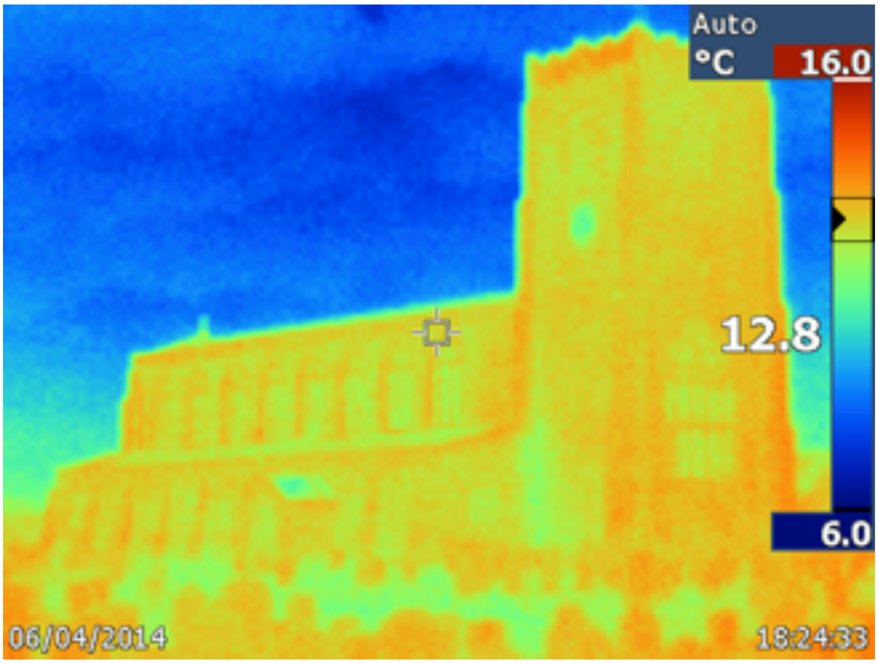
Energy Audit

St James' Church, Freiston

by Simon Pearson, Mar 2014



1. Introduction

St James' Church, Freiston celebrates its 900th anniversary in 2014. It was established as a priory church dependent upon Crowland Abbey. At the dissolution, it was the fourth wealthiest priory in England as judged by its asset value. Much of the priory has gone, but the current building is to a large extent the parish church of the priory. The building is grade I listed. It has a fine heritage reflected in some of the key features of the building, including its fine font cover from the 15th century and aspects of romanesque architecture. These aspects are described in the church's Conservation Management Plan available from the PCC (Feb 2014).

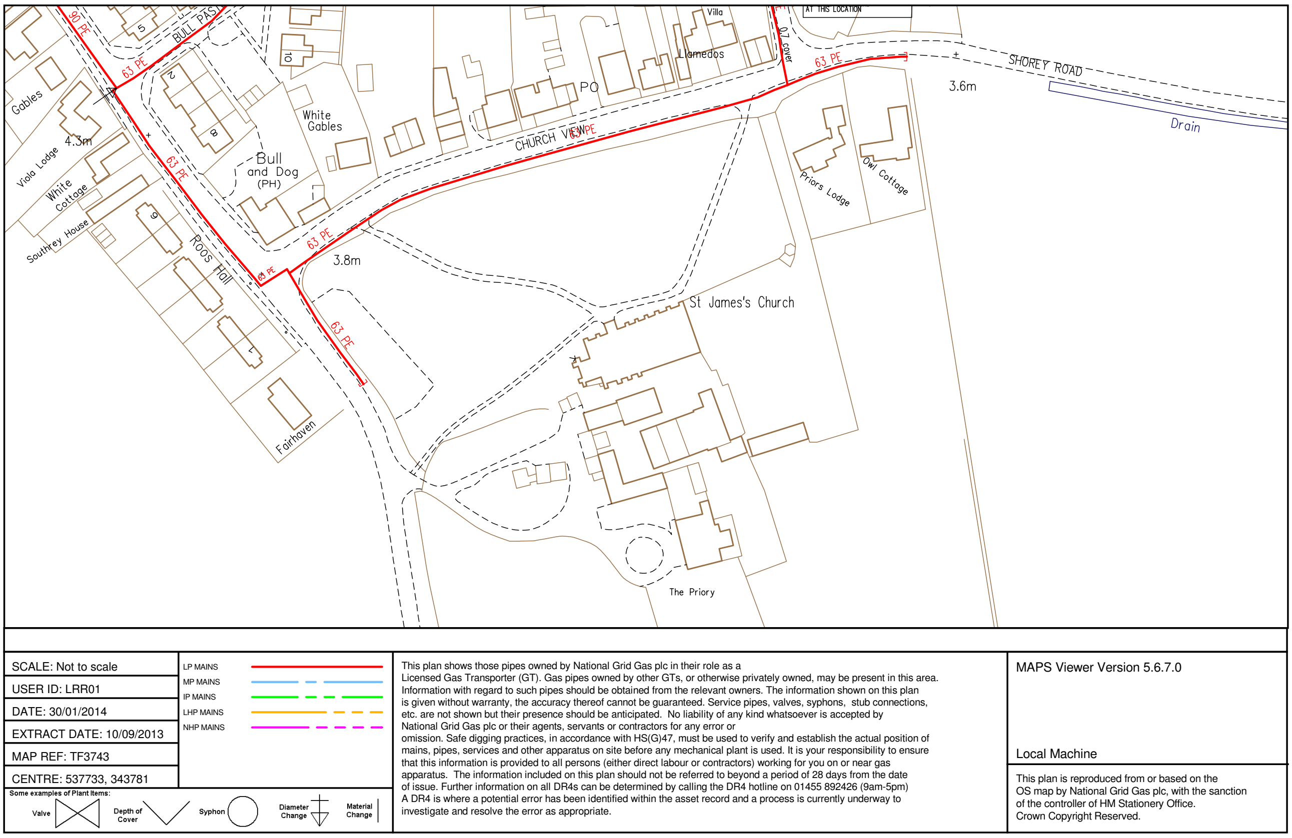
The building was reordered by James Fowler of Louth in 1870, when significant original features were removed. At the reordering, the original floor was removed (to a level c 30cm below the current surface), and a rudimentary coal fired heating system was installed, with one large underfloor duct and two exhaust points. This system is now defunct. The current heating system was installed more recently c. 1970, and simply comprises relatively high level banks of electrically powered radiant heaters. The installed load in the nave equates to c.79kW capacity. Within the community though the building is known as "freezing Freiston", indicating that the system is not sufficiently powered to provide warmth. This is an issue which does affect its potential use by the wider community. The electricity bill is c. £3000 per annum which is not financially sustainable. It is likely to have a high carbon footprint as the building is only powered by electricity.

