Energy Efficiency and Zero Carbon Advice

St Nicholas', Cuddington

PCC St Nicholas Church

Author	Reviewer	Date	Version
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1. Executive Summary

An energy survey of St Nicholas' 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 Nicholas' is a Grade II* listed mediaeval church constructed of stone with a pitched roof. Electricity and gas are supplied to the site.

There are number of ways in which the building 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.

Short Term: Energy saving recommendation	Estimated Annual Energy Saving (kWh)	Estimated Annual Cost Saving (£)	Estimated capital cost (£)	Simple Payback (years)	Permission needed	To be actioned by who / when?
Install Endotherm heat transfer fluid to heating system	10% gas 4,300	£123	£140	1.5	List B	Warden
Install reflective panels behind radiators	2% gas 860	£24	£50	2	List B	Warden
Install Infra red panel heaters in tower rooms	100	£13	£1,120	Many	Faculty	PCC

Medium Term: Energy saving recommendation	Estimated Annual Energy Saving (kWh)	Estimated Annual Cost Saving (£)	Estimated capital cost (£)	Simple Payback (years)	Permissio n needed	To be actioned by who / when?
Change light bulbs to LED	1,000	£130	£2,000	15	List A	Warden
Install new doors to porch to create draught lobby / door draughtproofing	3% gas 1,290	£37	Draught Proofing £500	13	Faculty	PCC
Install solar photovoltaic panels on portion of nave roof	All electricity 5,800 generated	£709 +	£10,750	15	Faculty	PCC
Install Chandelier mounted infra red heaters	43,000 gas Need half electric	Save £1,950 Cost £2,041 with solar: 91 extra	C £20,000	Not recovered	Faculty	PCC
OR						

Install ceiling mounted far infra red panel heaters	43,000 gas Need half electric	Save £1,950 Cost £2,041 with solar: 91 extra	£8,186	Not recovered	Faculty	PCC
OR						
Install Ground Source Heat Pump	43,000 gas Need ¼ electric	Save £1,950 Cost with solar £833 Overall saving £1,824	£40,000	22	Faculty	PCC

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

Based on the current contracted price of 15.5692p/kWh (weekday rate) and 13.0010p/kWh (evening and weekend rate) for electricity, and 2.8648p/kWh for gas.

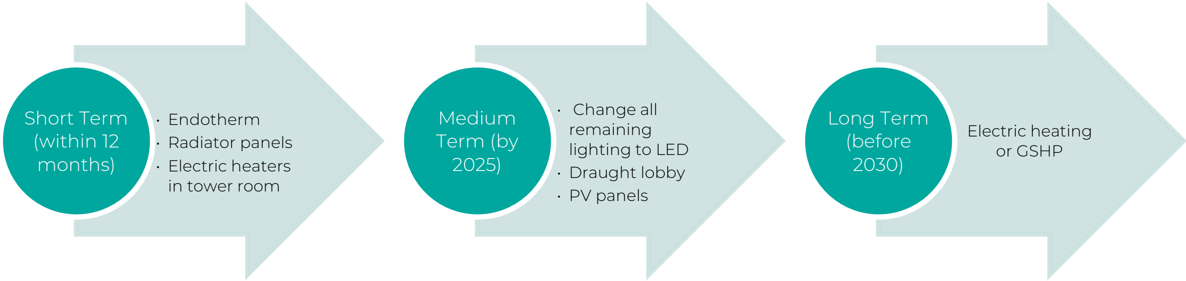
If all measures were implemented this would save the church in the region of £1,800 in operating costs per year [see Section 12].

2. The Route to Net Zero Carbon

Our Government has committed to move towards Net Zero Carbon – the point at which we have reduced emissions as much as we can and then balanced any residual emissions through removal of carbon from the atmosphere. They have done this as part of a worldwide agreement which aims to limit global warming to well under 2 degrees Celsius, with an aim of keeping it below 1.5 degrees Celsius. This will help protect all of us from the impacts of climate change.

In February 2020, the Church of England's General Synod set its own Net Zero Carbon target. The first stage of this target covers energy used by churches, cathedrals, schools, vicarages, other church buildings, as well as emissions caused by reimbursed transport. The target date is 2030. The Diocese of Oxford has a diocesan commitment to reach a more broadly scoped Net Zero target by 2035 or as soon thereafter as possible.

This church has a clear route to become net zero by 2030 by undertaking the following steps:



3. Introduction

This report is provided to the PCC of St Nicholas' to provide them with advice and guidance as to how the church building can be improved to be more energy efficient. In doing so the building will also become more cost effective to run.

An energy survey of the St Nicholas', Upper Church Street, HP18 0AP was completed on the 20th April 2021 by Dr Paul Hamley. Paul is an energy auditor with experience of advising churches and small businesses. He is part of the Church Energy Advisors Network developing advice for the Church of England and authored the "Assessing Energy Use in Churches" report for Historic England. He is a CIBSE affiliate 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 EcoCongregation.

