Energy Efficiency and Zero Carbon Advice

St Michael's Church, Bray, Maidenhead

PCC of St Michael's Church

Author	Reviewer	Date	Version
Paul Hamley	Matt Fulford	7th August 2020	2.0

Contents

1. Executive Summary

An energy survey of St Michael's Church, Bray, Maidenhead was undertaken by Inspired Efficiency Ltd to provide advice to the church on how it can be more energy efficient and provide a sustainable and comfortable environment to support its continued use.

St Michael's Church, Bray, Maidenhead is a mediaeval church dating from 1293 with additions in 1868. There is both gas and electricity supplied to the site.

The church has a number of ways in which is can be more energy efficient. Our key recommendations have been summarised in the table below and are described in more detail later in this report. It is recommended that this table is used as the action plan for the church in implementing these recommendations over the coming years.

Energy saving recommendation	Estimated Annual Energy Saving (kWh)	Estimated Annual Cost Saving (£)	Estimated capital cost (£)	Payback (years)	Permission needed	CO2 saving (tonnes of CO2e/year)
Contact suppliers to arrange for the lighting meter to be changed to smart meter	None	None	Nil	N/A	None	N/A
Switch electricity (and gas) suppliers to ones which provide 100% renewable (or green gas) supplies	None	None	Nil	N/A	None	0.8
Purchase a temperature monitor to optimise heating times	5-10% 6-12,000	£200-£400	£50	<1	None	1.1-2.2
Add Endotherm fluid to heating circuit	10% 12,000	£400	£50	<1	None	2.2
Draughtproofing entrance doors	5% 6000	£200	£200	1	List B / Faculty	1.1
Under pew heating [Long term; recent boiler], or use as top up and reduce boiler hours. Create a warm zone for the elderly and to use in shoulder months.	20-30%	£800-£1200 reduction in gas use from introducing partial electric heat	£6,500 for 20 heaters £37,500 for 120 heaters (two per pew)	6 13 for full under pew system with solar panels	Faculty	4.4-6.6
Install solar photovoltaic panels in roof valleys	Potential to generate 18000 (enough for complete under pew heating plus lighting and power) and	£1,100 electricity (£4000 gas costs could also be saved with complete move to electric heating)	£34,500 for full size system [160m2, 28kWp]	31.4 (based on electricity saving only)	Faculty	23

	save 120000 gas					

The Church should check any faculty requirements with the DAC Secretary at the Diocese before commencing any works.

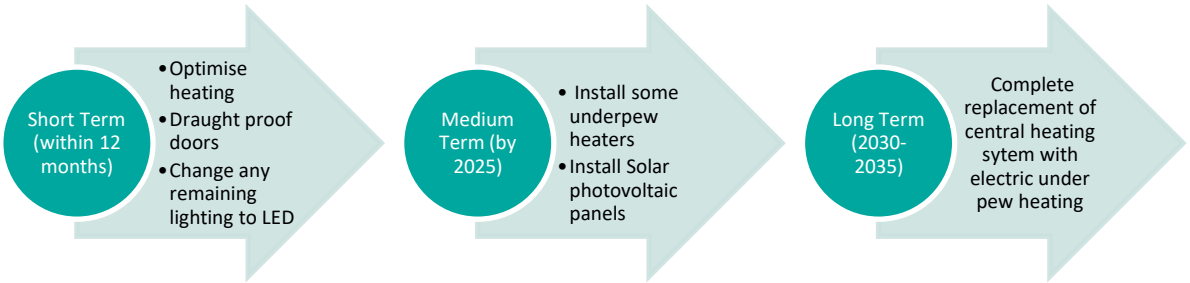
Based on current contracted prices of 11.75p/kWh (lighting) and 16.05p/kWh (power) and 2.0769p/kWh for electricity and mains gas respectively.

If short term measures were implemented this would save the church around £1,500 per year in operating costs. There is potential to reduce utility bills to net zero by installing solar photovoltaic panels with a battery and converting to fully electric heating and become zero carbon.

2. The Route to Net Zero Carbon

The General Synod of the Church of England has indicated that the Church of England should be Net Zero Carbon by 2030. Every church, cathedral, church school and vicarage will therefore need to convert to be a net zero building in the next 10 years.

This church has a clear route to become net zero by undertaking the following steps:



The church has an ideal roof for installation of solar photovoltaic panels with three separate pitched roofs offering two areas with valleys which are not visible from the ground. The potential output is greater than required for the current lighting and power requirements of church and hall *plus* an estimate of the electrical heating requirement for the whole church [See Section 8].

