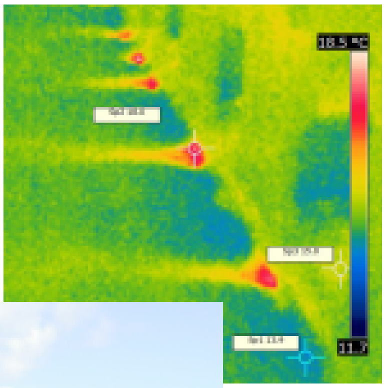
T4 Sustainability Ltd

Holy Cross Church, Ilam (Ilam Community Initiative):

Heating Ilam Church.

Version 1, Draft 3. 15/10/2010.



BRE CSEP Consultant: John Beardmore,
MSc EDM (Open), B.A. Chem (Oxon), CMIOSH, CEnv, MIEMA, MEI

Copyright and Acknowledgements

T4 Sustainability Limited,
181 Belper Road,
Stanley Common,
Ilkeston,
Derbyshire.
DE7 6FT

and the Client, referred to as the Holy Cross Church Community, later referred to as the Community.

Holy Cross Church,
c/o Paddock House,
Castern,
Ilam,
Ashbourne.
DE6 2BA

Disclaimer

While the Company strives to convey accurate information in good faith, neither the Company, its directors, or any of its staff can accept any responsibility for the information supplied in this document. Neither can they accept any responsibility for the actions of, or any information supplied by, any third parties referred to herein. The content of this document does not constitute legal advice.

Confidentiality

T4 will hold the project specific details of this work to be confidential, and will not reproduce these except in accordance with specific terms granted by The Client in writing, but grants The Client permission to distribute this document to further its work in any way.

Contents

Executive Summary

This document has been commissioned by the Community of Holy Cross Church in the village of Ilam, to identify opportunities to improve the energy efficiency of their Church building, and install micro-generation technologies which are appropriate to the setting.

Their objectives are to reduce energy costs, lower environmental impact, conserve the fabric of a historic building, improve user comfort, increase the utilisation of this community resource, and to educate all users of the building.

The overarching objectives are the sustainable conservation of the church as a heritage building, and its affordable use as a community asset and resource.

This has resulted in interest in energy conservation measures, and while necessarily limited in a historic building, those identified should be discussed with all relevant stakeholders, and all the ones deemed non destructive to the building should be implemented as soon as possible.

Renewable energy options are considered, taking account of what is appropriate to a historic church and community building in the Peak District National Park, and the feasibility of a warm spring water source heat pump is evaluated.

The possibility of developing a hydro scheme, perhaps based on an Archimedean screw turbine has also been examined, though detailed design by an installer will be required to establish that this can be be done without significant visual impact. This design can then be used as a basis for discussions with all stakeholders to see if a way forward can be agreed.

All stakeholders should be identified, and a meeting held to introduce them to the projects and involve them in the design process.

The uncertainties listed in Section 13 of this document should be resolved as far as possible, and the elements of this project, and any proposed alternatives fully costed. Ideally capital and revenue funding should be investigated so that lifecycle costs can be analysed. The necessary financial resources should then be secured, and the scheme implemented with some urgency to prevent further damage to the building due to the lack of appropriate heating.

1 - Aims and Objectives

This document has been commissioned by the Holy Cross Church Community in the village of Ilam, to identify opportunities to improve the energy efficiency of their Church building, and install micro-generation technologies which utilise local resources, and are appropriate to the setting on the South Peak Estate in the Staffordshire countryside.

The objectives are to reduce energy costs, lower environmental and carbon footprints, conserve the fabric of a historic building, improve user comfort, increase the utilisation of this community resource, and to educate all users of the building - in short,

> to make the use and conservation of the building affordable to the community, and as far as is practical, to demonstrate the sustainable use of a historic building.

As the building also attracts many visitors from the UK and abroad, this project also aims to contribute to the understanding and experience of sustainable energy systems in wider society by disseminating information about the project on site, through the local community, and perhaps through the Internet.

2 - Introduction and Problems with the Building

Holy Cross Church is a Grade I listed building, and Ilam is a Conservation Area within the Peak District National Park. While the National Park has a duty to promote sustainable development, it also has a responsibility to conserve the character and visual amenity of the region.

National Trust owns the South Peak Estate (Ilam Hall and Grounds, Home Farm, and four other houses on the estate). They own the land surrounding the churchyard, and a south edge strip of the churchyard was leased from the Trust in 1949 when the old graveyard was full.

Although the building is attractive and in a beautiful setting, it lacks many modern amenities including a water supply, toilets and cost effective heating.

The existing heating uses either storage heaters which are neither good at heating the building nor cost effective, or propane or butane heaters which heat the building better, but exacerbate problems with humidity and condensation.

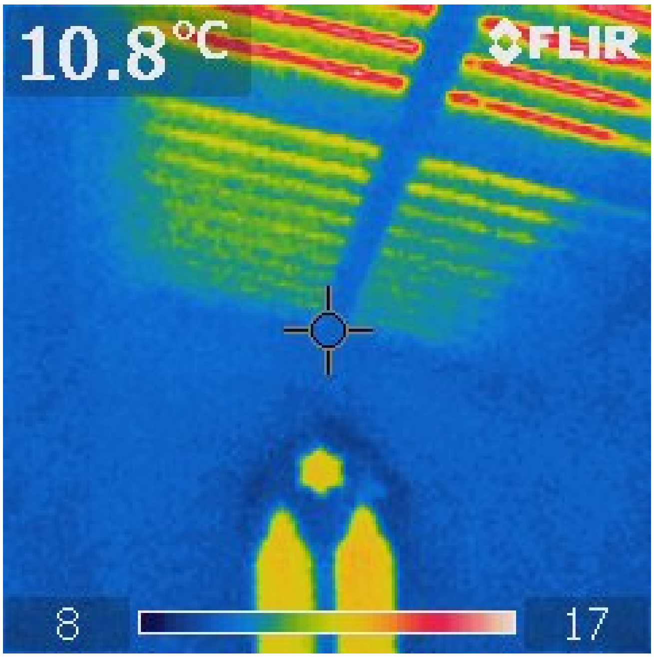
The electric heaters are old and prone to failure which increasingly limits their use, and the larger gas heaters are also too noisy to use during services. Because of the risk to the building fabric from high humidity, the Community would rather not use the propane burners at all.