The church was represented by James Stonham, Church Warden.

St Nicholas'	627603
Gross Internal Floor Area	275 m^2
Listed Status	Grade II*

The building is typically used for around 10 hours per week for the following activities.

Type of Use	Hours Per Week (Typical)	Average Number of Attendees
Services	2.5 hours per week	44
Church Use	1 hour per week	12
Community Use Schools (monthly), concerts, weekly toddler's group, monthly breakfast	3.5 hour per week	20-30 150 at school events, 250 Christmas
Occasional Offices	2 weddings p.a. 4 funerals p.a.	100 each

Church annual use: 500 hours

Heating hours: Background heating to maintain 10°C plus 18h each Sunday (540h)

Estimated footfall: 8,500 people

4. Energy Procurement Review

Energy bills for gas and electricity have been supplied for St Nicholas' and have been reviewed against the current market rates for energy.

The current electricity rates are:

Weekday Rate	15.5692p/kWh	Above current market rates
Evening & weekend rate	13.0010p/kWh	In line with current market rates
Standing Charge	59.1129p/day	N/A

The current gas rates are:

Single / Blended Rate	2.8648p/kWh	In line with current market rates
Standing Charge	196p/day	N/A

Both utilities are supplied by Total Gas and Power.

If this has been arranged through the Parish Buying scheme, then the tariffs normally 100% renewable electricity and a proportion of renewable gas and therefore are an important part of the process of making the church more sustainable.

However, the utility bill documentation shows the fuel mix for electricity generation being only 43% renewable.   This should be discussed with Parish Buying.

In future, we recommend that the church obtains quotations for 100% renewable tariffs from both this Diocese Supported parish buying scheme, http://www.parishbuying.org.uk/energy-basket and from the Big Church Switch https://www.bigchurchswitch.org.uk

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

VAT	5%	The correct VAT rate is being applied
CCL	Not charged	The correct CCL rate is being applied.

The above review confirmed that the correct taxation and levy rates are being charged.

5. Energy Usage Details

St Nicholas' uses around 4,200kWh/year of electricity, costing in the region of £700 per year, and 43,000kWh of gas, costing around £1,950 at current rates.

This data has been taken from the annual energy invoices provided by the suppliers of the site.

Utility	Meter Serial	Type	Pulsed output	Location
Electricity	S91E 012456	Sangamo SPA 02 Single Phase	No	Vestry, on wall
Gas	K00333 17 D6	Elster Bk-G10A	(Yes), non operative: No internet signal on site	External brick housing beside boiler room

5.1 Energy Profiling

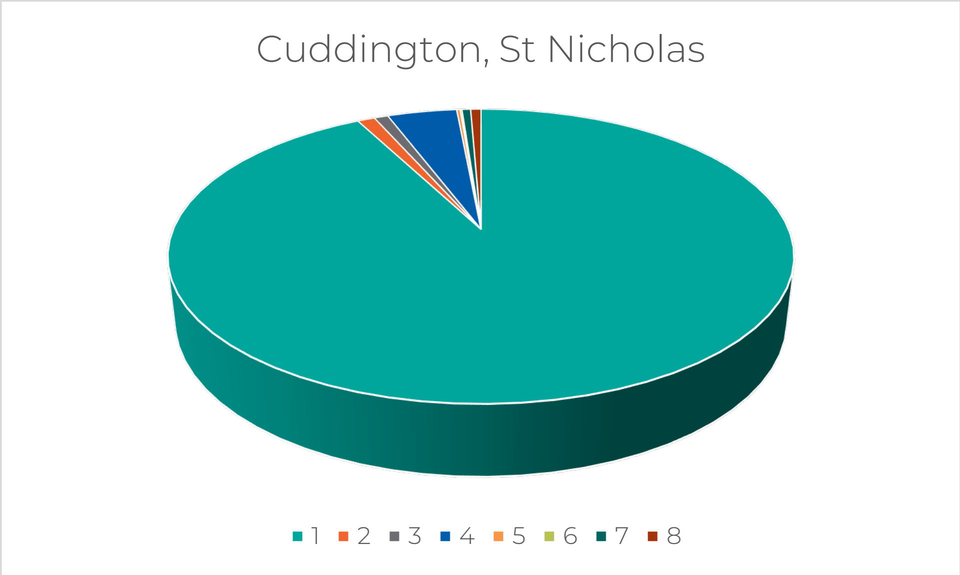
The main energy use within the Pastoral Centre can be summarised as follows:

Service	Description	Power kW	Annual Use/ kWh	Estimated Proportion of Usage %
Heating [Gas]	Gas boiler, Vaillant Eco Tec Plus 610		43,112	91%
Heating [Electric]	Ringing room: Portable fan heater, Dimplex 2 hours/ week Kitchenette (in tower) – electric heater Boiler circulation pump	3 2 0.2	180 120 200	1.2%
Lighting [Internal]	Nave; 12 halogen each 120W 117mm R7 6 downlights Aisles; 7 halogen 3 downlights Chancel; 3 halogen 1 spotlight Vestry (light use) Ringing room (2 hours/week) Tower room (2 hours/week) Toilet Bulkhead light TOTAL	3.6 0.2 4	2000	5.1%
Lighting [External]	Floodlights, Bega 8530 x 3 Use c. 50 hours per year (Christmas etc)	1.5	100	0.2%
Hot Water	Kettles Coffee machine (2 hours/week)	2 x 3 2	200 200	1%
Organ, PA	Organ 150 hours use Projector (every other week x 2 hours)	1.5 0.5	225 25	0.5%
Other Small Power	Vacuum cleaner	1.5kW	50	0.2%
Kitchen	Fridge	150W	300	0.8%

Estimated consumption; 3,500kWh

Total Annual Consumption 2019: 4,239kWh

The shortfall of around 700kWh may be due to increased hours of use of lighting than reported, perhaps associated with concerts or school use. It is worthwhile checking the hours of use of lighting and heating in ringing rooms, as instances of undisclosed preheating have been reported.



KEY 1 Gas heating 2 Electric heating 3 Hot water 4 Lighting

5 Floodlights 6 Small power 7 Organ, projector, sound 8 Kitchen

5.2 Energy Benchmarking

In comparison to national benchmarks for Church energy use[1] St Nicholas' uses 23% less electricity for lighting, etc and 4% more gas for heating than would be expected for a church of this size. The electricity value is due to the low hours of use.

	Size (m² GIA)	St Nicholas' use kWh/m²	Typical Church use kWh/m²	Efficient Church Use kWh/m²	Variance from Typical
St Nicholas' (electricity not for heating – 4,239kWh)	275	15.4	20	10	-23%
St Nicholas' (heating fuel – 43,112kWh	275	156.8	150	80	+4%
TOTAL	275	172	170	90	+1%

There currently no benchmark data which takes hours of use and footfall into account.

[1] CofE Shrinking the Footprint – Energy Audit 2013

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. Putting in place a heating strategy that is energy efficient and low carbon is, therefore, of the highest priority

The Church of England is in the process of reviewing its heating guidelines. The process has already established some principles for heating that can help churches as they seek an acceptable combination of comfort, conservation, affordability, and environmental care. The principles can be found at https://www.churchofengland.org/sites/default/files/2020-04/CBC%20Heating%20guidance%20principles%20FINAL%20issued.pdf

As the principles make clear, every church's strategy will be unique to it, informed by many factors, including the nature of its usage, the system it's starting from, the conservation needs of the building, and the resources available. The strategies in this audit are designed specifically for your church.

Our recommendations on heating generally fall within three major areas. Firstly, for all churches we make recommendations that will help to reduce energy wastage and, as a starting point, to optimise the system that you already have. In addition to these the church may also like to consider actions which help to improve thermal comfort for the congregation such as pew runners or cushions to insulate people from having to sit on colder pew surfaces and the used of breathable carpet matting to help insulate the congregation's feet from cold stone or timber floors.

Secondly, we recommend options for many churches that focus on heating people rather than the full volume of the church. Some of the changes that can help with this will be 'soft' changes – others will relate to the heating system itself.

Finally, we make recommendations about moving away from fossil fuels. Moves away from fossil fuels are key to cutting emissions. For most churches, this will involve moving from gas, oil or LPG to electricity. Electricity currently creates carbon emissions around the same level as mains gas, but the carbon emissions associated with it are reducing rapidly as the UK builds more renewable energy and decommissions its remaining oil and coal fired power stations. 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'. Some local areas may also be considering the option of district heating networks.

While moving away from fossil fuels may not always be possible, as the principles state, "churches should be expected to have at least carefully considered the option of moving away from fossil-fuel based heating (gas and oil boilers) towards electric-based heating." And if such options are not viable now, the churches "can try to be ready for a future retro-fit when technology and the grid has progressed."

The church currently uses gas fired boiler serving mostly cast-iron radiators to heat the church. The entire system including pipework dates from 2009 with each radiator having separate pipework fed from a manifold, which allows for diagnosis of any blockage or leak to be made. This is reported to work well but has been unable to reach the temperatures forecast with a maximum of 16°C being reported during winter. Section 7 will consider recommendations to improve the performance of the current system.

7. Boiler Replacement Options

As the boiler is now over ten years old, it can be expected to require repair or replacement by the end of the decade, so a boiler replacement plan should be developed now, so that the church will not be forced to replace like for like at short notice and has adequately considered the options.