The radiator system is inefficient at delivering heat to the congregation and could only be improved with significant additions of extra radiators, or fan assisted radiators, which in turn would require a boiler of larger output and consume yet more gas. Installation of electric under pew heating, which could be done on a rolling basis, is capable of meeting the comfort requirements of the congregation with far less energy use.

3. Introduction

This report is provided to the PCC of St Michael's Church, Bray, Maidenhead to provide them with advice and guidance as to how the church can be improved to be more energy efficient and also improve the levels of comfort where possible. In doing so the church will also become more cost effective to run. Where future church development and reordering plans are known, the recommendations in this report have been aligned with them.

An energy survey of the St Michael's Church, Bray, Maidenhead, High Street, Bray, Berkshire SL6 2AE was completed on the 13th July 2020 by Dr. Paul Hamley. Paul is an energy auditor with experience of advising churches and small businesses. He is part of the Diocesan Environment Officers Energy Group developing advice for the Church of England and authored the "Assessing Energy Use in Churches" report for Historic England. He is a CIBSE Associate member and a Chartered Scientist, with experience of the faculty process gained from chairing the building committee of a Grade I listed church, and has been an assessor for EcoChurch.

St Michael's Church, Bray, Maidenhead	
Church Code	627369
Gross Internal Floor Area	650 m^2
Listed Status	Grade II*

The church typically used for 7.5 hours per week for the following activities

Type of Use	**Hours Per Week (Typical)**	**Average Number of Attendees**
Services	4 hours per week	70 at 10am service 15 at 8am service 8 at Evensong
Meetings and Church Groups	0 hours per week	
Community Use	0 hours per week	
Occasional Offices	12 Weddings per annum 12 Funerals per annum	100 100

The church is normally closed during the week.

Estimated opening hours	400
Estimated heating hours	1500
Typical congregation size	70 (10 am service)
Estimated annual footfall	7,400

4. Energy Procurement Review

Energy bills for gas and electricity have been supplied by St Michael's Church, Bray, Maidenhead and have been reviewed against the current market rates for energy.

The current electricity rates are:

Lighting	11.75p/kWh	Below current market rates
Power	16.05p/kWh	In line with current market rates
Weighted average	12.725p/kWh	Below current market rates
Standing Charge	26.85p/day	N/A

The current gas rates are:

Single / Blended Rate	2.0769p/kWh	Below current market rates
Standing Charge	367p/day	N/A

The above review has highlighted that the current rates being paid are in line or below current market levels and the organisation can be confident it is receiving good rates.

However, the electricity is supplied by SSE so is not renewable. The church is encouraged to consider the Parish Buying scheme, offering group purchasing leading to economies of scale and delivering 100% renewable electricity and 20% green gas. We would therefore recommend that the church obtains a quotation for its gas and electricity supplies from the scheme, http://www.parishbuying.org.uk/energy-basket. This scheme only offers 100% renewable energy sourced energy and therefore it is an important part of the process of taking churches towards zero carbon output.

Alternatively; Bulb, Ecotricity and Good Energy offer 100% renewable electricity.

A review has also been carried out of the taxation and other levies which are being applied to the bills. These are:

VAT	5% [20% during part of 2018]	The correct VAT rate is being applied. A rate of 20% was applied to the gas charge from January-April and October-December 2018
CCL	not charged currently	The correct CCL rate is being applied.
FiT		A FiT charge is being applied for each of the electricity meters. It should be checked that this is being charged in accordance with the supply contract.

The above review has highlighted that VAT and CCL was charged for gas during two periods in 2018. The church is a charity and therefore can claim VAT exemption status. As such the PCC of St

Michael's Church, Bray, Maidenhead should send the supplier at VAT declaration confirming this and check all supplies on other sites. VAT declarations are available from the supplier's website and can usually be found by typing the suppliers name followed by "VAT Declaration Certificate" into most search engines.

5. Energy Usage Details

St Michael's Church, Bray, Maidenhead uses around 4,200kWh/year of electricity, costing in the region of £840 per year, and between 120,000 to 140,000 kWh/year of gas, costing £4,000 - £4,600.