Without cost effective heating, the fabric of the building is at risk, but the design of the building makes it hard to retain heat and control humidity, and revenue funding to spend on energy is limited.

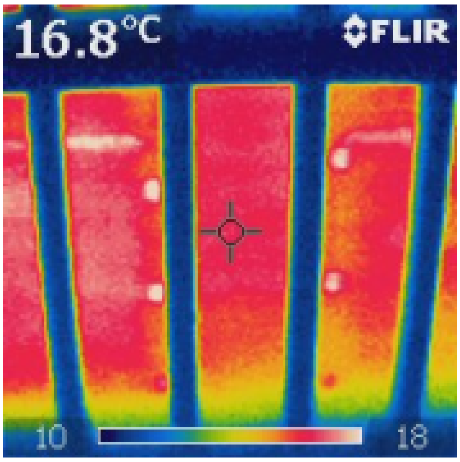
The church was virtually closed for much of last winter. While in part this was due to the hazard of reaching the church on icy paths, the heating was also described as a "lost cause".

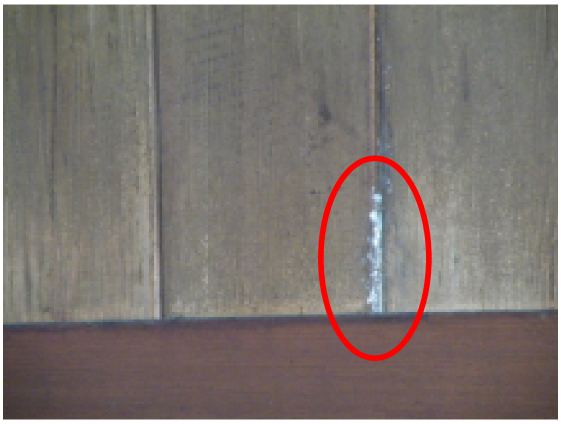
In addition, the expense of heating the church makes it a poor venue for community activities for small groups, especially those with vulnerable members, and the costs and types of heating available make the protection of the fabric of the building difficult.

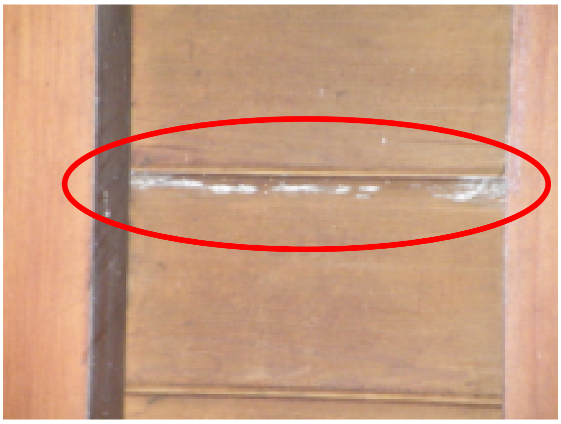
The roof of the building is generally in good condition, but while inspecting this with a thermal imaging camera while the sun was shining on the outside of the building, hot spots were noticed. Such areas might be due to the wood in the roof being saturated with water, or the density, thermal conductivity and thermal capacity of the wood being altered by fungal attack. Although such activity may not be initiated by condensation from within the building, the growth of fungi is generally supported by moisture, and condensation from within the building might contribute to this.



Above, the morning sun warming the roof of the north isle. Below, hot spots which might identify patches of damp or damaged wood. Close visual inspection reveals marks which might be consistent with fungal attack or water damage to the roof.







As the picture on the top right of the previous page illustrates, the single glazed thin glass windows of the building are quite transparent to radiated heat.

The walls of the building show some flaking of paint and plaster which might be exacerbated by high humidity.

The wooden sections of floor are also in a poor state of repair, particularly near the walls. This is assumed to be exacerbated by damp rising from the ground under the floor, and soaking though the stone walls.

Although the floor is supporting the pews adequately for the time being, some holes have formed, and the wooden underside of the floor boards feels slightly damp to the touch and is crumbling.

Below, an iridescent object four to six millimetres long was noticed in one of the pictures. This could be a beetle wing case. An expert might check under the floor to see if insects are also attacking the wood.

3 - Energy Efficiency Issues

The most significant consumption of energy on site is due to space heating and lighting, of which space heating is likely to be by far the most significant.

Previous work has already upgraded much of the lighting to use compact fluorescent lamps, but some incandescent lighting is still in use, particularly for spot lighting. In the long run, LED lighting might be used for spot lighting and to highlight architectural features, though while the power consumption and lamp life are far superior to incandescent lighting, at the moment LED lights are still a relatively expensive option, and should be viewed before purchase to assess their colour temperature ('warmth'), and aesthetic quality. It may none the less be worth looking at high power LED lighting, even if purchase is deferred until prices have fallen further. (Avoid low cost LED lighting for the time being. Some results have been disappointing.)

Space heating is delivered by a mixture of electric and gas heaters. The various gas heaters use either propane or butane from cylinders.

Top left, fitting upgraded to use a compact fluorescent lamp (CFL), but spot lights still use inefficient incandescent lamps.

The efficiency of the electric heaters (in terms of heat released in the building divided by kWh billed at the electricity meter) is nearly 100%, but their environmental performance is poor because of the inherent inefficiency of electricity generation and distribution. As a crude rule of thumb only about a third of the energy in the primary fuel (coal, gas or nuclear materials) consumed in the power station reaches the customers site, and for every kWh of energy consumed, approximately 0.544 kg of carbon dioxide is emitted by the generating process. This may increase in future as the proportion of coal used in electricity generation increases.