The church should develop a boiler replacement plan, by obtaining detailed quotations for the options presented in this report.

A church with low hours of use per week will always fall back to “base” temperature between heating events (it may take around 24 hours for the temperature to fall). A system which can heat rapidly, without sending most of the heat to the ceiling first, and in addition can be configured to heat small areas independently for small services or midweek meetings will be more efficient than one which seeks to heat up the whole volume.

7.1 Replacement Gas Boiler

Whilst there are plans to add hydrogen to the network, and "green" gas from anaerobic digestion; some suppliers offering up to 20% "green gas" tariffs, the majority of the gas supply will continue to be fossil fuel for the next decade. The economics of hydrogen production and the need to replace some pipework make full decarbonisation of gas unlikely.

If the gas boiler is repaired or replaced, then long term, the boiler will need to be made hydrogen ready. Some hydrogen is due to be added to the gas grid over the next five year period. If plans to decarbonise the gas grid are implemented; the hydrogen mix will eventually exceed 20% and a hydrogen compatible boiler (and piping) will be required. The transition will be overseen by the regulatory bodies in a similar way to that between town gas and north sea gas.

If the church is not prepared to incur higher heating costs, it will have to remain with gas and the carbon emissions that produces.

Carbon emissions which cannot be avoided by energy efficiency measures plus moving to lower carbon technologies can be offset, see Section 16.

7.2 Chandelier Mounted Radiant Heaters

Radiant electric heating can deliver heat to the congregation directly without the heat first travelling upwards to the roof. The nave at St Nicholas is quite narrow (5.3m), so installation of 2m diameter (approximately) chandeliers supporting infra red bar heaters would provide a good distribution of heat across the area where most of the congregation are seated.

Due to the height of the heaters at 2.5 to 3m above the floor the heat would be delivered directly, with less losses than for the other options. This option would have the greatest visual impact due to the introduction of several hanging objects into a relatively uncluttered building.

St Catherine's, Faversham, above, has higher arches and ceilings than St Michael's

Seven installations (three on the north side, four on the south) each containing 6 heaters; 42 elements of 1kW each giving a total of 42kW (similar to the current boiler maximum output).

The heaters could be controlled in three pairs giving low, medium and high outputs.

The system would not need to provide the same amount of heat input (kWh) annually as at present as much of the heat would be directed at the congregation, rather than being routed via the roof.

Currently heating uses around 43,000kWh annually; this could be expected to reduce to around half as more efficient heat delivery requires less, and only some of the heaters being used in the shoulders of the heating season. Estimating 21,000kWh use (500 hours if at full power, which may well be an overestimate) operating costs at present rates would be £2,730 with all power coming from the grid. The total site electricity requirement would then be around 25,000kWh p.a.

[St Catherine's Faversham, which has c. 260 annual occupancy hours recorded uses approximately 11,000kWh of heating via the radiant heaters.   St Nicholas, Cuddington has c. 500 occupancy hours].

Solar power could generate around 5,800kWh, so the majority of supply would still be from the grid.

Operating cost at current rates	£2,730 p.a.
Capital cost (based on Faversham data)	£20k

Installation of a three phase supply would be required (see Section 8.5).

7.3 Use of Electric Radiant Panels

A less visually intrusive electrical heating method is offered by the use of infra red panel heaters. These are rectangular, non glowing panels which can be finished in any colour (or with artwork printed, or camouflaged as stonework.

The roof structure, thought to be Victorian (it has regularly spaced, straight beams) has inter beam spacing which is too narrow for installation of panels between the beams as has been done at some churches. Instead, panels could be mounted on the beams and finished in white with brown stripes to align with the beams and disguise their presence. With the height above the congregation, higher temperature panels would be required.

This would probably be considered less of an aesthetic imposition on the building than chandelier mounted heaters. Research would be needed to procure the correct size of panel to fit the site.

The heating in the tower ringing room comprises of a small portable 3kW electric heater. A radiator fitted to the tower ground floor room is reported to be slow acting. Should these rooms be brought into regular use, installing a modern far infra red panel would offer rapid heating to the area. Slower acting forms of heating such as convector heaters are not worth it for a room in occasional use for short periods.

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Operating cost	£2,730 p.a.

Capital cost to supply 42kW of panels, equivalent to chandelier heating:

Using a mixture of near IR overhead heaters, the larger of 4.5kw (1440mm) installed above the nave and shorter 2kW (480mm) above the aisles distributed as below:

Distribution	North Aisle	Nave	South Aisle
		Chancel – none	
First bay	2kW	2 x 4.5kW	2kW
Second bay	2kW	2 x 4.5kW	2kW
Third bay	2kW	2 x 4.5kW	None – entrance area No seating
Fourth bay	X	2 x 2kW	2kW
Tower rooms	X	Low level panel heaters Section 8.4	X

Total: 6 x 4.5kW at £671 installed + 8 x 2kW at £520 installed = £8,186

Installation of a three phase supply would be required.

