heating system is inadequate and struggles to provide the congregation and members of the church with a comfortable thermal environment.

The heating system operates on a constant temperature circuit switched on and off by a time programmer, with a frost thermostat located in the boiler room and a control thermostat located in the south west corner of the south Aisle on the external wall. The heating time programmer is located in a cupboard on the south wall of the spire.

### *Boiler room and existing equipment*

The purpose built boiler room constructed with stone walls and lead roof is located to the south side of the spire containing a 'Potterton Commercial NXR 3' pressure jet gas fired boiler. The existing flue is assumed to be a twin wall metal flue and exits from the rear of the boiler discharging into the base of a brick lined flue rising from the boiler room up the full height of the spire with a balancing damper located at the base in the boiler room.

The boiler serves a single pressurised twin pipe heating circuit with a single circulation pump installed on the return pipe. A commercial heating pressurisation unit and expansion vessel are located within the plant room serving the heating system. For the purposes of this report, we have assumed the system is running on 80°C flow and 60°C return water temperatures. Note: The system is non-condensing.

The gas meter box is located in an external compound adjacent the boiler room. During the survey , it was noted that the meter box is damaged and not attached to anything, allowing easy access to the main isolation valve which could be tampered with. It is also not protecting the meter from the external elements.

The existing boiler equipment is at the end of its economic life and we have been informed there is an on-going issue with the existing gas fired boiler which causes it to intermittently not fire when required.



View in boiler room of existing flue arrangement and pressurisation kit.



View inside base of the existing brick built chimney.



External view of boiler room on south west corner of the church.

### Heat Emitters

The existing heating system is a mixture of exposed caulk jointed pipe loops at low level around the external walls of the church incorporating elegant engineered manifold arrangements at each change of direction, set or pipe size change. Along with an exposed pipe loop, a limited number of traditional column radiators and 2No. custom made triangular column radiators are located either side of the entrance to the Chancel. An exposed pipe loop beneath a grille in the floor in the North Aisle adjacent to the entrance door and an exposed pipe loop consisting of 4No. pipes stacked vertically in the South Transept, have also been previously installed.