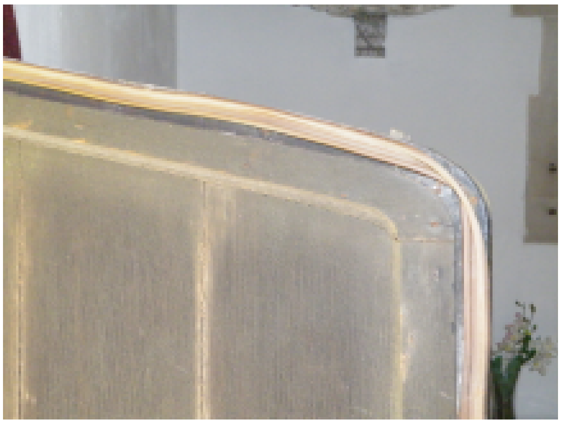
The efficiency of the gas heaters is also good, in that all of the heat given off by combustion must be released into the building as there is no flue to carry combustion gases and heat away. An unfortunate aspect of this however, is that all the moisture produced by burning the gas is released into the building, as are the gaseous combustion products. For every kg of propane burned, approximately 3 kg of carbon dioxide and 1.64 kg of water will be emitted. As this 1.64 kg water condenses, 1.64 litres of water will soak into the fabric of the building, especially the cooler parts.

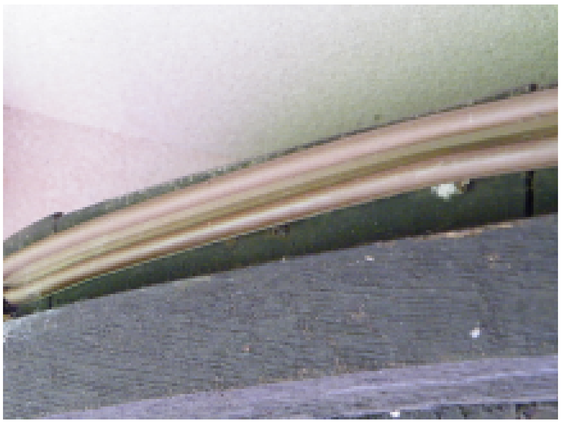
It is worth noting that atmospheric carbon dioxide concentrations of the order of 0.3% tend to make people feel sleepy. Further, if a lot of gas is burnt quickly, perhaps to heat the church before a service on a cold day, consideration might be given to the risk of carbon monoxide production. The burning of each kg of propane requires approximately 13 cubic meters of air, so it is unlikely that oxygen levels would fall enough to cause the production of significant amounts of carbon monoxide. None the less, some risk may arise from the use maladjusted or damaged equipment. The production of oxides of nitrogen, sometimes referred to as NO_x will also reduce air quality when the gas heaters are used, and may be particularly irritating to people with chest complaints such as asthma. The manufacturer's guidance should be followed re routine servicing and maintenance of the gas heaters, and it might be a wise precaution to install a carbon monoxide detector in the church.

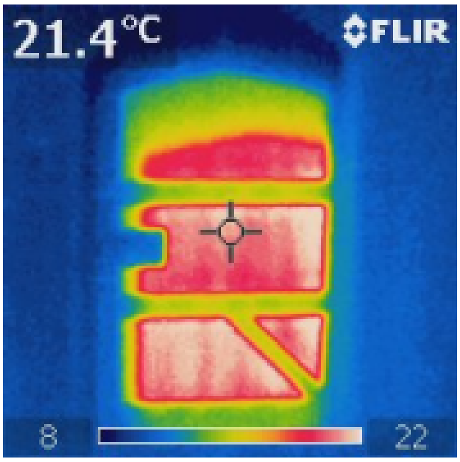
Heat loss from the structure is difficult to prevent without radically altering the character of the building. Doors are old, un-insulated, and fit against rather than into the door frame. Some attempts have been made to use draft excluders to limit the mass flow of air through the building. These efforts appear to be at least partially effective, and additional draft proofing materials might be applied around and under the doors as long as these can be removed without harm to the building. The original locks and other hardware will make fully effective draft proofing difficult to achieve, and compared to the walls, the solid wooden doors are relatively thermally conductive and have low thermal mass.

In addition to the doors, air can also flow through vents beneath the wooden floors under the pews. These vents appear to have been part of a heating system linked to the cellar. It is presumed that this heated the building by burning a smokeless fuel, perhaps charcoal, in an excess of air (to avoid the production of carbon monoxide), and that the fumes from this fire passed up ducts from the cellar, under the wooden floors that support the pews, then out through vents into the isles and the body of the church. Some air may still vent into the church through the cellar which is damp and at a fairly constant temperature. Some wood in the cellar is rotting, and if there is a draft from the cellar to the church, it is possible that this transports spores to the woodwork under the pews in the church, and beyond. Treating the rotting wood in the cellar might thus help to prevent the rotting of wood in the church.

The use of this method of heating would presumably have kept the floor under the pews dry despite the lack of a modern damp proof membrane, and significant concentrations of hot dry carbon dioxide may have inhibited the growth of fungi.

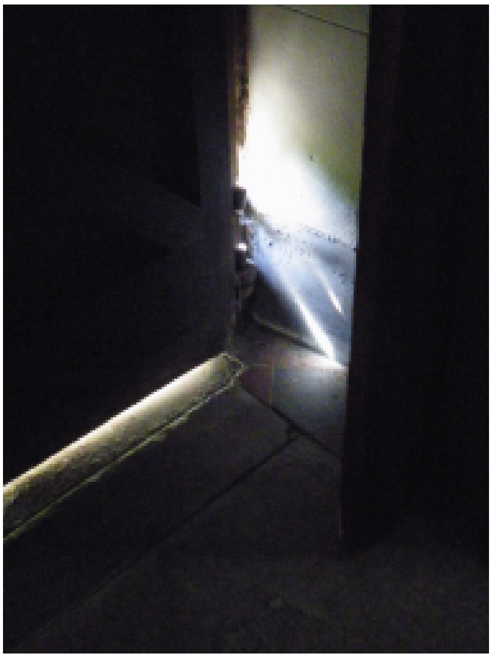






Above, a curtain reduces drafts and the loss of radiated heat, but improvements to the door seals would reduce heat loss more directly and should be used where appropriate.