Utility	Annual use/ kWh	from	to	Cost
Electricity - Lighting	3,269	February 19	January 2020	£551.92
Electricity - Power	959	February 19	January 2020	£287.99
Gas Church and Hall	119,407	31/01/19	31/01/20	£4,064

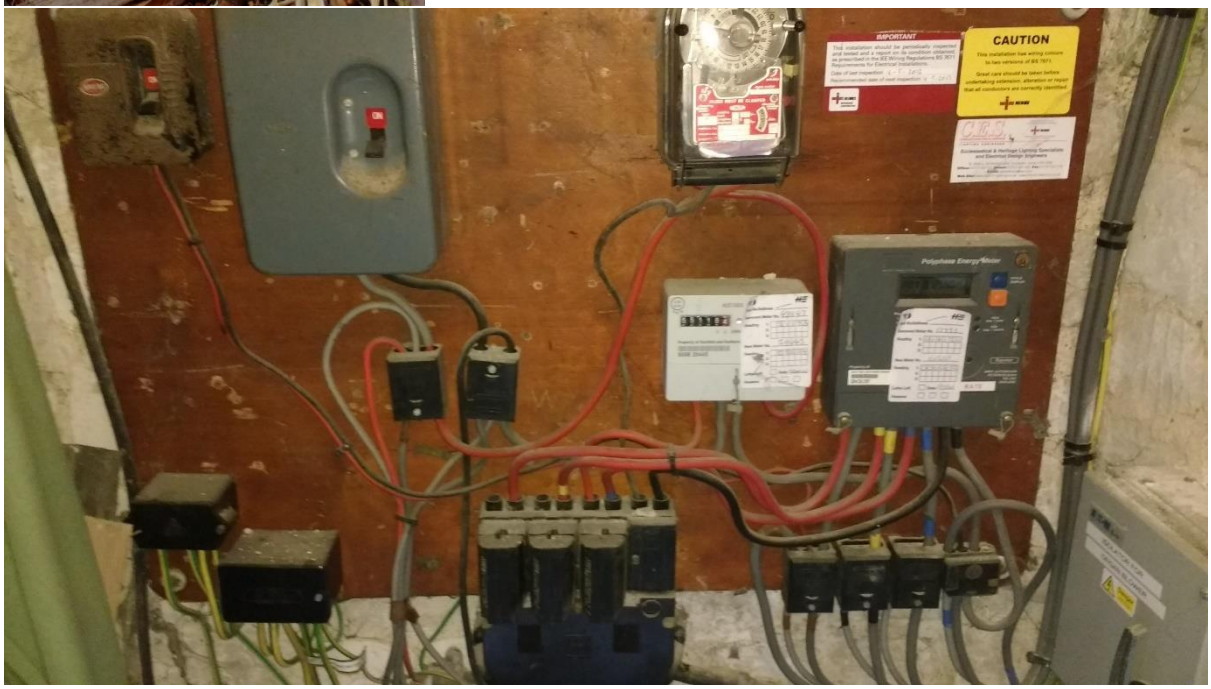
Gas use figures over a 13 month period covering 2018 and January 2019 show an annual use of 140,814kWh. The meter also measures the consumption of the church hall 40kW boiler which is set to run for two 30 minute periods on a Sunday. This will use between 1200-1600kWh annually, less than the annual variability in the church heating use.

This data has been taken from the annual energy invoices provided by the suppliers of the site.
St Michael's Church, Bray, Maidenhead is supplied with three phases of power with two electricity meters, one for lighting and a two phase meter for power and the organ. There is one gas meter serving the site which includes the church hall.

Utility	Meter Serial	Type	Pulsed output	Location
Electricity – Lighting	S06R29445	SSE ACE 1000	No	Tower stairwell
Electricity - Power	D04C01207	AMPY Polyphase energy meter	Yes	Tower stairwell
Electricity – Hall				Under stair cupboard in hall
Gas – Church And Hall	M025 K02636 10 D6			External gas meter cupboard next to toilet block

The gas and power meters are AMR connected and as such energy profile for the entire energy usage should be possible.

The gas meter is fitted with a smart meter interface.