The narrow area just inside the porch which is unseated probably does not require heating.

7.4 Infra-red Panel Heaters for Tower Rooms

These rooms are used for bellringing on Sunday and practice for c. 1.5 hours weekly. Currently this space is heated from a a 3kW portable fan heater. Fitting a near infra-red wall mounted panel heater is an option – this would deliver instantaneous heat. A 900W unit (1200mm length) is around £560 installed cost.

The ground floor room could similarly be fitted with an IR heater to give rapid warming.

These heaters, which would be installed on low level walls, do not reach as high surface temperatures as the ceiling mounted near IR heaters do.

Note that with the low hours of use of these rooms, the cost of installation cannot be recovered through energy efficiency savings: the change would be for increased comfort, and to provide rapid heating to make the rooms more easily used during the winter.

7.5 Three Phase Supply Installation

To be able to have sufficient electrical power to supply enough energy into an electrical heating system the church will need to increase the existing electrical supply from single phase supply to a 3 phase 100A supply.

The upgrade to the supply has to be carried out by the District Network Operator in the areas.

The DNO in your area is UK Power Networks - www.ukpowernetworks.co.uk; 0800 029 4282 (London, South East and Eastern England)

The cost of bringing in a new 3 phase supply can range from £300 to £30,000 but the DNO will provide a quotation for free so it is well worth obtain a quotation in the short term so that decisions can be made on a well-informed basis.

7.6 Ground Source Heat Pump

The intervention with the least aesthetic impact would be to retain the existing network of radiators, but heat them using a Ground Source Heat Pump.

As has already been mentioned, the low hours of use of the building (about ten per week) make an Air Source Pump (which has a lower capital cost) technically non viable. ASHPs also look like air conditioning units and need an external location where they can be hidden.

GSHPs consume electricity but deliver around 4 times the amount of heat in kWh that they consume. This is measured by the Coefficient of Performance, or COP, 4 is a reliable assumption. This means that they will be around four times as efficient as a direct electric heating method, although the heat will still rise to the ceiling first. They are suited to regularly used buildings, and need to be operated constantly or semi constantly throughout the heating season.

The age of the churchyard indicates significant burials, and lack of sufficient space for ground source heat pump coils. If it were possible to drill a borehole, a GSHP becomes a viable option (although at relatively high capital cost). The area required for the borehole connections itself can be very small (i.e. the size of a manhole, as installed in one corner of the churchyard of St Mary the Virgin, Ashford town centre). However, there needs to be sufficient space for the drilling rig. At St Nicholas, as the churchyard is raised by about 1 metre from the road situated 10-15m to the north of its walls, access may be problematic – but it should not be ruled out. The obvious place to drill a borehole is on the north side of the churchyard, connecting to a heat pump located where the present boiler enclosure is. A larger enclosure will probably be required than the current shed.

There may be an area of land free of burials to the NE of the church (above); otherwise the only position to drill a borehole is immediately adjacent to the existing boiler room, in the gap between the north aisle and the vestry.

Heat pumps generally deliver water at around 55°C (although there are higher temperature ones on the market which require more energy to run); thus are compatible with a building which is regularly used and can be supplied with constant, medium heat, rather than a full power heat up on Sunday mornings.

The boiler capacity is unknown (there are several options within the Vaillant EcoTec Plus range). The inability to exceed 16°C suggests a lower capacity of 40kW or less. Current annual heat input is 43,112kWh.

18 hours heating from 18:00 Saturday to 12:00 Sunday at full power is 18 hours x 30 weeks = 540 hours x 40kW = 21,600kWh. The remaining 21,400kWh are for heating at other periods and background heating.

GSHP

Capital cost, 40kW output unit £40,000 [Regular heating does not require a larger powered unit than once per week heating does]

Efficiency savings from installation of Endotherm fluid (10%), installation of radiator reflective panels (2%) and draughtproofing (3%) will reduce the amount of heat required to 85%.

Operating cost: 0.85 x 43,000kWh output/COP4 = 9,150kWh.   Without solar, x 15.5692p/kWh = £1,424

With solar assume half of needs from grid during winter; 2,288kWh = ~ £356, offset by some sale of surplus electricity generated during summer.

8. Energy Saving Recommendations (Heating)

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

8.1 Install Reflective Sheets Behind Radiators

The church is heated by radiators served from the boiler. These radiators are located on the external, uninsulated walls and have no reflective or insulated surfaces directly behind them at present. They therefore lose much of their heat into the masonry of the wall behind the radiator rather than giving it out into the body of the church.