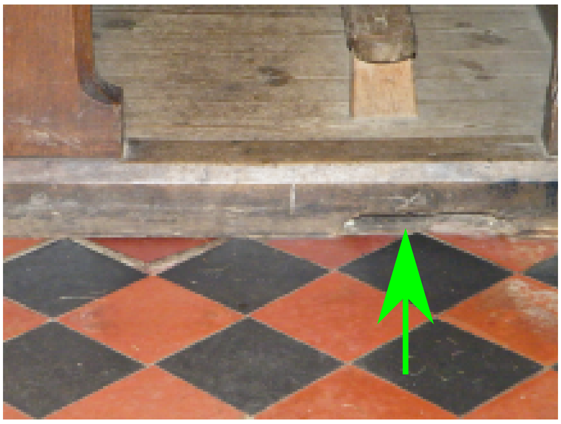
Left, a thermal image of the south door which is much more thermally conductive, and has much smaller thermal capacity than the stone wall.



Above, light shines past the edges of the closed door which does not seal to the door frame.

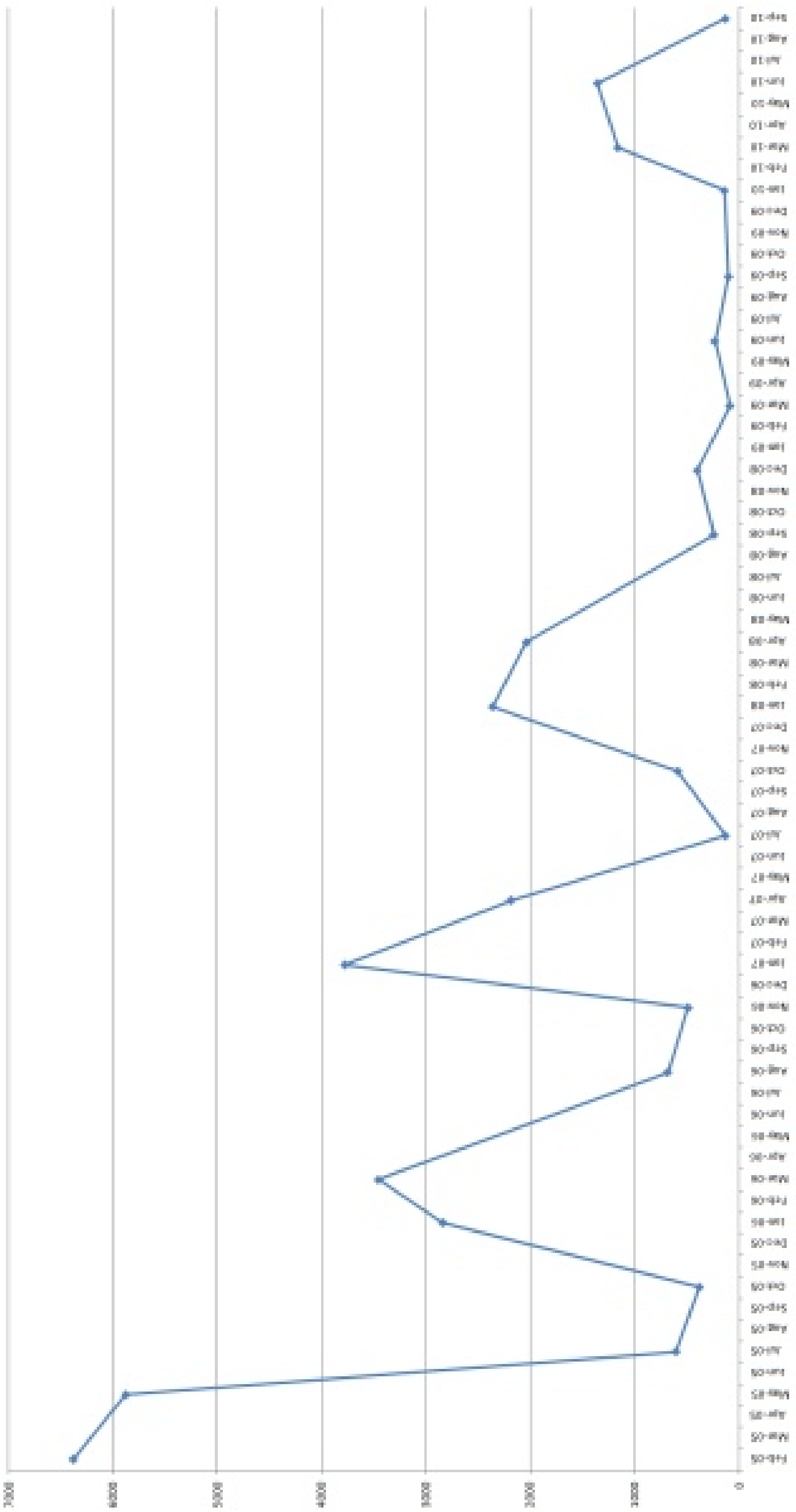
Left, rotting wood in the cellar might release spores which drafts could carry into the church.

Below left, blackened bricks in an area of the cellar that was presumably used as a hearth to heat the church. Below right, one of many vents (indicated by green arrow), from the shallow void under the pews to the isles of the church.



4 - Energy Data Analysis

The church has presented electrical energy data which is relatively complete and largely based on actual readings, with the caveat that the oldest 2005 data would be the least accurate.