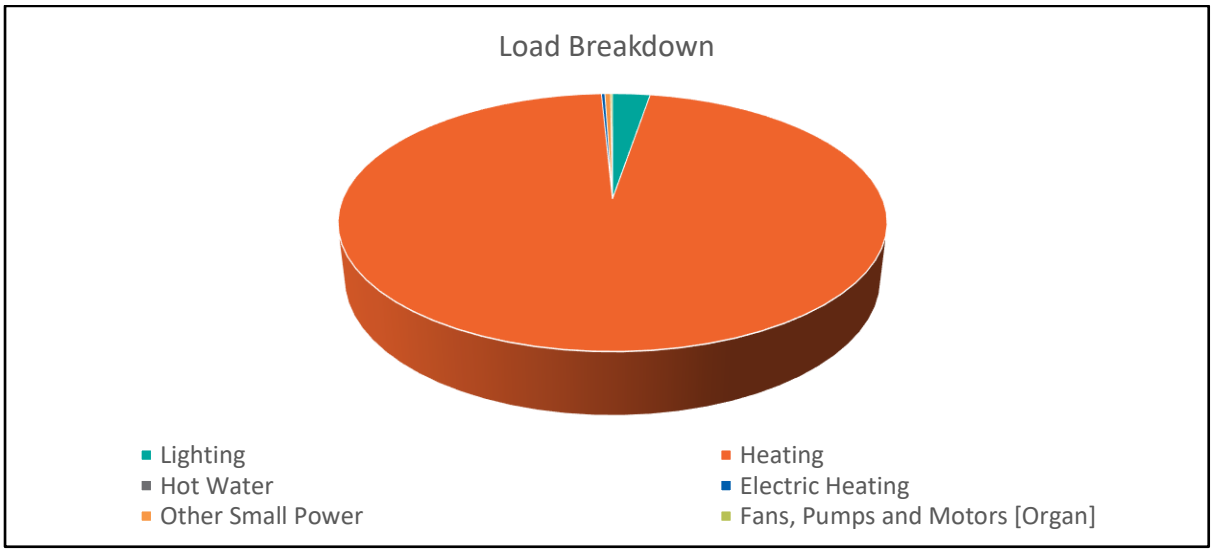


A three phase supply is provided to the church; which will allow easy installation of under pew heating in the future if desired.

5.1 Energy Profiling

The main energy use within the church can be summarised as follows:

Service	Description	Estimated Proportion of Usage
Lighting	Changed to LED, 4228kWh in 2019	2.6%
Heating	80kW boiler, 1500 hours annually, 120,000kWh	96.6%
Hot Water	None in church	0%
Other Small Power	959 kWh annually, 2019	0.7%



As can been seen from this data, the heating makes up by far the largest proportion of the energy usage on site. The other significant load is lighting.

5.2 Energy Benchmarking

In comparison to national benchmarks for Church energy use St Michael's Church, Bray, Maidenhead uses 76% less electricity and 18-38% more heating energy than would be expected for a church of this size.

	Size (m^2 GIA)	Annual Energy Usage [kWh]	St Michael's Church, Bray, Maidenhead use kWh/m^2	Benchmark Large Church Use kWh/m^2	Variance from Typical
St Michael's Church, Bray, Maidenhead (electricity)	650	4,228	6.50	27	-76%
St Michael's Church, Bray, Maidenhead (heating fuel)	650	120,000 140,000	184 215	156	+18% +38%
TOTAL	650	124,228	191	183	+4%

6. Efficient / Low Carbon Heating Strategy

The energy used for heating a church typically makes up around 80% to 90% of the overall energy consumption. Heating also often uses gas or oil as its primary fuel, these are fossil fuels with high carbon emissions and little opportunity to decarbonise in the future. Electricity currently has carbon emissions around the same level as mains gas but the carbon emissions associated with electricity are reducing rapidly as the UK builds more renewable energy and decommissions its remaining coal fired power stations. Churches which procure 100% renewable electricity can substantially reduce their carbon footprint and can achieve net zero more easily if electric heating is employed. Mains gas does have some potential to reduce its carbon content through the use of bio gas and hydrogen but these are less developed solutions and will be unable to deliver 'zero carbon mains gas'. It is therefore critical to review energy use and plan to make it more efficient and less carbon intensive. One way to achieve this is to consider a transition to electrical heating where this also represents a more efficient and comfortable solution for churches. As with most medieval churches, this church would have survived most of its life without any form of heating; the modern addition of heating is not needed to preserve the fabric but only to provide thermal comfort to occupants. The previous trend of 'conservation heating' for fabric issues is now largely considered to be unnecessary and is being avoided by the likes of The National Trust and English Heritage.