The objectives of this audit were therefore to;

1. Review the buildings current energy use and heating system.
2. Consider how the building can be made more sustainable both environmentally and financially.
3. Consider whether there are options to use renewable energy technology at Freiston.

2. Location

The church is located in the centre of the village, and quite exposed. The current building has electricity provided by cabling entering at the the south of the tower. There is a 63mm gas main located approximately 100m from the building, but this has not yet been installed (see map). To install the main it would need to be trenched along the graveyard service route, which is via the southern boundary.



3. Energy Use

All the energy provided in the building is via electricity. The bills for 2012 and 2013 were £2599 and £3137 respectively. This equated to an energy consumption of 25925 kWh in 2013.

The power is consumed for space heating, lighting, the kitchen facility and water heating. There is no precise data describing how this energy is consumed, however, the following electrical components are found in the building;

A) Heating. Within the nave and tower there are 18, 2 to 4kW radiant heaters (total installed capacity c.47kW, this is estimated as there are no records of actual installed capacity), within the north and south aisles there are 12, 2 to 4KW heaters (total installed capacity c.24kW). There is also 8kW of mobile radiant heater capacity. Thus total radiant heater capacity equates to c. 79kW. The fixed radiant heaters tend to be used for Sunday services (2 hours per week) and the mobile units for meetings, including the weekly coffee mornings (2 hours per week). Demand peaks for the Christmas tree festival when the radiant heaters will be on for 12 hours per day, using 1896 kWh of energy based on run time x likely load, a significant proportion (c. 10%) of the church's electricity use. Even for full Sunday services the church frequently does not reach a comfortable temperature, suggesting a general lack of heating power. None of the heaters have any controllers other than manual on/off. The fixed radiant heaters are mounted relatively high on the clerestory or aisle wall and tend to only heat "heads" rather than the people.

B) Lighting. The nave lighting system comprises of 14 glass luminaries each fitted with 100W tungsten bulbs. Elsewhere in the north and south aisles (including the kitchen and Vestry) there are 7 tungsten lights (c. 100W), 21 (c.75W) halogen spotlights and two 400W halogen flood lights. This gives a total installed lighting capacity of c.3 to 4 kW. There is only one compact florescent tube, mounted in the porch. There are also two external spot lights mounted on the roof, bulb type unknown.

C) Kitchen Facility. The equipment in the kitchen is quite rudimentary and an eclectic mix of domestic appliances. The equipment includes two kettles, a toaster, a small oven (2.5kW), 2x hostess trollies, a 3kW water boiler, 2 x microwaves (c. 600W) and an old polaris fridge. The fridge is unlikely to have an energy rating and requires testing to examine whether it holds temperature in warm conditions.

D) Water Heating. The water heaters comprise two electric powered units, one in the kitchen and one for hand washing in the toilet, both powered to 3kW.

4. Carbon footprint

The carbon footprint of an organisation is a measure of the greenhouse gases emitted directly or indirectly by that organisation. It is widely accepted that greenhouse gas emissions are affecting the climate and the UK government is committed to reducing emission by 80 percent by 2050. The Church of England has adopted the same target, and in 2006 launched its "Shrinking the Footprint" campaign. The CofE's recent energy audit[1] suggested that emissions from the church in the UK were equivalent to between 608,706 and 1,013,490 tonnes of carbon dioxide per year. This costs in the order of £124m per annum. There is also a clear linkage between environmental and financial sustainability.

Direct carbon emissions are relatively simple to calculate from energy use meter readings and understanding the fuel used. Electricity is relatively inefficient in terms of carbon dioxide production and 1kWh of electricity produces 524g CO_2 /kWh, compared to 183.6g CO_2 / kWh for gas. Renewable energy sources produce carbon emissions significantly lower than those using fossil fuel. Their are a number of renewable energy systems and all of these differ in their ability to reduce carbon.

For St James, Freiston given that the only fuel source was electricity the 25925 kWh consumed in 2013 would have produced 13.6 tonnes of carbon dioxide.

Energy consumption at Freiston is low relative compared to other CoE churches. The Symonds review of church energy use showed that church's of Freiston's relative size consume 61kWh per m^2 of floor space compared to 41 kWh per m^2 in this instance.

5. Energy loss

Given the feedback from church user at St James and the low relative energy use, it is worth considering whether the current heating system is adequate. The heat loss of a building can be determined by calculating the rate that heat is lost from all elements of the building (walls, doors, floors and windows) when it is held at a steady state temperature. The heat loss of an element is determined by its U-value, the rate at which heat (W) is lost per m^2 of surface per degree of difference between the inside and outside temperature.

Typical U-values (Wm-2 C-1) for church building elements are 5.5 for windows, 0.8 for the stone walls and 2.0 for a thick door. High values show a high rate of heat loss,

[1] Symonds (2013). Energy audit 2013/13, shrinking the footprint. Churchcare.

therefore at Freiston given the relatively large amount of windows these will be a main driver of heat loss. Given that the Church is grade I listed fitting secondary glazing will not be an option, but nevertheless good window maintenance will be important in minimising heat loss.