Graph of kWh billed against time. The early peak might be dismissed as the oldest data is known to be unreliable, but subsequent annual peaks suggest power consumptions of about 1,200 kWh per month in winter billing periods, and 120kWh per month in summer billing periods during 2006 and 2007. This seasonality is as expected for a heating and lighting load, and the decline in recent years due to electricity costs, equipment failures and some use of gas heating has already been discussed. The peak in February to June 2010 should however be investigated.

It must be kept in mind that each point on the graph represents a number of kWh, used since the end of the previous billing period.

An average number of kWh per day of electricity can be calculated by dividing the amount of energy billed for the period, by the number of days covered by the bill. This suggests that in 2006 to 2007, average daily winter consumption might be about 40 kWh per day, and summer consumption about 4 kWh per day. It should however be kept in mind that the peak consumption on the coldest days will have been much higher than the average figure, but that this energy may not have been used effectively, i.e. it may not have reached the users and fabric of the building effectively. Further, it is not known how much gas might have been used during this period. This limits the extent to which energy consumption can be used to size a replacement heating system.

The church changed its electricity tariff recently when it was discovered that more was being paid in standing charges than energy charges. It is thus not expected that significant savings could be made by changing tariff at this time, unless a heat pump or other equipment is installed that can exploit an off peak tariff.

Gas data was also examined (propane and butane), but this is known to be incomplete as people do not necessarily give the Treasurer invoices for gas, effectively donating the fuel to the Church. This reduces the monitoring of gas consumption to guesswork, which is compounded by gas sometimes being purchased in quantity, but not necessarily used in the same year. Although gas is used as little as possible due to the water released by combustion, small gas heaters (perhaps using 11kg cylinders) are used fairly regularly during services in winter, and large heaters (perhaps using 47kg cylinders) are used before services at the coldest times of year. Gas use is thought to have increased in response to rising electricity prices and failures of the electric heating equipment, but while significant, this cannot be quantified.

Given the uncertainty about the amount of gas used, it may be sensible to assume a total daily winter energy consumption well in excess of the 40 kWh identified above.

5 - Review of Energy Management and Efficiency Issues

The main problems are summarised below.

The buildings current heating system is neither effective at heating the important parts of the building, nor cost effective to use.

The fabric of the building is at risk, and the wooden floor under the pews may already need to be replaced.

It isn't cost effective to heat the building for use by small groups, particularly of vulnerable people who may not be comfortable at the temperatures and relative humidities that can be achieved with the current heaters.

The building envelope leaks heat and moisture, and is difficult to draft proof.

The situation might be improved by making some simple changes to address drafts, and more major changes which might include replacing the floor under the pews, and installing a new heating system using more cost effective and less carbon intensive sources of energy. Starting with low cost improvements, a provisional list of suggestions follows.

Information about energy consumption could be improved particularly for gas. It would be easy to read the electricity meters once per week, and gas use might be recorded by logging the number of hours each heater is used, along with the rated power of the appliance.

A carbon monoxide alarm might be installed in the church while the unflued gas heaters are in use.

Improve spotlights by the use of LED lighting, or if this is not affordable, the use of reflector spot lights which use a halogen lamp internally to offer a small efficiency advantage over standard incandescent lamps, and 'whiter' light.

Check the north isle roof to investigate possible fungal and water damage.

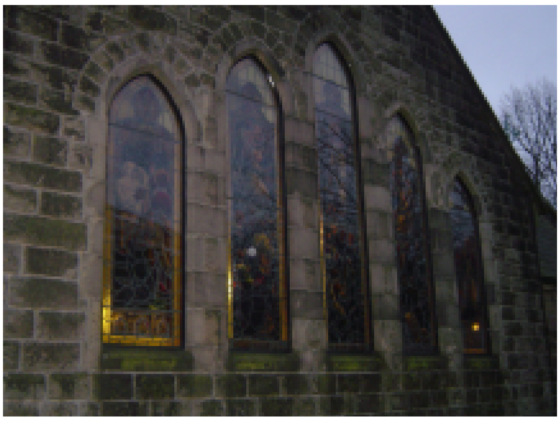
Continue to work on the provision of draft excluders around the doors.

At the moment, the outside of some windows is covered in wire mesh. While this may be effective at reducing vandalism, it does nothing to retain heat. Some churches have applied external rigid plastic sheet to insulate the windows. A number of materials can be used, but some based on polycarbonate are highly transparent, good at retaining heat and strong. Polycarbonate plastics are used both as riot shields and as glazing for solar panels. Consider the use of external secondary glazing, perhaps based on polycarbonate rather than glass. Consult the Diocesan Advisory Committee and local planning authority to see if this change would be consistent with the listed status of the building.

When the floors under the pews are replaced, the new flooring should be installed over a damp proof membrane and insulation. The floor could be replaced with wood, and heaters installed under pews (though see later comments on the problems this poses). Alternatively wet underfloor heating embedded in concrete might be employed to emit heat over the entire floor surface over which the congregation sit. This option also opens up opportunities to use some of the space currently equipped with pews as a community space where groups could meet, or even sit and play on a comfortably warm floor. If concrete is used as the flooring material, this might be tiled to match or contrast with the existing tiles in the church, or might be stained a dark colour, textured, and treated with a dust inhibitor, or alternatively could be carpeted with minimal underlay to minimise thermal resistance.

A new energy source for the heating system should be selected, ideally reflecting the aspiration that the use of this energy source should be as sustainable as possible. This decision should be made taking account of the emitters and flooring to be used.

Right, the south windows at Holy Cross Church with wire mesh covers. Below, windows at Buxton URC with external secondary glazing. Below right, detail of the fixing of the external glazing at Buxton URC.



6 - The Distribution of Heat Within the Building

Hot air is less dense than cool air and so tends to rise. The greater the temperature difference between the hot and cold air, the greater the energy available to make the cool dense air displace the heated air.

When heating tall buildings, warmed air tends to rise to the top of the building where it cools before sinking back to a lower level. The cooler (less well insulated) the roof, the more quickly heat is lost in this process, and the cooler the air that sinks back towards the ground.