The church has recently installed a new 80kW gas boiler, which interfaces with the legacy heating system consisting of just two large cast iron radiators situated 3/8ths of the length of the nave from the west end next to the entrance / circulation space and five radiators in the chancel area, four of which are in the south east end. There is 160m of unlagged 2" pipe in the church which also contributes heat. This uneven distribution system delivers heat initially to the ceiling and does not easily lend itself to efficiency improvements. The current heating regime is for Sunday only use and involves heating over one period from Saturday midday. The temperature is set to 16°C, but allowed to drop back to 14°C overnight before being set to 16°C again at some point on Sunday morning. The heating will be running until after Evensong at approximately 5pm.

The two radiators are situated between the third pillars from the front on each side and are the only ones fitted in the nave (area 450m^2).

Further radiators are all situated in the chancel area.

Radiators could be replaced by fan assisted radiators – this would allow heat to be delivered more rapidly but would probably lead to a greater demand on the boiler and higher gas consumption. A higher heating rate might also cause issues with the fabric. This approach is not recommended.

Installation of more radiators would also lead to greater gas consumption, and would be unlikely to receive faculty permission.

Attempts to increase heating by adding more radiators, or operating for longer hours have to overcome the large volume of the building, with heat rising to the ceiling, cooled by the clerestory windows.

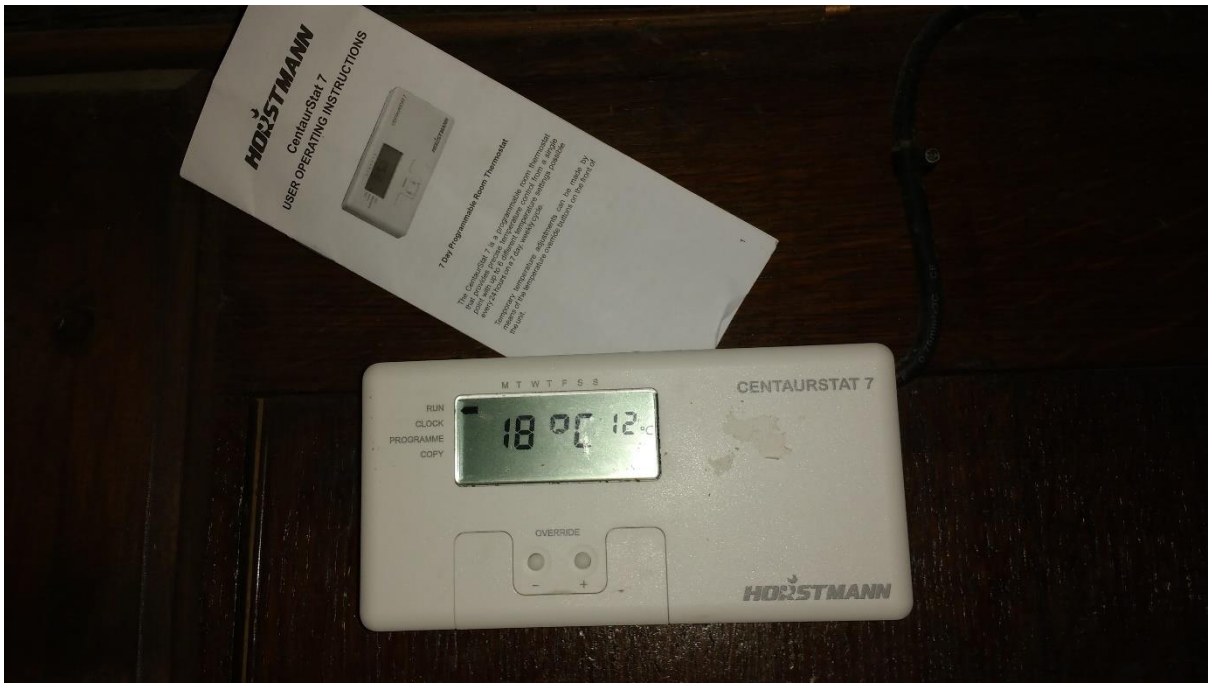
6.1 Current Heating System Optimisation

The church is strongly recommended to purchase a temperature monitor and use this to optimise heating on/off times and the thermostat setting.

If the temperature rises above 14°C during Saturday and is then allowed to fall to 14°C overnight, the excess heat is being wasted. This could be seen from a graph produced by from temperature monitor data. It may be that a later start time for heating will deliver the same temperature at (say 6am) on Sunday morning, with the thermostat set to 16°C.

Radiators filled with hot water retain their heat for a considerable period. Measurements at over 70 churches in the Diocese of Lichfield show that the heating system can be turned off 45 minutes before the end of the service (i.e. approximately 16:15 on Sunday) and heat will still be emitted.