The second key factor is the ventilation rate of the building. This is usually measured as the air exchange rate. Simply adding the rate of heat loss through all the the elements of the building to the ventilation rate gives the total heat loss. Ventilation heat loss is usually estimated from typical values measured in similar buildings. However for a building with the large volumetric space of Freiston it will be a key driver of heat loss. The leaks at Freiston will be via all manner of joints, including through window gaps, roof vault connections to walls, doors etc. maintaining tights seals in a building of this antiquity will be very difficult.

Heat loss models work well in reasonably modern buildings under steady state conditions. In medieval church's with thick walls and high volumetric spaces, the buildings can present some complex challenges in terms of managing heating systems. Firstly, the thermal mass of the walls and the large air space can take quite a long while to heat up as they will absorb very large amounts of energy. Heating a cold building from a zero start for meetings such as Sunday services, can therefore be difficult as the mass and volume of the building will create a large thermal lag. Additional heating system boost capacity will be required at start up to drive any required air temperature rise. The second complex issue will be the way air moves around the building. In Freiston it is likely that air will rise through the body of the nave and this will create down drafts along and down the clerestory walls. The potential for internally driven drafts are therefore significant. This is likely to be exasperated if the internal heat exchangers are focussed on small high energy radiating surfaces alongside walls.

The calculated energy requirement for St James to maintain an internal temperature of 19 degrees compared to an external temperature of 2 degrees was 107kW. This is somewhat higher than the current radiant heating system output. Of the energy loss the biggest driver would be external ventilation (assuming an air exchange rate of 1.5 per hour) which equated for 47 of the 107kW demand. A significant heat loss was through the windows and these equated to 18kW of the requirement.

This suggests the current Freiston heating system (c. 79kW capacity) does not have enough load to meet the requirements of a modern specificised heating system. This combined by the large volume and thermal mass of the building will lead to the acknowledged perception that the church is cold.

6. Electrical supply

Given that all the energy input into the church is via electricity it is pertinent to consider the current supply system.

<u>Main Distribution Board</u>

The Church is supplied by a three phase cable suspected to be fused at 150amp per phase (Total Load rating circa 108kW) at the west end of the church with a distribution board located on the South Tower wall (see photograph). There are two switched 18 way (6 Circuit breakers per phase) distribution boards with all 36 outlets in use. The installation was designed to support the large electrical load of the heating system. Originally there were 30 ways dedicated to heating with just 6 spare ways for the rest of the church's electrical needs. This was subsequently modified to 29 ways for heating (Two heaters now share one circuit with an either-or two way selection witch) and 7 ways for lighting and power needs. The extra way was used to establish a distribution board in the kitchen area.

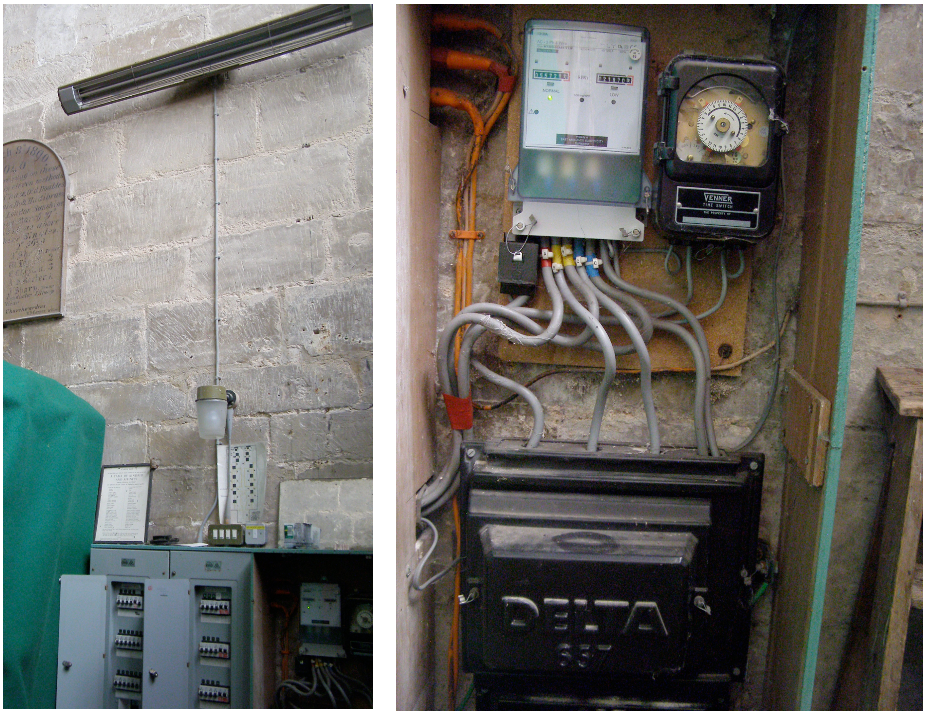


Figure 6.1. Main electrical boards in the tower.

There are limited circuits for providing power around the church. The use of electrical devices for cooking, music, artistic performances, worship or presentations means that the provision of electrical power around the church is no longer fit for purpose and extension leads from other areas of the church are often run to support the needs in another area – Particularly for community coffee mornings when portable heaters are used in the winter months.

<u>Electrical Supply – Heating</u>

In terms of electrical equipment in the building, the main heating system is via radiant heaters. These are expensive to run and have a high financial and carbon running costs. They are also relatively ineffective at heating the space. A more suitable heat distribution system needs to be considered and this is dealt with later in the document.