Exposed Pipe loop caulked manifolds



Custom radiator at entrance to Chancel



Exposed pipework below grating in North aisle



Typical 2 Column Princess cast iron Radiator



Typical 4 Column cast iron Radiator



Stack Pipe loop in south transept

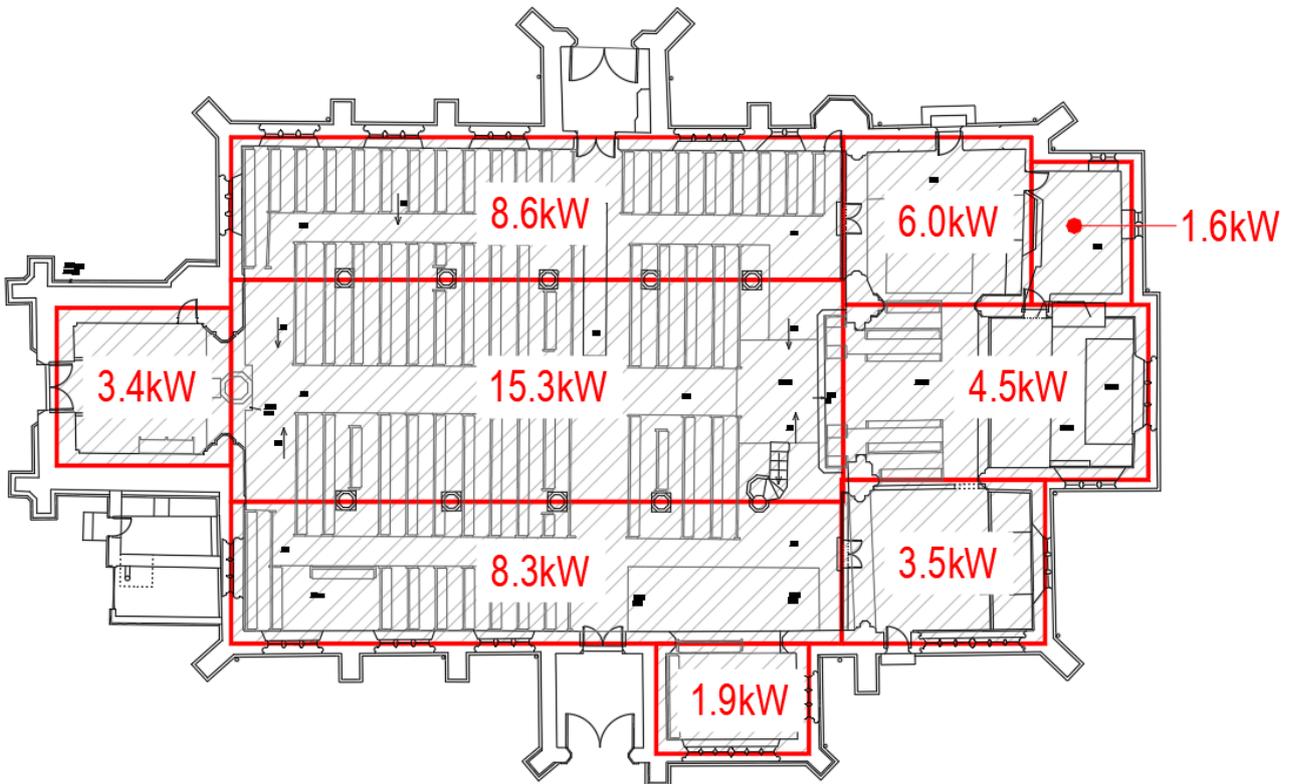
## 6.0 Existing heating system output

### *Existing heating system output*

We have calculated the existing heating system is providing approximately 53.2kW heat output. This would indicate the installation has been installed to provide fabric protection only.

The existing boiler and circulation pumps are at the end of their life expectancy and as such their efficiencies will be greatly reduced.

The image below demonstrates the heat distribution around the church from the existing heating system.



As the image above demonstrates, the existing system cannot provide enough heat output to meet the thermal comfort levels required for the space when occupied.

## 7.0 Energy Usage and Carbon Emissions Assessment

### Energy usage assessment

We have reviewed predicted energy consumption and carbon emissions for five different heating system options (please refer to Section 8 for technical review of each option) and two different usage profiles.

The two usage profiles modelled are as follows:

1. Building occupied for 4 hours per day on 2 days only of each week, heating at setback at all other times.
2. Building occupied for 4 hours per day every day of the year, heating at setback at all other times.

The estimated energy costs below are based on continuous background heating of the church through the winter period to a minimum of 10C, boosting to 18C air temperature at times of occupancy in line with the above usage profiles.

The table below provides estimated annual energy usage, annual carbon emissions, equipment costs and maintenance costs for each heating system option for the first usage profile (4 hours occupancy on 2 days each week only).

COMPARISON OF DIFFERENT HEATING SYSTEM OPTIONS FOR ST ANDREWS CHURCH, CHEDDAR.

Option	HVAC system	Predicted Annual Energy Consumption	Predicted Annual Carbon Emissions	Estimated Equipment cost	Total annual energy cost	Total Annual Maintenance Cost	Total Estimated Annual Running Cost	Annual Saving Over Base Option 1	Lifecycle cost (over 20 years)
		kWh	Tonnes	£	£	£	£	£	£
1	Replacement Gas Fired Boiler	89943.5	21343.6	85,975.00	10,523.39	600.00	11,123.39	-	648,140.05
2	Combined replacement Gas boiler and ASHP	39114.6	9060.6	142,837.50	5,957.54	1,200.00	7,157.54	3,965.85	504,572.52
3	ASHP	28482.1	5814.2	204,687.50	9,228.20	600.00	9,828.20	1,295.19	701,395.11
4	Combined ASHP For Fabric Protection Only and Overhead Electric Radiant Heating for In Use Boost	34911.8	7126.8	241,613.75	11,311.42	600.00	11,911.42	788.03	843,604.82
5	Combined Replacement Gas boiler For Fabric Protection Only and Overhead Electric Radiant Heating for In Use Boost	89435.9	20903.3	141,463.75	12,460.41	600.00	13,060.41	1,937.02	801,523.94

#### NOTES:

- 1 Annual inflation allowance applicable to running costs set at:- 5.00%
- 2 The predicted annual energy consumption is based on the church heating running at set back for 24 hours per day 5 days of the week and 20 hours per day and occupancy temperature for 4 hours per day for 2 days of the week. Previous reports by others appear to have been based on only 16 hours run time per week for the heating. If continuous fabric protection is not deemed essential, then the energy consumption figures can be reduced accordingly.
- 3 Estimated equipment costs exclude upgrade to the electricity supply connection and distribution equipment which would be required by options 2, 3 and 4.
- 4 Options 1 and 2 - Replacement of the gas fired boiler includes flue installation
- 5 The estimated equipment costs do not include alterations to the domestic water services and ventilation which are common to all options.