This intervention is recommended.



6.2 Providing Extra Heat Where it is Required

16°C may be considered slightly cool by some of the congregation, especially the elderly. Raising this temperature using the central heating system would require either many hours extra operation, or the installation of extra radiators which would require a larger capacity boiler.

In fact, the system may be unable to exceed this temperature due to the large volume of the building and the heat being circulated firstly to the roof.

An alternative is to create a localised “warm zone” using under pew electric heaters.

Initially, it is envisaged that these be provided for a selected group of pews specifically for use by the elderly or those with health conditions. This small area of the church could also be heated entirely by the under pew heaters, thus allowing small meetings to take place at any time during the week. Evensong, with an average reported attendance of 8, could now take place with electric only heating. The central heating could be switched off at the end of the morning service. It would be expected that the air temperature in church would fall to perhaps 14°C from 12:00 to 16:00; the under pew heating would be providing a warm environment in a small area without needing much preheating.

Equipping a larger area of pews (not necessarily all) would enable the whole church to be heated electrically in the “shoulder” months of September and May and parts of October and April with warmer weather. A gradual introduction which takes into account the congregation size could allow large economies in gas use.

The substitution of electric heating for gas is usually economic despite the approximately 4x higher cost of electricity compared to gas: (i) there is little need for preheating compared to the 12-18 hours commonplace for central heating systems and (ii) only the pew heaters required need to be switched on.

Ultimately, gradual introduction of under pew electric heating would mean that a whole church solution could be achieved by the time the boiler is life expired.

Under Pew Heating Options

Area	Type/ Size	Length (mm)	Watts	Number Required	Unit Cost	Total Cost
Initial warm zone 10 pews, two heaters each	Electric Under Pew 300W	525	300	20	£ 313.00	£ 6,260
All pews, one heater each	Electric Under Pew 450W	702	450	60	£ 329.00	£ 19,740
All pews, two heaters each	Electric Under Pew 300W	525	300	120	£ 313.00	£ 37,560

Notes:

The church is already equipped with a three phase electricity supply

Maximum load for 120 heaters at 300W each is 36kW

The boiler output is 80kW, losses in pipework and to the ceiling mean that perhaps only one quarter of this heat reaches the congregation.

The number of heaters required for a congregation of 100 may not require heaters under every pew, just those occupied.

A gradual introduction of under pew heaters (perhaps in three phases) will allow a decision to be made on how many are required for adequate comfort, whilst space heating is still available initially.

Savings can be made by reducing use of central heating at each end of the heating season, by lowering the temperature reached by the central heating and using the pew heaters as a top up.

Reduced operating costs will be achieved by on site generation of electricity.

7. Energy Saving Recommendations

In addition to having a revised heating strategy there are also a number of other measures that can be taken to reduce the amount of energy used within the church.

7.1 Lighting (fittings)

The lighting makes up a relatively large overall energy proportion of the electricity used within the church. The church reports that LED lighting has been installed during 2019 at a cost of around £5k.

Depending on when during the year the lights were changed, the annual lighting use of around 4200kWh could reduce considerably. It has not been possible to see a variation from the series of quarterly lighting bills since October 2018 since 5/8ths of the bills are estimates. Installation of a smart meter for lighting should give more reliable data.

7.2 Endotherm Advanced Heating Fluid

In order to improve the efficiency of the current heating system further it is recommended that an advanced heating fluid (http://www.endotherm.co.uk/) is added to the heating system.

This fluid in in addition to, and complements any existing inhibitors in the heating system and is added in a similar way. The fluid works to improve the ability of the boiler to transfer heat into the heating system and for the radiators and other heating elements to give out their heat into the rooms. It does this by reducing the surface tension of the water and increasing its capacity to transfer and hold heat. Case studies have demonstrated that the addition of this fluid into heating systems reduces heating energy consumptions by over 10% as well as helping the building heat up quicker. This additive should be installed into the radiator circuit side of the heat exchanger, NOT the boiler circuit.

Endotherm can be self-installed.

7.3 Insulation of Pipework and Fittings

The pipework in the boiler room is adequately insulated.

A plate heat exchanger is installed to interface between the Viessmann Vitodens 80kW boiler and the radiator circuit.