In order to improve the insulation directly behind the radiators, a reflective panel can be installed. This helps to make sure more of the heat from the radiator goes into the space and requires less overall heating from the boiler to achieve the set point. There are a wide variety of reflective panels for installing behind radiators on the market. It is recommended that these panels are installed behind all radiators within the building

The installation of radiator panels can be carried out by anybody competent in basic DIY and does not require the radiators to be removed.

7.3 Boiler Maintenance; Clean / Flush Existing Heating System

To ensure longevity, the system should be periodically flushed and cleaned to remove any scale and corrosion. The church should have a record of when this was done last.

It is strongly recommended that the heating system is cleaned to remove sludge from the system, this is done by using a chemical clean and/or power flush procedure where cleaning chemicals are put into the system which is then turn on and run through a filter consisting of high power magnetics to remove the sludge.

The cleaning of a heating system can be carried out by any competent heating engineer and typically increases the efficiency of a system by between 10 to 15%. This can dramatically improve comfort for the occupants.

7.4 Endotherm Advanced Heating Fluid

In order to improve the efficiency of the 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.

Endotherm can be self-installed (via the magnetic particle filter pot) by anyone who is competent to depressurise and repressurise the system.

8.2 Corrosion Inhibitor

This should be added to the system whenever the system is drained down and refilled.

8.3 Reduce / Discontinue Background Heating

As with most medieval churches, this church would have survived most of its life without any form of heating. The modern additional 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 National Trust and English

Heritage. The only times when background heating may be required is if there are historic wall paintings or to for the preservation of large artefacts such as tapestries. The organ (and other sensitive areas such as historic papers stored in the vestry) may require some local background heating specific to that area. In general, sensitive paper records should be removed for storage in the county archive and organs can be installed with a local background tube heater such as https://www.dimplex.co.uk/product/ecot-4ft-tubular-heater-thermostat within the organ casing in order to provide the heat where it is required. The fabric is often subject to the greatest damage by humidity (which is naturally higher when the air is warmer as warmer air has greater capacity for holding more moisture), as a result of large temperature swings (from central heating systems turning on and off) and from the excessive drying out/baking of timbers where high temperature heating units have been fixed to them (such as overhead heaters fixed to timber wall plates)

Providing constant background heating to the church building as a whole is wasteful of energy.

For parts of the heating season, the temperature within the church will drop back to a level between 10 and 12 degrees between weekly heating events (unless there are huge draughts or doors left open for long periods). During very cold spells, the temperature will drop further, and there should be a frost setting to ensure that the heating comes on to prevent freezing of pipes – although this is not necessary if antifreeze has been added to the system. As the boiler is located in an external cabinet, this is where a frost thermostat should be located.

Heating the church to ten degrees from Monday through to Saturday will consistently lose heat.

Temperature monitoring shows that it takes about 24 hours for a brick built church to lose heat from 20°C to 12°C, [0.3 degrees per hour].

If the external temperature is zero, it will take more energy to keep the building at 10 degrees for six days than at 5 degrees (frost setting). Warming from 5 degrees will take longer than from 10 degrees; a heating rate of one degree per hour is likely (the reported maximum winter temperature in the church at Cuddington of 16° suggests the heating rate is not high. It is known that heating rates of 2°C per hour and above can damage fabric e.g. organs). So rather than heating the building to 10 degrees for six days when it is not in use, it is recommended to use a longer preheating time to raise the temperature (once) from five degrees. This would be around five hours heating, if one degree per hour is reached, perhaps double this time – but this is still less heating hours than will be needed for background heating over the week.

8.4 Boiler Timing Optimisation

The boiler timings for Sundays are reported to be ON Saturday 18:00, OFF Sunday 12:00 [18 hours raising temperature from ~10 to ~16 degrees]. The church service begins at 10:00 with people present until 12:00. Radiator systems with hot water remain hot for several hours after the boiler is switched off – experiments in the Diocese of Lichfield at over 50 churches have established that hot water radiator heating can be optimised by being switched off 45 minutes before the end of the service. The church could experiment with turning the heating off at 11:00, 60 minutes earlier, but beginning heating (with no background heating during the week) earlier on Saturday, for instance 12:00.

8.5 Purchase a Temperature Datalogger

Purchasing of a temperature datalogger will allow the time for the church to heat (in different weather conditions) to be understood, as well as the times to switch on and off to be optimised. This would require someone with a computer to plug in the device and download the readings.

Suitable equipment is available from suppliers such as Easylog or Mindsets:

www.lascarelectronics.com/easylog-el-usb-lite

mindsetsonline.co.uk/shop/mini-temperature-datalogger/

8.6 Draught Proofing to Doors

There are a number of external doors in the building. Often historic timber doors do not close tightly against the stone surround and hence a large amount of cold air is coming in to the church around the side and base of these doors.