The building is served by 30 fixed overhead 2 to 4kW ceramic tungsten quartz heaters each fed via its own dedicated cable feed via a 20A circuit breaker at the main distribution board (see Figure 6.2). The heaters can only be switched on manually, preventing the instantaneous switching of the whole heating load. This means that the heating cannot be set to come on automatically in advance of an event. It relies on someone coming into church earlier than needed to switch it on. The minimum time needed for the heating to be effective is about an hour, though a two hour lead time would be preferred on a cold day. Limitations on the distribution board mean that two heaters (chancel heater 4 and the vestry heater) share a single circuit and have a two way either –or switch near the vestry. So only 29 heaters can be on at any one time. Figure 6.3 shows the heater diagram located at the distribution board. Even with 30 heaters there are still areas of the church not covered by the heating scheme. The church has earned the nickname “Freezing Freiston” and the weekly coffee morning has only grown by supplementing the existing heating system with portable heaters fed by extension leads from other areas of the church.

Figure 6.2 A view of the radiant heaters from the coffee area.

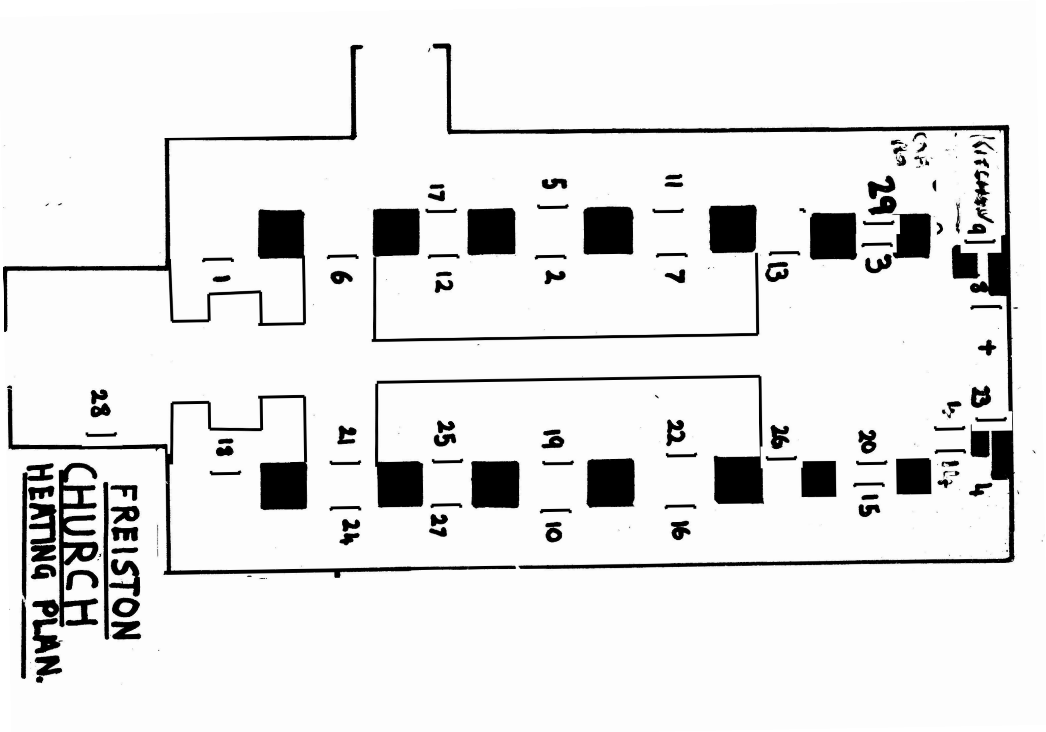


Figure 6.3. current heating schematic plan located by the main electrical distribution board in the Tower.

A fluke thermal imaging camera was used to understand the heat distribution from the radiant heaters. The camera showed the heaters emit energy at a very high temperature circa 370C. To assess heat distribution the camera was used after the heaters had been turned off. This showed very warm patches below the heaters, indicating areas of high localised energy.