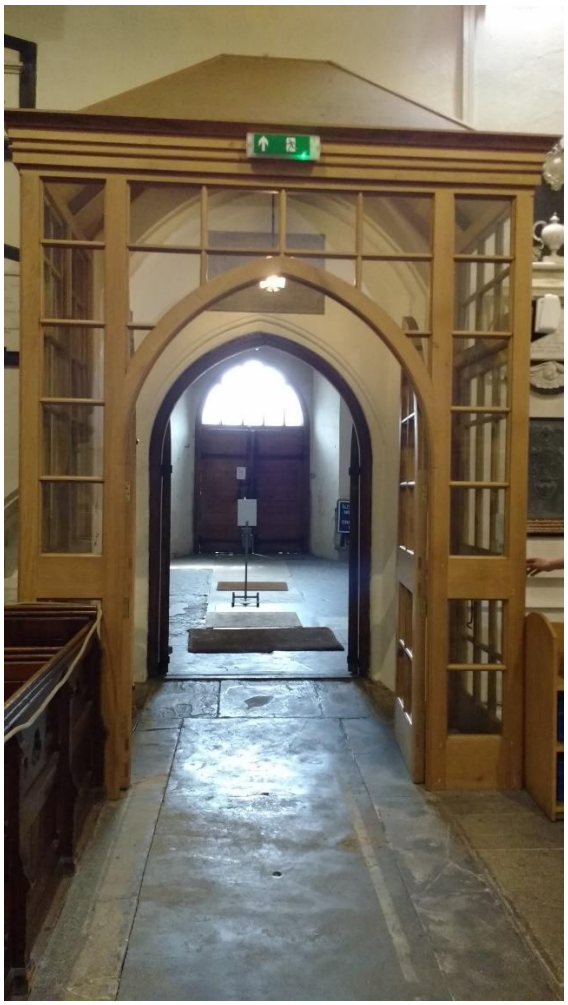
7.4 Draught Proof External Doors

The entrance to the church is via a door under the large tower located south of the south aisle. Historic timber doors often do not close tightly against the surround and hence a large amount of cold air can enter the church around their sides and base. It is recommended that the draughtproofing around the door is kept well maintained and improved where practical. This could be achieved in a number of ways:

For timber doors that close onto a timber frame, it is recommended that draught proofing is fitted to all external doors. A product called QuattroSeal (see link below) is often used in heritage environments to provide appropriate draught proofing.
http://www.theenergysavers.co.uk/application/files/1714/7197/4194/National_Trust_Case_Study.pdf

For other doors and those of which close onto a stone frame, brush draught strips could be rebated into the edge of the door by a skilled joiner. Other traditional methods such as using hessian or felt pads tacked to the door could be used and keeping the door maintained in a good condition is important. For little used doors, or those which will be closed for long periods during the week simple measures such as placing a 'sausage dog' draught excluder at the base of the door (suitably weighted using pea gravel or similar to ensure it stays tightly in place) can be employed.

Keyholes can be sealed temporarily by using a fridge magnet painted black over the keyhole.



Light can be seen around the top, bottom and left side of these doors showing areas where there is no seal. Draughts can blow fairly continuously and even small draughts can waste around 5% of heat.

Entry is through this side door in cold weather.

Windows are covered in polycarbonate sheeting externally. This does not appear to be sealed to form a double glazed unit (for heritage reasons) but will offer a degree of protection against bad weather.

8. Renewable Energy Potential

The potential for the generation of renewable energy on site has been reviewed and the viability noted.

Renewable Energy Type	Viable
Solar PV	Yes
Battery Storage	Yes
Wind	No – no suitable land away from buildings
Micro-Hydro	No – no water course
Solar Thermal	No – insufficient hot water need
Ground Source Heat Pump	No – archaeology in ground and poor radiator system. Borehole has been investigated and was considered too expensive
Air Source Heat Pump	No – insufficient radiator network and large building
Biomass	No – air quality issues

8.1 Solar Photovoltaic Panels

Approximate calculations are as follows:

The south facing roof valleys offer two areas giving maximum useable areas of 35m x 3m; when discounting the visible areas at each end of the roof this gives two areas of approximately 80m^2 each.

Each area of 80m^2 at the roof inclination and orientation to south would give a 14.4kW peak system and a total annual generation of 9,000kWh. This is much greater than the church's current annual electricity use (4,228kWh). The combined total for church and hall is around 5,200kWh.

Adding a full complement of under pew heaters with 36kW load [60 pews each with two of 300W], used for 6 hours on 40 Sundays per year requires 8,640kWh. Adding church plus hall use requires less than 14,000kWh.