Tower door

Vestry door (note J cloth filling keyhole)

Tower door internal – the insulating effect of the inner glass doors is largely lost by the large open keyhole – this could be easily blocked using a small piece of thick card or plastic and plasticene.

The church is proposing to create a draught lobby by moving the wooden (Victorian era?) doors to the outer arch and installing glass doors to the inner arch. It should be ensured that the glass doors close against a polymer seal and that there is a suitable seal between them to ensure air tightness. Moving the wooden doors will expose them to sun, wind and rain, so they will need more regular varnishing and maintenance. An alternative consideration would be to install glass doors (again with a good seal) inside the outer archway, which would preserve the current appearance of the porch (ideally using a non-reflective glass coating).

Where a timber door closes against a timber frame it is recommended that draught proofing is fitted. 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. Note this cannot be used where the timber door closes directly against a stone surround.

Other simple measures such as using a small fridge magnet painted black over the large key hole or the use of 'sausage dog' type draught excluders at the base of little used doors can prove to be very effective. Doors should be reviewed in daylight and gaps where the light shines through sealed or filled in whatever the most appropriate way is for the specific door.

8.7 Windows

If there are draughts caused by hopper windows (such as the bottom right four panels of the left window) not shutting correctly, a temporary solution is to use black plasticine to fill gaps.

9. Energy Saving Recommendations (Electricity)

9.1 Lighting (fittings)

The lighting is responsible for about half of electricity use. Many of the lights have 100W halogen R7 linear bulbs, 118mm long. These can sometimes be replaced directly by LED linear bulbs, but because the LED units are “fatter” they may not fit within the luminaire, as the R7 bulb is positioned close to the reflector surface. A type of LED bulb where the connections are offset to its centre are a possible solution, these are variously described as 270 degrees base, asymmetric base or J118. Examples are supplied by Bonlux and Ecobelle, rated at 20watts each.

If all these lights were changed the total capital cost would be £550 (22 x £25). The annual cost saving would be £143 resulting in a payback of around 3.8 years. Many of the lights could be self-installed and therefore cost much less than the supply and fit cost above. In this case the £150 grant available through this process could be very usefully employed to fund the purchase of replacement LED lamps which the church installs themselves.

9.2 Lighting (control for internal lights)

The church is well lit in daylight, with relatively large south facing windows without any stained glass, therefore the number of lights used to light the church during summer could be reduced with some experimentation. A small number of lights on a selected circuit could be used to light the church for visitors.

It is recommended that a motion sensor is installed on specific lighting circuits so that the lights come on only when movement is detected in the space and turn off approximately two to five minutes after the last movement has been detected (note that the duration of the time lag after which the light goes off needs to be considered alongside the type of light that is fitted. LED lights are much more suited to being switched off after only a short duration than some fluorescent lights). These movement sensors (commonly called PIRs) also have light sensors integrated into them so they can be used to make sure that the light does not come on if there is already sufficient daylight in the space.

Your existing electrician or any NICEIC registered electrical contractor can install PIR sensors onto existing lighting circuits. This can be carried out without significant disruption to the use of the space.

9.3 Lighting (external lights)

The external three floodlights are currently only lit for the Christmas period or special occasions. This gives a low energy use, so there is no priority to replace these lamps under the present conditions of use. When they do become due for replacement, LED floodlight units are available.

Should future low power LED lights be required to operate for longer periods than at present, it is recommended that a timer is installed to switch off the external lights at 11pm daily. A timeclock with a time and day capacity is recommended over those that only have time of day capacity. Sangamo (http://sangamo.co.uk/) make a wide range of commonly used timeclocks which any qualified electrician can install.

10. 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, small installation only, visible roof
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	Possible
Air Source Heat Pump	No – insufficient hours of use, no location
Biomass	No – not enough heating load as well as air quality issues

Since the church roof is visible from most angles (including the valley between the south aisle and nave roofs) it is considered unlikely that more than a small solar photovoltaic array could be fitted, which makes electric heating more expensive. A heat pump will reduce the operating expenses. The current hours of use of the building (about ten per week) are too low for an Air Source Heat Pump to be viable technically. A Ground Source Heat Pump would be more efficient; installation would require a borehole, but it is questionable if there is enough space for access for the drilling plant. If the church is prepared to accept hight (electric) heating costs as part of it's mission (on behalf of the environment, to lower carbon emissions), an electric heating method is preferrable.

10.1 Solar PV potential

Virtually all of the roof is visible, with just a small portion of the nave roof not visible – that area which is shaded by the south aisle and tower.

The south facing aisle roof is visible and therefore does not offer a location for solar panels.

The south facing chancel roof may offer a site, although it will often be shaded by the south aisle and the tower.