6 Energy Consumption Tariffs used in energy cost calculations:-

Energy Source	£/kWh
Gas	0.117
Electricity	0.324

7 Carbon emission and Primary Energy Factors used:-

Energy Source	Carbon Emission Factor	Primary Energy Factor
Gas	0.21	1.13
Electricity	0.136	1.501

The second table below provides estimated annual energy usage, annual carbon emissions, equipment costs and maintenance costs for each heating system option for the second usage profile (4 hours occupancy on all days of each week).

**COMPARISON OF DIFFERENT HEATING SYSTEM OPTIONS FOR ST ANDREWS CHURCH, CHEDDAR.**

Option	HVAC system	Predicted Annual Energy Consumption	Predicted Annual Carbon Emissions	Estimated Equipment cost	Total annual energy cost	Total Annual Maintenance Cost	Total Estimated Annual Running Cost	Annual Saving Over Base Option 1	Lifecycle cost (over 20 years)
		kWh	Tonnes	£	£	£	£	£	£
1	Replacement Gas Fired Boiler	105349.8	24999.5	85,975.00	12,325.93	600.00	12,925.93	-	739,238.70
2	Combined replacement Gas boiler and ASHP	55534.8	12902.7	142,837.50	8,218.29	1,200.00	9,418.29	3,507.64	618,828.38
3	ASHP	33360.8	6810.1	204,687.50	10,808.89	600.00	11,408.89	1,517.04	781,281.63
4	Combined ASHP For Fabric Protection Only and Overhead Electric Radiant Heating for In Use Boost	55864.6	11404.0	241,613.75	18,100.14	600.00	18,700.14	5,774.20	1,186,699.99
5	Combined Replacement Gas boiler For Fabric Protection Only and Overhead Electric Radiant Heating for In Use Boost	103573.2	23458.5	141,463.75	19,105.51	600.00	19,705.51	6,779.58	1,137,360.47

**NOTES:**

- Annual inflation allowance applicable to running costs set at:- 5.00%
- The predicted annual energy consumption is based on the church heating running at set back for 20 hours per day and occupancy temperature for 4 hours per day. Previous reports by others appear to have been based on only 16 hours run time per week for the heating. If continuous fabric protection is not deemed essential, then the energy consumption figures can be reduced accordingly.
- Estimated equipment costs exclude upgrade to the electricity supply connection and distribution equipment which would be required by options 2, 3 and 4.
- Options 1 and 2 - Replacement of the gas fired boiler includes flue installation
- The estimated equipment costs do not include alterations to the domestic water services and ventilation which are common to all options.

6 Energy Consumption Tariffs used in energy cost calculations:-

Energy	£/kWh
Gas	0.117
Electricity	0.324

7 Carbon emission and Primary Energy Factors used:-

Energy Source	Carbon Emission Factor	Primary Energy Factor
Gas	0.21	1.13
Electricity	0.136	1.501

From the tables above, different advantages for each heating option are apparent:

Providing a replacement gas boiler has the lowest estimated installation costs (circa £86k) with a combined replacement gas boiler and overhead radiant heating, being the second lowest (at circa £142k), and a combined replacement gas boiler and ASHP coming a very close third (at circa £143k).

The lowest predicted annual energy consumption is ASHP for both usage profiles at circa 28,500 up to 33,000kWh depending on usage profile. For the lower usage profile, the ASHP combined with overhead radiant heating is next lowest at circa 35,000kWh, but as usage increases, the combined replacement gas boiler and ASHP option becomes comparable with the ASHP/Overhead radiant option, with both consuming circa 55,500kWh.

The lowest annual estimated heating energy cost for both usage profiles is offered by a combined replacement gas boiler and ASHP at circa £6k up to £8.2k depending on usage profile, with the full ASHP option following at circa £9.2k up to £10.8k.