If it was not planned to increase the hours of use of the church or hall, then the system size should be scaled back to reduce capital costs. It is no longer cost effective to export electricity now that the Smart Export Guarantee has replaced the Feed in Tariff. The Smart Export Guarantee rates are no more that 5.5p/kWh and have to be negotiated with the utility company. It does not offer a financial incentive towards installation of a larger SPV system than is needed for the site.

Also, a large system will require a battery so that power can be stored for use in the evenings – without a battery there will still be reliance on grid electricity. With a battery, the roof is large enough to enable the church to become independent of the grid.

Using average 2018 installation costs for larger systems (£1,200 per kWpeak); each 14.4kWpeak system would cost £17,280. This does not include cost of any battery.

The cost of the largest system at around £35k would be offset by large savings; annual gas bills of £4000-4600, together with church plus hall electricity of £1100.

Battery Storage is not strictly a renewable energy solution, but battery storage does however provide a means of storing energy generated from solar PV on site to be able to be used at peak times or later into the day when the PV is no longer generating. It therefore extends the usefulness

of the existing PV system particularly in this sort of church. This is a new but fast-growing technology with prices expected to fall substantially over the next 2 to 3 years therefore investment into this may be worth delaying at this stage.

The suitability of the roof structure to accommodate the extra weight and wind loading, as well as appropriate fixings would have to be confirmed with your inspecting architect.

- Wind turbines require highly exposed sites and should be located 250m way from buildings as such this site is not suitable for a wind turbine to be installed.
- Hydro electricity is a highly efficient source of renewable energy but requires a body of flowing water with a differential height which is not present on this site.
- Solar thermal installations are best suited to heat water for use in washing up, hand washing and bathing. There is minimal hot water demand at this church so such an installation would not be viable.
- Heat Pumps are a low carbon method of creating heat, their use and suitability for this church have been considered previously by the church.
    - Ground Source Heat Pump coils are not permissible due to the large number of burials adjacent to the church
    - A borehole has been ruled out due to cost
    - A Water Source Heat Pump has been considered, but the trenching costs to the Thames are considered too great.
- Air to Water Source Heat Pumps would use the existing radiator network, which is inadequate, and would have to work extremely hard to upgrade heat during the winter. This would use much electricity and not be economic. There is no obvious location for the pumps except in the roof valleys which would lead to pipework installation difficulties.
- Air to Air Source Heat Pumps would similarly need a rooftop location and also be faced with heating a very large volume of building.
- Biomass is an alternative boiler and fuel to oil or gas. It requires wood chips or pellets to be delivered on site, stored and then fed into a large boiler for burning. While the fuel is not a fossil fuel there are emissions from the burning of wood and these can be detrimental to local air quality particularly in more built up areas for all these reasons it is not considered a viable recommendation for this site.

9. Funding Sources

This audit programme offers each participating church the chance to apply for a grant of up to £150 towards implementing some of the audit's recommendations. An application form is included with this report.

There are a variety of charitable grants for churches undertaking works and a comprehensive list of available grants is available at https://www.parishresources.org.uk/wp-content/uploads/Charitable-Grants-for-Churches-Jan-2019.pdf .

Trust for Oxfordshire's Environment (TOE) does have some funds available (over and above the small implementation grants of £150 available through this scheme) to support energy efficiency improvements in community facilities. If your church is used by the wider community, visit www.trustforoxfordshire.org.uk or contact admin@trustforoxfordshire.org.uk to find out if your project is eligible for a grant of up to about £5,000.

10. Faculty Requirements

It must be noted that all works intended to be undertaken should be discussed with the DAC at the Diocese.

Throughout this report we have indicated our view on what category of permission may be needed to undertake the work. This is for guidance only and must be checked prior to proceeding as views of different DACs can differ.

Under the new faculty rules;

List A is for more minor work which can be undertaken without the need for consultation and would include changing of light bulbs within existing fittings, repair and maintenance works to heating and electrical systems and repairs to the building which do not affect the historic fabric.

List B is for works which can be undertaken without a faculty but must be consulted on with permission sought from the Archdeacon through the DAC. This includes works of adaptation (but not substantial addition or replacement) of heating and electrical systems and also the replacement of existing boilers so long at the same pipe work, fuel source and flues are used. It can also be used to replace heating controls.

All other works will be subject to a full faculty.

Works which affect the external appearance of the church will also require planning permission (but not listed building consent) from the local authority and this will be required for items such as PV installations.

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