The roof offers a maximum area of around 50m^2. This could generate 0.15kWpeak/m^2 giving a 7.5kWpeak system. A 1kWpeak system can generate up to 1000kWh annually, with no shading. Orientation factor (roof slope and angle from south) is 0.97. Shading from the adjacent roof and tower will be considerable.

Annual Generation (kWh) = Area x 0.15kWp/m^2 x K factor x Orientation Factor x Overshading Factor

= 50m^2 x 0.15kWp/m^2 x 1000kWh/kWp x 0.97 x 0.8

= 5,820kWh

This is much larger than the church's annual recent electricity use (4,239kWh),– although once the amount required to operate a heat pump is added, generation is less than demand as an extra 11,000kWh is required. If a heat pump is installed, solar power greatly enhances its viability, as the pump can run for free whenever the sun shines.

Electricity requirements of a heat pump are estimated at 9,150kWh (GSHP)), Totals: 9,150 + 4,250 = 13,400kWh p.a. minus any efficiency savings from lighting.

The Smart Export Guarantee pays about 5p/kWh for electricity generated and exported to the grid (the Feed in Tariff having ended). One of the issues for churches is that most lighting use is at periods when the electricity is not being generated, so installation of a battery to make maximum advantage is recommended. Using a battery will extend the usefulness of the power generated during the day into the evening, but some exporting of power to the grid in summer, and purchase from the grid for winter evenings will occur.

Battery Storage is not strictly a renewable energy solution but provides 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. This is a new but fast-growing technology with prices expected to fall substantial over the next 2 to 3 years therefore investment into this may be worth delaying at this stage.

Using average 2019 installation costs (£1,450 per kWpeak); a 7.5kWpeak system would cost £10,875. This does not include cost of any battery.

Sources: Tables H3 & H4, SAP 2009, http://www.bre.co.uk/filelibrary/SAP/2009/SAp-2009_9-90.pdf

https://www.theecoexperts.co.uk/solar-panels/cost

The government Smart Export Guarantee pays for electricity generated and exported to the grid (the Feed in Tariff having ended). It needs to be negotiated with the purchasing utility company. One of the issues for churches is that most lighting use is at periods when the electricity is not being generated, so any implementation of an SPV system must wait until the SEG terms are guaranteed to assist financial viability.

11. Cost Comparison

Item	Annual consumption/ kWh	Annual Cost/ £
Electricity	4,239	709
Lighting	2,000	
Lighting Projection with LED	1,000 less	
Heating to tower, projected	100 less	
Total electricity projected	**3,100**	
Gas Heating, current	43,112	1,950

Total current expenditure		2,659
Savings from draughtproofing, Reflective radiator panels, Changed heating hours, =25%	Projected heat need 32,333	
Electricity required to supply 32,333kWh heat by GSHP at CoP of 4	8,083	
Total projected requirement	11,183	
Solar PV annual generation	5,820	
Grid requirement	5,363	835
Annual Saving		1,824

12. Other Issues

The masonry on the south side of the church includes some areas of soft mortar which is being excavated by mason bees. The image below is an area of the wall immediately to the right (east) of the porch, which can be easily kept under observation. This issue should be discussed with the inspecting architect of the church as it may require remediation and there may be further damage in inaccessible areas which could allow water to penetrate the walls.

The following link to a surveyor's website contains advice from the Society for Protection of Ancient Buildings: Masonry Bees | Holes in Structural Walls (woodwardsurveyors.co.uk)

www.woodwardsurveyors.co.uk/blog/holes-in-structural-walls-by-harrow-chartered-surveyor.html

13. 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 on this Parish Resources page: https://www.parishresources.org.uk/resources-for-treasurers/funding/

14. 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.

15. Offsetting

As you take action to reduce your emissions, you may also wish to offset those that you cannot yet reduce. If you would like to engage in offsetting, it is important to use a reputable scheme. The Church of England recommends Climate Stewards, which has a simple calculator that can help you to work out how much you would need to offset. https://www.climatestewards.org/

> Climate Stewards encourages people to 'reduce what you can and offset the rest' as part of your journey to Net Zero carbon emissions.
>
> Having reduced as much of your organisation's carbon footprint as you can, there will always be unavoidable emissions from your work and travel. Carbon offsetting allows you to compensate for the negative impact of your carbon emissions by funding projects which take an equivalent amount of CO_2 out of the atmosphere. These either involve locking up ('sequestrating') CO_2 as trees

16. Report Circulation

In addition to the PCC, this report is also sent to:

1. Your DAC secretary and your DEO, because
    - They maybe be able to offer you help and support with implementing your audit
    - They want to look across all the audits in your diocese to learn what the most common recommendations are.
2. Catherine Ross, the officer in the Cathedral and Church Buildings team centrally who leads on the environment, who wants to learn from all the audits across the country. She will be identifying cost-effective actions churches like yours might be able to make.

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