The technology with the lowest 20 year life cycle cost is the combined replacement gas boiler with ASHP installation at circa £505k up to £619k depending on usage profile, although it should be noted that this is based on the current gas and electricity tariffs. Differentials between tariffs for these different energy sources could vary significantly in years to come and may change this calculation in favour of all electric heating, particularly as the renewable energy contribution to the electricity grid increases in future years.

The lowest carbon emitting technology is ASHP (circa 5,800 to 6,800kg depending on usage profile) with a 72% improvement over the gas fired boiler replacement option (circa 21,300 to 25,000kg), followed by combined ASHP and overhead radiant heater (circa 7,100 to 11,400kg) at 54% to 66% improvement over the gas fired boiler replacement option depending on usage profile (the improvement reduces with greater usage).

It should be noted that the figures provided in this section are calculated estimates for illustration and comparison, and that real life figures will vary depending on usage profiles, system control settings, final equipment selections, energy tariffs, final installation costs, and actual winter weather conditions experienced in use.

## 8.0 Heating System Upgrade Options

The focus of our heating upgrade review has been the following statement taken from the Church of England's route map to net zero Carbon;

*'The Church of England see a future in 2030 where the buildings of the Church will be warm, bright and welcoming, powered by renewable energy and using low or zero carbon technologies for heat and light. Energy consumption for the Church as a whole will have fallen, on-site renewable energy generation will have increased, travel will be by low carbon means and carbon emissions will be less than 10% of those now, offset in verified schemes.'*

Based on the Energy usage and Carbon Emissions review in section 7.0 The following section sets out the 4 options to upgrade the existing heating system, along with a brief scope of the works involved for each option.

Further investigation and design development will be required to establish the extent of existing pipework which needs to be replaced, provide equipment selections and agree final positions of plant.

### *Option 1 - Replacement of Existing gas fired boiler.*

This option is a straight replacement option of the existing commercial boiler with a new high efficiency boiler. To meet building regulations, this option will require the addition of a new concentric flue running externally to discharge a minimum of 450mm above the gas meter enclosing wall, (final route and location to be reviewed). Consultation will be required with the Planning authority to obtain permission for the new flue installation which could be powder coated (eg. black) or clad in stone to disguise the flue outlet.

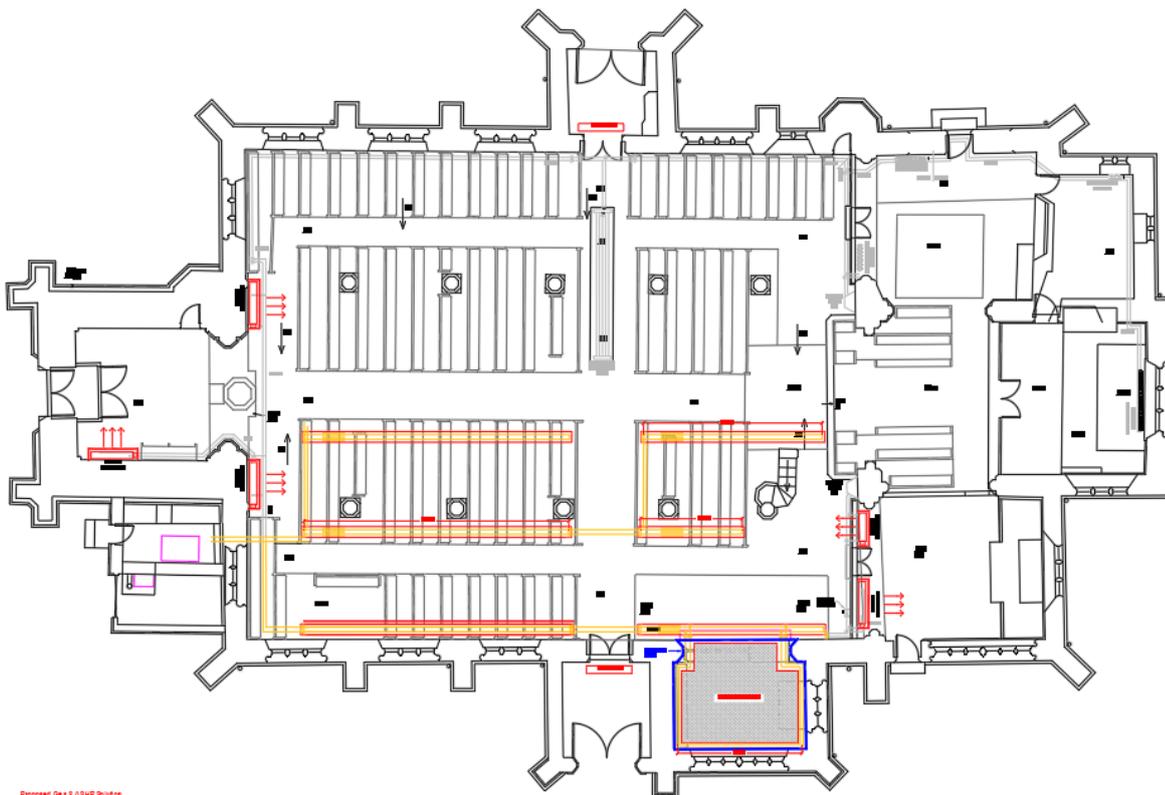
The existing heating system is undersized and unable to achieve a level of heating to satisfy the building when it is in use without the addition of radiators or fan convectors. Additional heat emitters are also required in the other options.