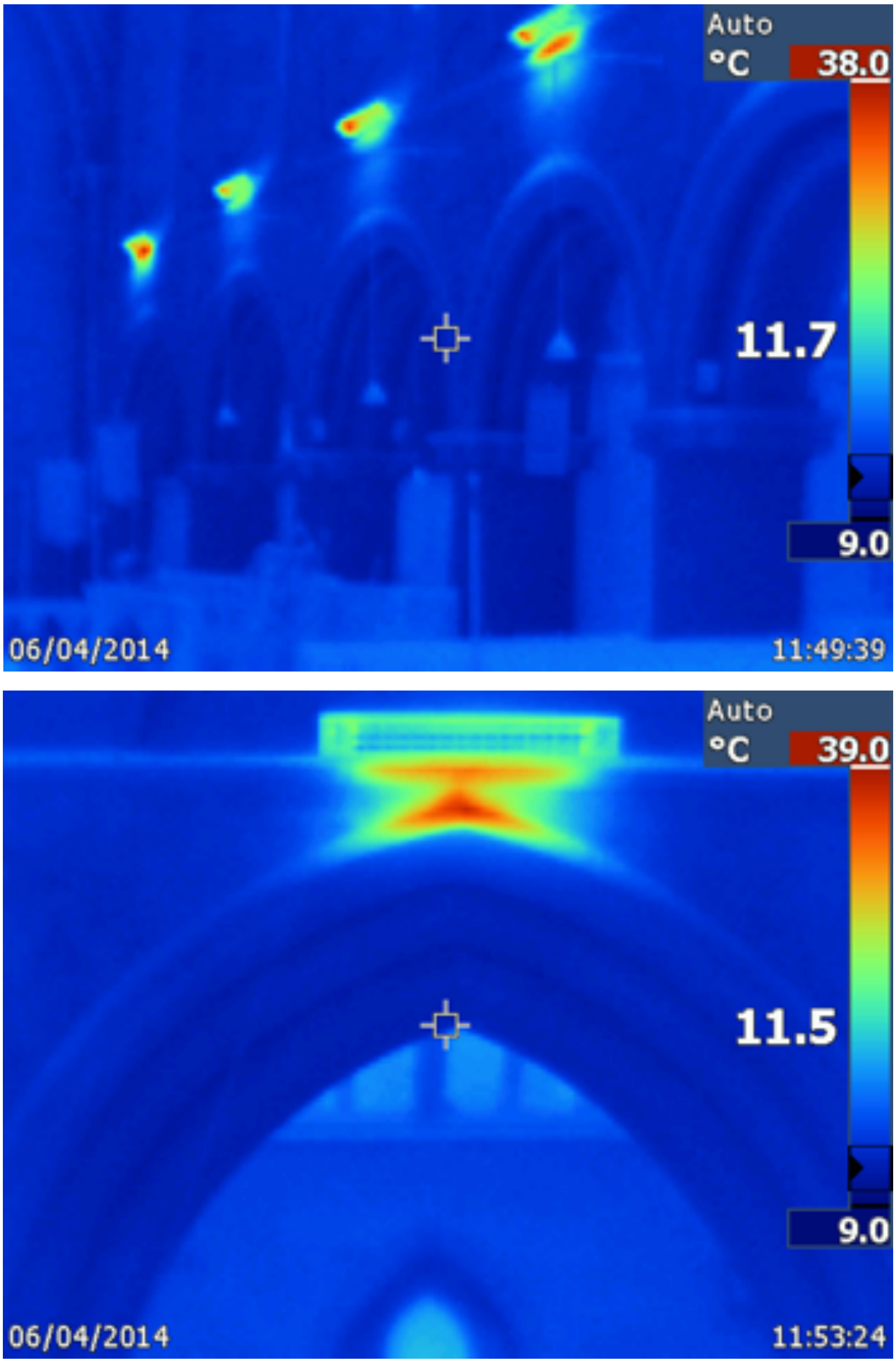


Figure 6.4. Thermal image if the nave showing the heaters and thermal heat build up below the heaters.

The greatest concern was found with the aisle heaters. These are in close proximity to a wooden roof, and a large amount of heat has transferred into the roof (Figure 6.5a). This must be a concern for the long term fabric of the roof. Figure 6.5b shows the internal fabir of the church after one hour of heating. Energy has transferred into the wooden pews and font cover, all stone work remains very cold. The building contains very large temperature variants and will no doubt be susceptible to condensation.

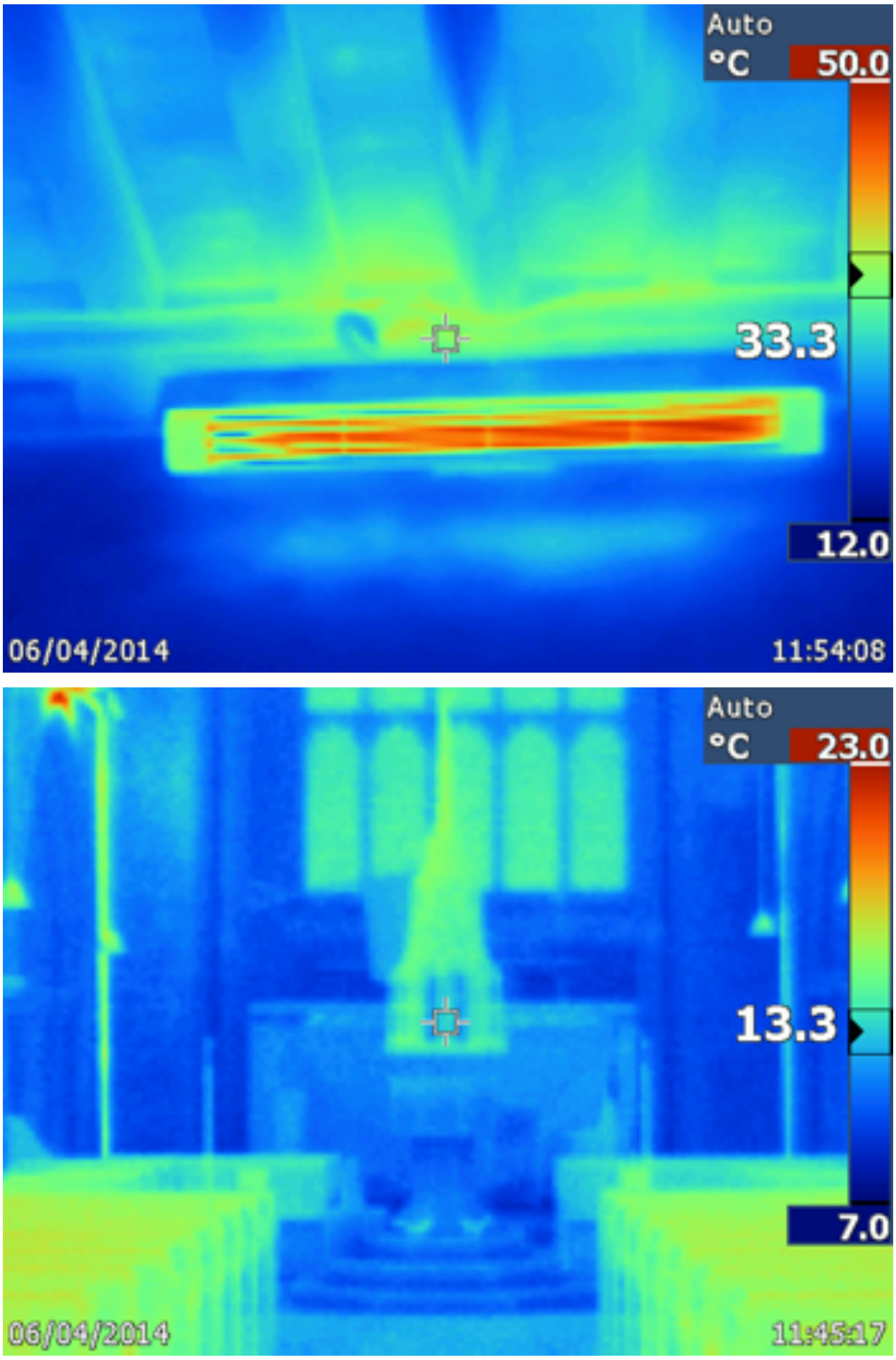


Figure 6.5a and b. Localised heating in the wooden aisle roof, and impacts of the heating system on the internal fabric temperatures.