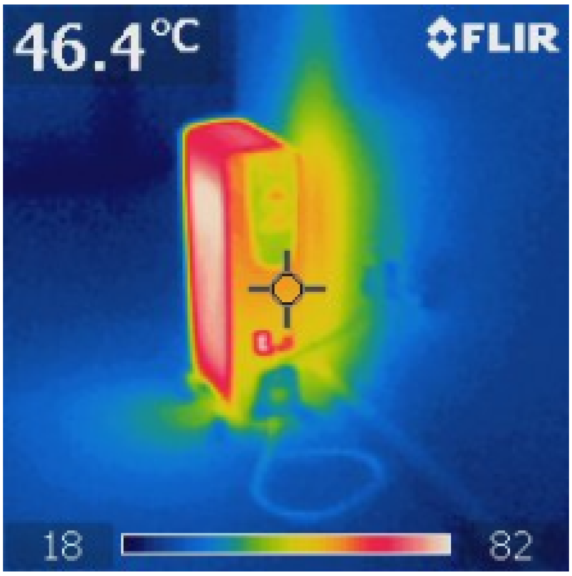
If a small but intense source of heat is used, a narrow plume of warm air is emitted, and in a high building, be it a church or an industrial unit, the building will tend to fill with warm air from the top down, rendering much of the energy inaccessible to users of the building at floor level.

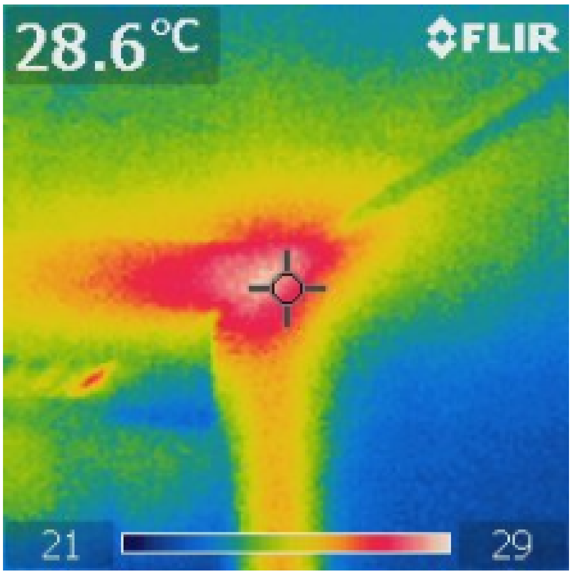
This may be illustrated by the three thermal images at the top of the next page. The first shows a simple electric fire. The second shows the wall and ceiling above the fire heated by the rising plume of warm air. The third shows a warm region at the top of the room which is of no benefit to the people lower down.

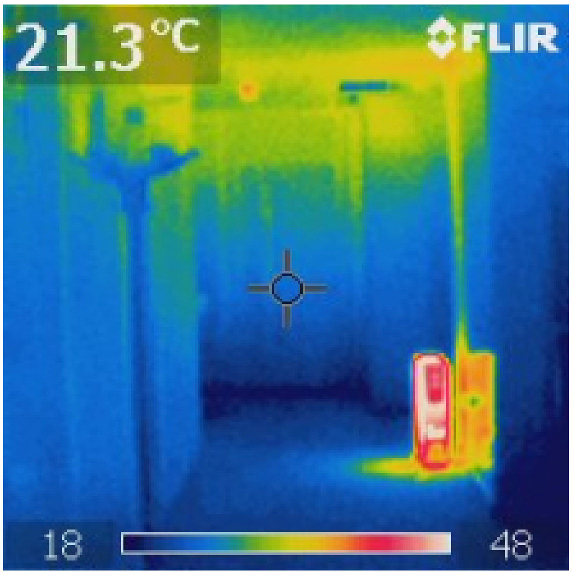
It is likely that the existing church electric heaters, while emitting significant amounts of heat, loose most of it to the poorly insulated roof of the church, with little of the rising plume of warm air touching the worshipers who sit or kneel close to ground level.

The gas heaters may achieve slightly more as these will radiate some energy rather than nearly all of it being delivered by the convection of warm air. None the less, this radiated heat will not reach worshipers efficiently, and only those within a small number of meters of a gas heater, with 'line of site' to it, are likely to gain significant heat. This is not likely to be a significant proportion of users of the building if the source of radiant heat is located at ground level.

One approach then, might be to locate a source of radiant heat at a higher level. Such a heater might be powered by gas or electricity, but as gas would have a smaller carbon footprint, and powering such a device from propane might be the more sustainable option for the time being. Companies such as Ambirad manufacture radiant tube heaters powered from propane which could warm the congregation from above. The space below the heaters would be warmed over a wide area by the radiant heat, but localised heating would be modest. While this creates some difference in air density at ground level, it is mild compared to a small hot radiator, so the tendency of the warmed air to rise from the items heated on the ground is much reduced. This approach might be worth of serious consideration, though the use of water source heat pumps with underfloor heating is likely to be more cost effective, with less direct dependency on fossil fuels.







A similar warming over a wide area might be obtained by using large low temperature emitters under pews, or by using under floor heating. In either case, the warmed air should rise slowly around and between the worshipers, rather than bypassing them as might occur from a more intense and localised heat source.

The use of heaters amongst the pews has been tried before with electric heaters, (see top of next page) but this has been problematic in that there are not many of them, and they are very hot to the touch and may pose some risk of causing burns. As a resistive electric heater, their use also has a high cost and carbon footprint.

Another source of concern with heaters mounted on the floor is that as they are placed under pews they may be damaged by being kicked as people kneel down. Although location under pews might give the best thermal performance for a floor mounted heater, the amount of space is quite limited, and if kicked by accident, a

leak of hot water might occur from a 'wet' system.

A final heat distribution approach which might be considered is the reinstating of the use of the ducts from the cellar to the void under the pews.