This option is not in line with the low or Zero carbon targets required by the Church of England. Therefore we have not taken this option any further in the design process, but have included it in the Energy usage and carbon assessment for comparison.

*Option 2 - Combination of new domestic sized gas fired boiler and Air Source Heat Pump.*

This option is a stepping stone towards meeting the Net Zero 2030 target. It looks to limit, as far as practically possible, the works within the church to the south side where the current re-ordering is proposed to take place. Conversion of a number of the existing cast iron radiators to fan convectors will still be required in order to achieve the thermal comfort levels needed for the occupants.

This scheme is based on the assumption the existing pipework is routed from the boiler room into the main church floor void in the south west corner of the Nave. Also the branch circuit serving the west end of the Nave, Spire, North aisle, Organ, Vestry and behind the Alter would be retained. This will require intrusive survey to determine its current state.



We propose the installation of a new 70kW net input condensing gas boiler within the existing boiler room with a balanced concentric flue discharging through the plantroom wall into the external compound adjacent the boiler room, and installation of a new 60kW air source heat pump in a purpose-built screened enclosure. Please refer to the section at the end of option 4 below for further details of the proposed screened enclosure.

This option looks to provide new heating pipe loops installed within new purpose built boxes insulated on 3No. sides with a grated timber cover within the existing timber floor section in the South Aisle and South side of the Nave.

Within the South Transept it is proposed to install a low level pipe loop boxed in with a decorative grating and then to build up the existing floor to provide an area of underfloor heating in this area. This would be suitable for activities where children are possibly playing and is more suited to the lower temperatures of an air source heat pump.

The existing cast iron radiators within the Choir changing area, Spire and West side of the Nave will need to be

upgraded to fan convectors. The fan convectors would be speed controllable and manually switchable from the pulpit to allow the units to be switched to low speed (quieter setting) during services.

This option would also include the addition of direct electric air curtains within the North and south door lobbies. Direct electric is proposed since installation of a wet system would be difficult due to the extensive builder's work required, and the use of the heater would be limited to only occupied times on colder days.

This option provides a reduction in carbon emissions and is a good initial step toward the low / Zero target, but will require further development of the other parts of the church heating in the future.

### *Option 3- Air Source Heat Pump scheme*

Option 3 is the ASHP only (no gas heating) solution, involving an upgrade to the whole church heating installation, but providing a low carbon heating solution.