Lighting

The lighting system is now very out of date and reliant on a combination of tungsten and or halogen spot and flood lights. No lights are dimmable and the only focused lighting is on the font and altar. There is no spot or floodlighting at the front of the chancel where groups generally perform at concerts and community events, such as the Christmas tree festival or Heritage Days (see Figure 6.6).

Figure 6.6. Views of the nave lighting, and the south aisle floodlights.

One circuit provides power to a lighting distribution board for the church. The light switches are located next to this sub-distribution board from which they are fed on the wall between the organ and kitchen. Most of the lights in the church are switched from here. This location is in a very awkward place for access. It is very conspicuous if lighting changes are required during concerts and services (see Figure 6.7). There is one switch located by the north porch door which switches three lights at the west end of the north aisle. There is one switch by the tower distribution board to operate the light above it and there are two other light switches, one located in the vestry and the other in the kitchen and toilet.

Figure 6.7. Left and centre photographs show the narrow gap on the right hand side of the organ which gives access to the main set of light switches, a torch is required in the dark to find the switches. The left photograph shows the three lights by the porch which are the only lighting available on entering the church.

For lights at the west end of the nave, the cable runs from the west end of the church to the light switches at the east end and then cabled back to the lights at the west end. This is both wasteful on cable and inconvenient, as someone has to get to the light switches at the east end in the dark, with a torch and squeeze behind the organ to operate them.

<u>Emergency Lighting</u>
Currently, candles provide emergency lighting, there is no battery backed DC lighting at present.

<u>Kitchen</u>
The kitchen has a dedicated power supply with 4 x 13 amp sockets above the worktop and a water heater above the sink. However, the size and length of the cable run from the West end of church means that the socket load is limited to around 30 amps. In terms of electrical equipment, most of it is found in the kitchen. Very little of this is now fit for purpose. The fridge is very old and may not safely hold temperature, although this needs testing in the summer. However, it is also likely to be very energy inefficient and should be replaced with an A rated fridge. The cooker is also old, small and not fit for purpose. The same applies to the microwaves which are now very old.

<u>Bell Tower</u>
The Bell tower has a dedicated feed for lighting the tower stairs and chambers. The bell ringing chamber has lighting, a 13 amp socket for a heater and the Church clock has electrical auto winding motors.

<u>13amp power sockets</u>
13 Amp sockets are at a premium in the main body of the Church, with just six serving the main body of the church (excludes kitchen and bell tower).

There is one single 13amp socket at the west end of the north aisle and one at the west end of the south aisle. There are two 13amp sockets located in St Thomas chapel behind the choir stalls, one 13A socket in the vestry and one 13A socket behind the organ. This last socket has a 4 way adapter that feeds the heater for the organ, the “Coffee Room” light (the side aisle north of the chancel by the organ.), the PA system (which has 5 sockets) and in the winter a portable 2kW heater.

During weddings, funerals, concerts and community events the spare socket in the PA cupboard can be used to feed a PA amp, speakers and mixer, CD player and other equipment needed for performances. If there is a band with its own PA then power is fed from the St Thomas’s chapel on the south side of the chapel via extension leads. The modern trend for multi media and for amplification means that the front of church socket loadings have to be carefully managed. There have been a few occasions where 13amp fuses have blown due to overload and one 13amp 4 way extension burnt out as the load exceeded its rated 3 kW (12.5amps), but was less that the 14.5 amps to blow the 13 amp fuse. Such budget sockets are now fused at 10 amps.

For the Christmas tree festival, power is needed around the church for Christmas tree lights and local electricians run temporary cabling around the church to deliver more power from the distribution board at the west end. They also install temporary external flood lighting so that the church is lit at night. This demonstrates that the supply cable is sufficient to meet the electrical needs of the church, but that the installation within the church is no longer fit for current needs.

For community events such as banquets, heritage days and the Christmas tree festival, additional equipment is used in the north side chapel area near the kitchen to heat food. Again power has to be carefully managed and on an occasions portable gas rings are used to heat food to avoid overloading the electrical system.

Future Considerations

The electrical System is no longer fit for modern needs. Sub distribution boards are needed at the east end of the church to provide many greater socket numbers and loading. Potential relocation of the kitchen to the west end of the church will keep high load cable runs to a minimum. A new LED lighting system should be considered with switches located by each door to provide light to the main switching points. It Is suggested that these be located in the west tower, or where appropriate the north aisle entrance door. New LED technology with its much lower loading gives the opportunity for the main lighting to operate at 110V DC with a centre tapped earth. The whole system could have a battery backup. The main lighting system would then also serve as an emergency lighting system. Lighting that is dimmable and can focus on ceiling, performers and give light to read in different areas of the church can greatly enhance the experience of worship. It would enable drama productions to be performed in the building.

Heating is a major issue for the church. Whilst underfloor heating might serve certain areas of the church if there are cost constraints, electrical low power under pew convector heaters could be a very effective and value solution. To enable this, two 13A sockets under the centre of each pew would be required with loading balanced across 3 phases. This arrangement would allow easy replacement if a particular heater went faulty without the need for a qualified electrician.

It is suggested that the main distribution be located outside in a new ancillary services block by the south side of the west tower, where the old coal bunker is currently located.