The feasibility of this has been verified by piping the output of a large propane heater into the brick ducts in the cellar, and monitoring the vents at the edge of the woodwork that supports the pews, (see pictures on next page).

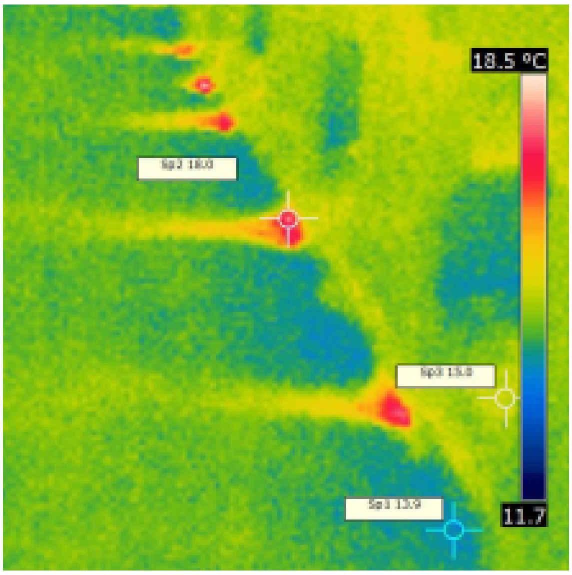
This revealed that warm air could be blown though, but concerns remain re the condition and lack of insulation of the ducts which might render them a very inefficient way of delivering warm air.

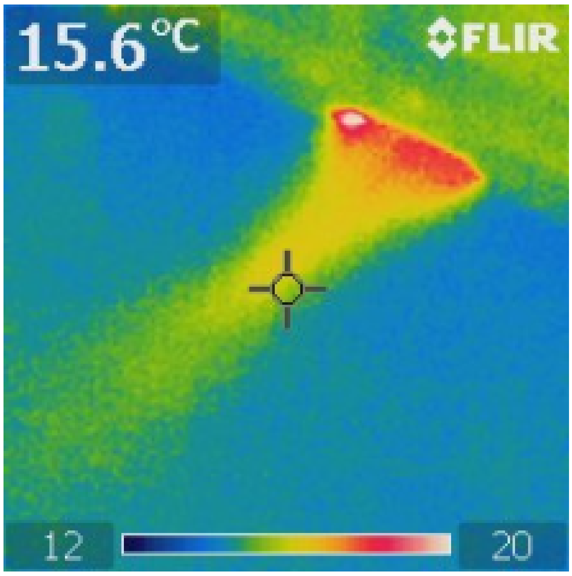
The pictures above show the propane cylinders and burner used to provide the warm air for the experiment.

The images at the top of the next page show condensation forming on the cool floor tiles as the heated air blew out from the vents at the edge of the raised wooden floors on which the pews stand. This interpretation is confirmed by the thermal infrared views.

These show that the heated air from the cellar was able to warm the tiles immediately in front of the vents to around 5°C above the ambient floor tile temperature, though having established this, the experiment was discontinued to avoid making the floor on which the pews stand even more damp.

Although the condition and lack of insulation of these ducts may make them inefficient for the delivery of warm air to heat the building, they should be kept in mind as possible routes for pipes that might for example, link a heat pump in the cellar with an under floor heating system in the church above.


18.5 °C
11.7


15.6°C
FLIR
12
20

7 - Review of Renewable Energy Options and Site Potential

It is important for project developers to evaluate all options while taking account of local norms and relevant planning guidance. Within the Peak District, the document "Supplementary Planning Guidance For Energy Renewables and Conservation" is of particular significance.

This evaluation should take account of likely changes to conventional fuel prices, the desirability of reducing dependency on fossil fuels, fuel security, and making long term cuts in carbon emissions.

Adding insulation to buildings may usually offer the most cost effective gains. In addition to reducing ongoing fuel costs, this will reduce the size of the heating system required. This in turn reduces the capital spend required when premises are refurbished, but it is accepted that in a listed historic building, the scope for the addition of insulation will generally be limited.

The use of a range of renewable energy options has thus been discussed with the community, and the conclusions are summarised below.

Solar water heating was thought unlikely to be a significant benefit as the building has no water supply. Even if this is addressed, the demand for hot water in the building is likely to be relatively low. Planning issues might also need to be overcome because of the visual impact of solar panels on a building at such a sensitive location. A solar photovoltaic system was also rejected on aesthetic grounds, although there is increasing precedent for installing these on church buildings.

Hydro power should be considered, though the constraints are significant.

Biomass was not recommended as there was no obvious place to store fuel, and local supplies are limited in this part of the Peak District.

A wind turbine might yield significant amounts of energy if sited appropriately, but this was also felt to be inappropriate mounted on, or within, the curtilage of a historic building. Higher ground away from the church might offer better wind speeds, but such sites would be very unlikely to gain support because of damage to visual amenity. Cable resistance and cost might also become a problem.

The inclusion of a heat pump in the scheme was considered as it would cut green house gas emissions by displacing fossil fuels that would otherwise be used to heat the building, and reduce operating costs at a time when gas prices may rise faster than electricity. It was noted however, that to be efficient, (to get the best coefficient of performance), under floor heating would need to be installed in the parts of the building to be heated. It is reasonable to assume given local resources, that the lowest revenue heating costs will be incurred by the use of a water source heat pump, and this option should be given serious consideration. No aspiration has been expressed to provide cooling in the building. If at all possible, to save energy, the use of heat pumps for cooling should be avoided in favour of natural ventilation. The thermal capacity of the stonework prevents extreme temperatures within the building, which reduces the need for cooling compared to other building types.

The use of a Combined Heat and Power (CHP) system was also considered as it offers good use of the primary fuel, but it was noted that natural gas is not available, and propane and oil are relatively expensive. The economics are also compromised because the church need only be heated for arounf half the year, and any noise from the CHP system in such a tranquil location would be a significant loss of amenity.

The use of a heating only water source heat pump and hydro electric generation will be considered in subsequent sections.