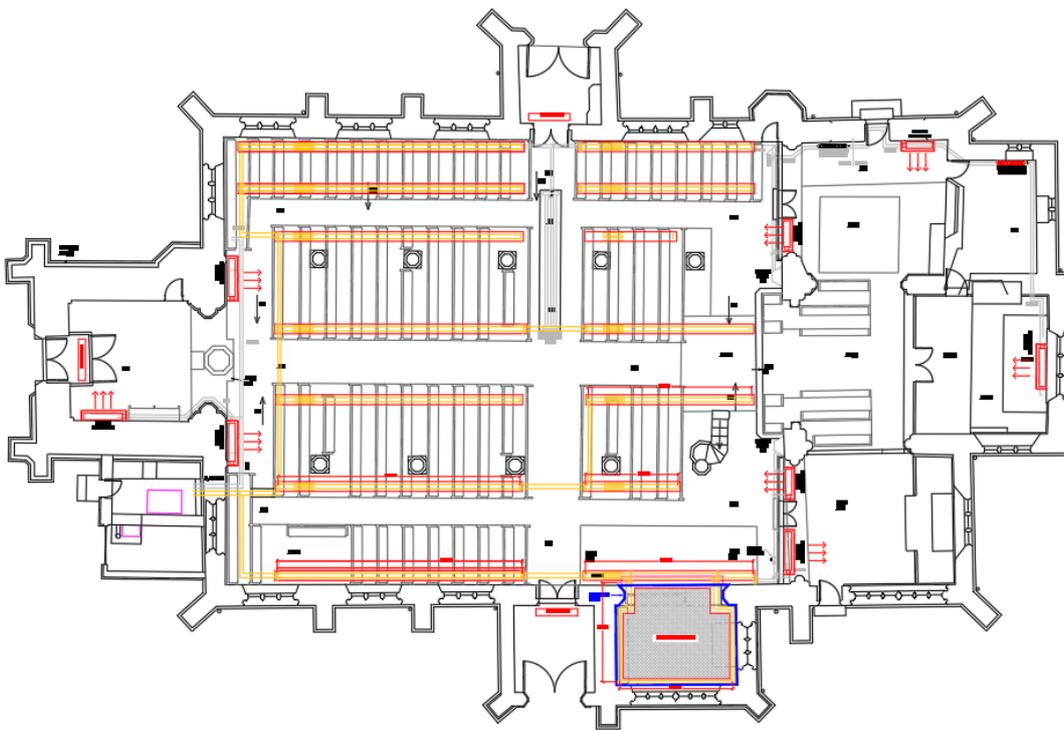


Figure 3-ASHP Solution

The existing pipe loops running down the North and South Aisle would be removed. As with the combined solution, it would provide new heating pipe loops installed within new purpose built boxes insulated on 3No. sides with a grated timber cover within the existing timber floor sections, but now covering the South Aisle, north and south sides of the Nave, and North Aisle.

The South Transept would be upgraded in the same way as the combined new boiler and ASHP solution, with a low level pipe loop boxed in with a decorative grating and then building up the existing floor to provide an area of underfloor heating in just this area.

The existing cast iron radiators within the Choir changing area, Spire, West side of the Nave and Alter would all be upgraded to fan convectors. One of the existing cast iron radiators within the Organ space would be retained, and one replaced with a new fan convector. The existing radiator within the Vestry would be replaced for one of the existing larger radiators which have been stripped out. The fan convectors would be

speed controllable and manually switchable from the pulpit to allow the units to be switched to low speed (quieter setting) during services.

3No. direct electric air curtains located within the Spire's Lobby and the north and south door lobbies have been added. As above, direct electric air curtains were preferred, since installation of a wet system would be difficult due to the extensive builder's work required and the use of the heaters would be limited to only occupied times on colder days.

2No. new 60kW ASHP's would be installed in a purpose built enclosure (refer to separate section below option 4). By having 2No. separate ASHP units, which when combined, can meet the occupancy load of the building but each capable of delivering the buildings fabric protection load on their own, the church heating will have some resilience should one heat pump require repair or maintenance during the heating season.

#### *Options 4 and 5 – Combined ASHP (or Replacement gas boiler) and Overhead Infra-red Radiant Heaters.*

Overhead radiant heaters offer less effective fabric protection since they only heat the surfaces that they are directed towards (ie. the floor) and not the air which comes into contact with all of the building fabric. In order to maintain fabric protection, it is therefore necessary to provide background heating in conjunction with overhead radiant heaters. This option also therefore needs to include upgrade of the existing system with either a new gas boiler, ASHP or combination of them in order to provide the fabric protection for the building.