7. Potential improvements to energy supply and the heating system.

The energy audit has indicated that St James has a dated, expensive and relatively ineffective energy supply system. There may therefore be a number of strategies available which could be used to reduce the buildings operating costs and to make it both more financially and environmentally sustainable. There is also a move towards installing more renewable energy systems, driven by the need to reduce climate impacts from burning fossil fuels. Furthermore, there may be more effective ways to apply fossil fuel based energy into the building. This could include switching from electricity to gas.

In terms of renewable energy systems, the following elements were considered;

A) *Solar photovoltaic cells.* These systems are applied to the roof of buildings and convert solar energy into electrical energy. They attract significant government support via feed in tariffs at a level depending upon the energy efficiency rating of the building (EPC rating). Income is also generated if some of the electricity is exported to the grid, and this is paid at c 4.7p per kWh. Savings are also made if own generated electricity is used to replace any which would have been bought from the grid. There are though two complications for using solar in old church's and especially those that are grade I listed. The first complication relates to planning permission and it is considered that on a grade I listed building if the solar pv's can be seen then planning permission may not be granted. Secondly the FIT tariff is dependent upon the EPC rating of the building and to attract the higher rate the building must be EPC D rated or better, this is extremely unlikely in any medieval church and especially not at Freiston which currently uses one of the most inefficient heating systems available. Furthermore, planning consent to internally insulate the building to improve the EPC rating is also unlikely as it is grade I listed. The EPC issue can though be avoided if the solar PV is installed as an asset of a community interest company or co operative. To effect this St James would need to create a separate legal entity, i.e. set up a community interest company. This adds complexity to the organisation, though this would be rewarded by a higher FIT tariff, c. 12.5 p per kWh against 6.6 p per kWh without an EPC D rating or better. The investment cost of solar pv at St James may be in the order of £30k, this could be partly grant funded or even loan funded as the FIT tariff scheme is government backed for 20 years and should provide a return from the energy generated. This needs to be worked through in detail at a later date. Solar PV therefore has potential at St James, but it needs to be considered in view of possible issues with planning permissions and legal set up.

B) *Biomass.* Biomass driven renewable energy systems use fuels generated from sustainable sources such as wood chip, straw pellets, miscanthus etc. They attract government subsidies through the government renewable heat incentive (rhi) scheme. Biomass boilers can be difficult to maintain and need to have large fuel bunkers which are mounted outside of the church. These need to be easily accessible on church land. It is likely at Freiston that access to the church for refuelling and also planning permissions to install bunkers would be difficult to achieve. This is despite the church being next to a wood yard. It was considered that although wood could be purchased from the wood yard, the ownership and use of the yard by the current owner could not be warranted to continue for the duration of the rhi incentive. Therefore change of ownership or use of the woodyard within the next 20 years could place the church's access to energy at risk.

C) *Wind.* Given that the church is grade I listed, it is highly unlikely that planning permission will be granted to install wind turbines on or near the site.

D) *Ground source heat pumps.* This technology extracts heat from the earth and drives it through an electrically driven refrigeration cycle to convert it to a higher temperature status, useful for the heating if buildings. Heat pump performance varies but for in the order for every 1kW of electrical energy input they provide about 3 to 5kW of heat output. They attract government rhi subsidies. However, to extract energy, coils need to be buried in the ground, either in shallow pits or in a vertical deep pile. This is both expensive and at St James, the site of an important medieval priory, the archeological issues would be very problematic and likely expensive.

E) *Air source heat pumps.* This technology uses an electrically driven refrigeration cycle to extract heat from the air and convert it to a higher temperature for use in a heating system. Air source heat pump performance is lower than for ground source, but can convert 1kW of electrical and thermal energy into 2kW of heat output. The issue with air source heat pumps is that for non domestic applications they do not currently attract government rhi subsidies. Furthermore, their efficiency can drop during cold weather, such that the electrical energy input can be greater than the output. Furthermore, the prime energy source is still electricity which is fossil fuel driven and costs St James c. 12p per kWh.

F) *Gas absorption heat pumps.* This is an old technology but is a renewable energy source. These are basically reversed refrigeration units powered by a gas burner. Unlike ground and air sourced heat pumps these units use ammonia as the refrigerant and therefore have high green credentials in terms of CFC use. These units can be air or ground sourced, but for Freiston given the archaeology issues an air sourced unit would be appropriate. An air sourced version has energy conversion efficiencies of 1kW input gas to an output of heat of up to 1.4kW. Highest levels of efficiency occur when they are run at lower output temperatures, i.e. they are best at providing low level heat over sustained periods. They are highly rated by the EU and have been given an A+++ energy rating. The key carbon benefit for Freiston would be the ability to move to a renewable energy source, but also to move to a gas powered generation system. Moving to gas over electricity in itself reduces the carbon cost of 1kWh from 0.53Kg CO_2 kWh^{-1} to 0.18Kg CO_2 kWh^{-1}, a very significant reduction. At Freiston if gas was used rather than electricity, assuming the same energy input the carbon dioxide savings would equate to 8.7 tonnes (64% reduction). The financial saving would also be significant as 1 kWh of electricity currently costs 12p compared to c 3p for gas. If the heat pump has an efficiency of 1.4 then 1KWh of heat would effectively cost 2.14p, a cost reduction of 81% per kWh. The carbon cost would also reduce to 0.12Kg CO_2 kWh^{-1} a reduction compared to electricity of 77%. The capital cost of a gas absorption heat pump is likely to be in the order of £30,000 and therefore some grant funding may be required to achieve the benefit. We are not aware of any gas absorption heat pumps being used in any other church within the UK. Although the technology is well established, the recent interest in renewable heating systems has only just brought it back to a wider interest. Going forward these heat pumps are being considered for inclusion in the government rhi scheme, with a formal decision to be taken towards the end of 2014. Rhi inclusion would be of additional benefit as the church could claim back much of the costs of the heat generated from the government.