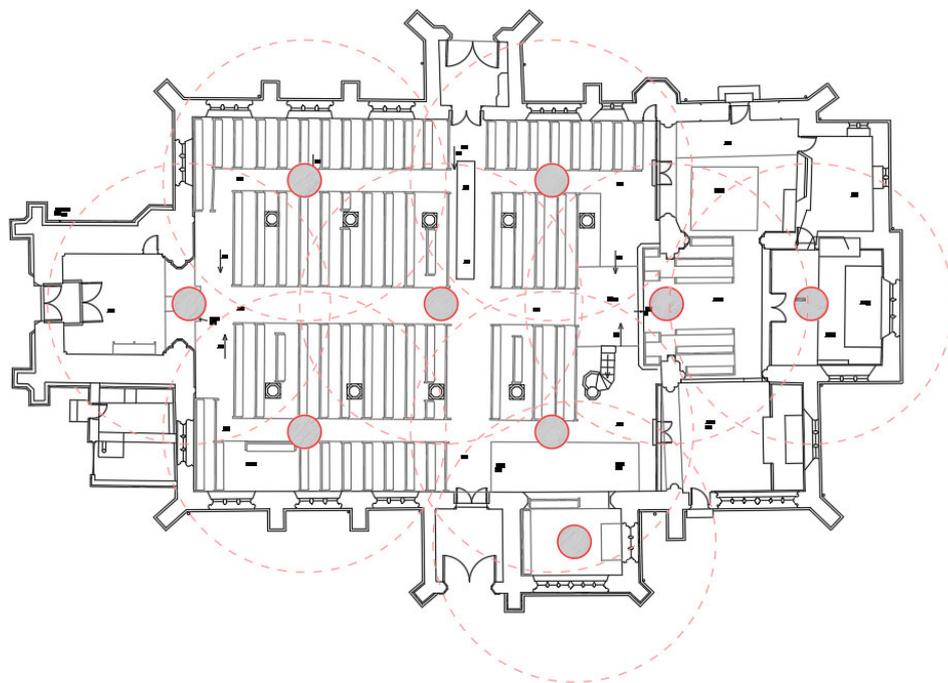
For Option 4 (ASHP combined with overhead radiant), this approach provides almost identical internal pipework and fan convector changes to option 3, however, the sizes of the ASHP and fan convectors can be reduced. The addition of overhead radiant heaters is then included. For Option 5 (gas boiler combined with overhead radiant), this approach limits the need for replacement pipework and heat emitters compared to Option 4.

Whilst this is a possible consideration for the church, we are concerned about comfort issues which are often associated with this type of system, ie. Warm head but cold body and feet. It is also difficult to get good coverage of radiant heat to all occupied areas.

We would also note that overhead radiant heating can also be visually intrusive and will require working at high level for mounting and wiring both during installation and when being maintained.

Infra-red radiant heaters are classed as direct electric which means you get 1 unit of heat out for every 1 unit of electricity consumed. This is a small improvement on a modern high efficiency gas boiler, but less efficient compared to an ASHP which provides 3 units of heat for each unit of electricity consumed. The Church currently has a low usage pattern which could make the use of overhead radiant heating seem favourable in terms of carbon reduction, but if usage increases, as is the intention with the re-ordering proposals, the energy cost benefits of this type of system quickly reduce.