To summarise moving to a gas powered energy generation system could produce dramatic savings over the current electrical system, both in terms of carbon and also financial cost. This assumes a similar level of energy input, however, given that the Freiston heating system is under rated in terms of heat output, moving to gas would allow a far greater overall level of energy input into the building (making it fit for purpose). This could be achieved whilst still achieving a substantial carbon and possibly financial saving. Using an air sourced gas absorption heat pump would multiply the benefit, and also enable the church to move to a renewable energy input system. Planning permission would need to be sought to install the heat pump externally outside the Tower, though the units are relatively small and quiet (45dB at 10m).

In terms of installing gas, a main runs through Church View road and also partially down Church End road, approximately 100m from the Tower.

8. Heat exchange

The current method to exchange heat in the building is via electrical radiant heaters. Going forward, if the heating system is converted to a gas based or renewable energy generation system the method of heat exchange needs to be considered. To avoid using fan based distribution systems which create noise within a building that demands quiet, the three options which are available are still electrical radiant heaters (though hugely inefficient), conventional hot water based radiators, either installed around the walls or under the floor, with heat emitting from vents, or an underfloor heating system. In terms of underfloor heating, these systems emit energy up to $150Wm^{-2}$. For Freiston, the calculated energy requirement using the U-value model was $160Wm^{-2}$ assuming the entire floor space is heated (quite close to the system output). However, there are significant issues for underfloor systems, in many churches these are associated with impacts on the archeology on site. At Freiston archeological issues are unlikely, though this needs proper assessment, as much of the original floor was removed by James Fowler in 1870 (see

Conservation Management Plan for details). The second issue is cost, and this can equate to over £200m2 if a new floor is required on the surface of the heating system. Cost may therefore prohibit a full role out at Freiston, though certain zones within the church may be appropriate for an underfloor heating, such as around the font and under pews. Underfloor system do though give a very uniform heat and have the benefit of warming a boundary zone up to head height, rather than the entire volumetric area of the building. For Freiston, given cost constraints a combination of underfloor and conventional hot water piped radiators may be appropriate, though this needs careful design. Impacts of drafts and down drafts will need to be considered. Underpew electrical heaters may also be cost effective in terms of capital installation cost, though these will be expensive to run as they are electrically powered.

9. Summary and Recommendations

- The current heating system at Freiston is now not fit for purpose in terms of its financial and carbon sustainability. It is also under rated in terms of the energy requirement of the building. Switching to a gas based system, rather than electricity would provide a cheaper and more sustainable energy system.
- Two forms of renewable heating systems may be suitable for Freiston, if planning permission is possible a solar PV installation, implemented as an asset of a community interest company, may provide a renewable form of electricity which provides a financial income. Secondly a gas absorption heat pump could also provide a renewable source of energy which is effective and highly cost efficient.
- The current radiant heaters may be causing issues to the fabric, in particular the Aisle roof which is wooden and in close proximity to the heaters. Thermal images show high localised heating.
- The heat distribution system in St James should be carefully reviewed, and a combination of underfloor and conventional vented radiators may be appropriate.
- Any new heating system should be installed with proper control systems.
- Care should be taken to minimise drafts as ventilation heat losses will be significant in a building of this size. It is assumed planning constraints would prevent the use of significant insulation approaches.
- The current lighting system in Freiston should be reviewed and potentially switched to more efficient LED based systems.
- Current electrical appliances should be reviewed, in particular the fridge (which may not be safe) and the cooker which is not fit for purpose.
- The electrical distribution system in the church requires review, there is not sufficient capacity available in the current system to adequately distribute power to all elements of the building.

Improving the energy systems will not only make the church more sustainable, but increase it's wider community use. The building’s reputation for being cold is a significant issue.

Appendix 1. Model of the heat loss of St James, Freiston.

Heating temperature		19			
External Temperature		2			
U Value	Roof	2	source Bordass 1996		
Wm-2K-1	Tower Roof	1			
	60cm Stone wall	0.8			
	Single glazed Window	5.5			
	Door	2			
	Floor	0.8			
			Heat loss		
Ventilation rate	a/c per hour	1.5			
	Volume of building (m3)	5154			
	Heat Loss (A/c*V*Sp Ht* (Tin -Tout)			47.3	KW
		m2 area	Heat Loss (W)		
Nave	Roof Area	281.3	9564.2		
	External North Wall Area	143.2	1947.52		
	External South Wall Area	142.6	1939.36		
	Window Area	118.4	11070.4		
	Alter Wall	83.4	1134.24		
	Alter Window	15.4	1439.9		
	Floor Area	311.3	4233.68		
				31.3	KW
South Aisle	Roof Area	114.8	3903.2		
	External Wall Area	145.4	1977.44		
	Window Area	8.3	776.05		
	Alter Wall	18.5	251.6		
	Alter Window	1	93.5		
	Rear Wall	15.5	210.8		
	Rear Window	4	374		
	Floor Area	121.3	1649.68		
	Door	2	187		
				9.4	KW
North Aisle	Roof Area	161	5474		
	External Wall Area	152.6	2075.36		
	Window Area	24.6	2300.1		
	Alter Wall	15.1	205.36		
	Alter Window	0	0		
	Rear Wall	6.9	93.84		
	Rear Window	3	280.5		
	Floor Area	139.6	1898.56		
	Door	5.2	486.2		
				12.8	KW
Tower	Roof Area	26.5	901		
	External Wall Area	44.1	599.76		
	Window Area	20	1870		
	Tower Wall	150	2040		
	Tower Window	0	0		
	Floor Area	26.5	360.4		
	Door	2.6	243.1		
				6.0	KW
Summary				Heat Loss	
Ventilation heat loss				47.3	KW
Nave				31.3	KW
South Aisle				9.4	KW
North Aisle				12.8	KW
Tower				6.0	KW
Heat requirement				**106.9**	**KW**