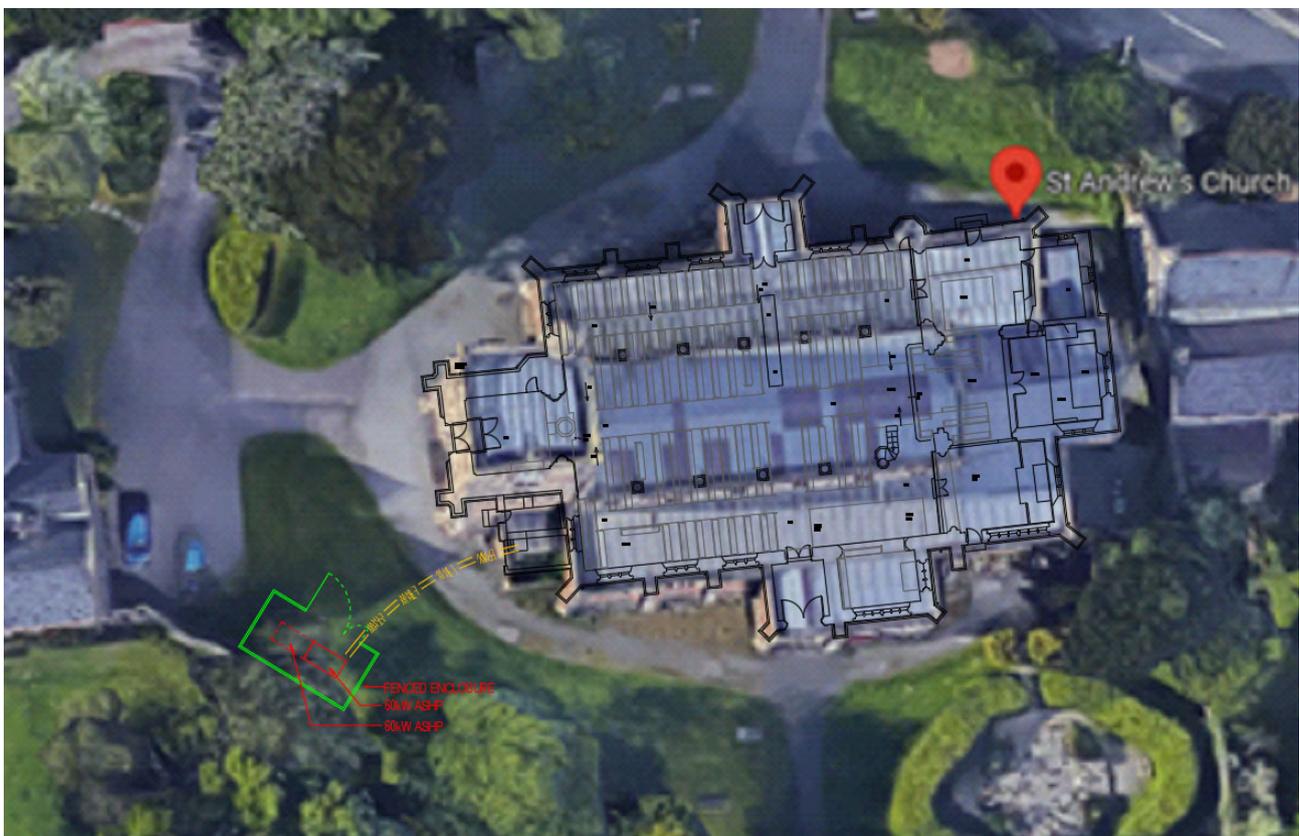
Overhead radiant heaters require line of site to work, and due to the change in heights across the church and to ensure coverage of all areas used by the congregation, this option includes a minimum of 9 no. 4.8kW units, providing 43.2kW of heat output, as indicated in the diagram below.



*Location for External Air Source Heat Pumps*

A new compound would be created with staggered panel (hit and miss) fencing to house the ASHP(s) required by options 2, 3 and 4 above. Allowance would be made for the full ASHP option (option 3) of 2No. ASHP units, each of which can provide the fabric protection load and together can provide the total load requirement for the church.

The location indicated below allows for limited length pre-insulated below ground pipework runs to link the ASHP's with the existing boiler room. The closer the ASHP's are to the boiler room, the lower the resistance in the pipework and the power required to run the circulation pump. The proposed location minimises excavation and external works. The proposed enclosure location could also potentially house an air source heat pump to serve the next door vicarage in the future.



## 9.0 Further Investigation

1. It was noted during the survey that the main pipework from the boiler room below the floor is heavily corroded due to a leak from the previous repair. The pipework is heavily pitted and requires immediate attention to prevent the pipework from failing and potentially flooding the void below the main church.



Please see the photo below which show visible extent of the degradation.

2. Intrusive survey of the existing pipework to determine overall condition and give an indication on life expectancy.
3. In-depth review to determine the most appropriate location for the air source heat pumps and routing of the pipework.

## 10.0 Recommendation

The aim of the upgrade to the heating system is to find a pathway towards a low / zero Carbon heating solution. The existing heating system is undersized and unable to provide more than background fabric protection heating.

Based on the findings of this report we would recommend the Option 3 full ASHP heating solution, subject to capital funds being available for this investment.

By moving to an ASHP solution, this will provide the required heat output and take a major step toward meeting the low / zero carbon emissions target for 2030. It also removes the need for additional works and alteration in the future, as the existing system in the North Aisle, Nave, Organ, Vestry and Chancel would already be completed.

If funds are not available for the investment in the full ASHP heating solution, we would recommend the combined gas fired boiler and air source heating (option 2) as the best alternative, which still leaves the option to proceed to the full ASHP solution in the future.