8 - Introduction to Heat Pumps

A heat pump is a device that transfers thermal energy from one location and medium to another, though more importantly for our present purpose, it has the property that the heat energy delivered by the system can be at a higher temperature to the heat source.

As heat is moved from one place to another, the *heat source* is cooled, and the destination, usually referred to in the terminology of thermodynamics, as the *heat sink*, is warmed.

Common examples of heat pumps include refrigeration systems where the heat source is the inside of an insulated box (the interior of a fridge), and the heat sink is the 'radiator' at the back of the fridge which feels warm to the touch.

When used to heat buildings, heat is moved the other way, from some medium outside the building, normally the ground, the air, or water, to the inside of the building, the 'insulated box'. Here, it is typically distributed by radiators or an under floor heating system. In the process, the ground, air or water outside is cooled, and the temperature of the building is increased.

In addition to thermal energy from the heat source, energy is required for a heat pump to operate. The greater the temperature difference between the heat source and sink, the more energy is required to move a given amount of thermal energy from the heat source to the heat sink. Although practical heat pumps almost invariably use mechanically driven components, they are generally operated from an external electrical energy source rather than being driven via a mechanical shaft. The use of electrical rather than mechanical drive makes it easier to seal the refrigerant gasses in the system. It is important that these do not leak out, as loss of these materials will cause failure of the system, but more importantly, the chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) chemicals used, either cause damage to stratospheric ozone, are remarkably potent greenhouse gasses, or both. As a consequence of this, heat pumps must be maintained and disposed of with care by competent personnel. (Also see discussion at end of Section 12.)

In heating applications, the heat delivered can be assumed to be the sum of the energy obtained from the heat source outside the building to be heated, and the electrical energy provided to operate the heat pump. The performance of such systems is usually indicated by the ratio of heat output power divided by the electrical input power. This is usually termed the coefficient of performance, abbreviated to COP or CoP. By current standards, well designed systems with COP values of over 5 are likely to be seen as good performers, where as those with COPs of under four should be examined with care to see if the design can be enhanced, or if they are financially and environmentally beneficial at all. COP values improve as the difference between the heat source and sink temperatures is reduced.

Maintaining an adequate temperature in a heated building requires that at a comfortable internal temperature, the heat loss from the building on the coldest days can be met by the heat available from the heating system. Where a heat pump is used, this requires that either the heat source medium can be continually replaced as it is cooled, e.g. an air source system in which large fans blow high volumes of air through the machine to act as a heat source, or a ground source system in which the soil and rock around pipes buried under ground have a high thermal capacity so that they cool very little as heat for the building is withdrawn.

Air source heat pump systems have the problem that on the coldest days of winter when most heating is required, the outside air temperature is low so that the COP is poor. Ice should not be permitted to build up around heat exchange surfaces in air source systems, and the need to defrost these when the air is cold may also reduce efficiency. On cold winter days air source machines may have COPs close to 1, so may be little better than resistive electric fires under these conditions.

Ground source systems have to be large enough that the available thermal capacity of moisture, soil and rock can meet short term peaks in heat demand without excessive cooling, but also large enough that adequate amounts of heat can flow into the ground source system over the course of a year to avoid excessive ongoing local cooling. The success of a ground source system then, depends on the thermal capacity and conductivity of the surrounding soil and rock, but is also influenced by the mass flow of water through the heat source site, as water brings relative warmth into the cooled heat source region. The formation of ice due to over cooling should also be avoided around the pipework of ground source systems, as less heat will reach the ground source pipe work if ice prevents the flow of water through the soil near the pipes. As a precaution, the pipework of ground source heat pumps is generally filled not with pure water, but with water containing about 33% of a glycol antifreeze. Ethylene glycol (similar to the antifreeze used in many cars) has been used in this application, but we would rather see the use of propylene glycol, as in the event of leaks, accidental contamination, or human contact, this is much less toxic to humans. See the manufacturers safety data sheet enclosed with this report.

In winter then, air source systems typically have to operate with very low COPs in frosty conditions, and while well sized ground source systems should operate with source inlet temperatures above freezing, heat source operating temperatures may sometimes not be far above freezing by the end of the winter heating season.

Where available, moving water, or large bodies of still water may be used as heat sources. A range of water source systems are available. Closed loop systems may draw heat from moving water in streams or rivers, or from lakes, passing antifreeze mixtures through pipes which are warmed by the surrounding water. Open loop systems may use a pair of wells or boreholes, drawing water from one and discharging to another. Heat may then enter the system by the movement of water through the aquifer, and by the conduction of heat through the surrounding rocks.

Boreholes can also accommodate closed loop heat exchangers, but as these become deeper the static pressure in the heat exchange loop increases so materials which can withstand this must be chosen. It is normal to backfill such boreholes with a thermally conductive material such as bentonite grout rather than conventional concrete, though the use of some lime based mixtures may also be possible which may reduce the 'embedded' carbon footprint.

In this case, it is hoped that it will be possible to harness an 'off the shelf' closed loop water source heat pump to raise the buildings temperature by a useful amount, though this is contingent on the amount of available spring water being large enough to deliver the necessary thermal energy. It is hoped that as heat is only required from October to May, that there will be an abundance of spring water which should offer a higher temperature heat source than trench or borehole ground source systems.

In the UK, the use of a closed loop system has the advantage that the cost of an abstraction license which must be paid when water is abstracted from wells or watercourses can be avoided. The source heat exchanger must be generously sized however to avoid a significant reduction in inlet temperature which would reduce the COP. This report will assume that a closed loop system will offer the best return, but prior to purchase this might be sanity checked, taking account of any improvement in COP that an open loop system might offer, and the cost of any necessary abstraction license.

The view is taken in the community that heating the church to a comfortable 'shirt sleeves' temperature is not an affordable objective, but raising the temperature by a few degrees to improve user comfort and reduce the relative humidity for most of the winter to control damage to the fabric of the building is an appropriate target.

If a heat pump is installed, it might also contribute to the production of 'domestic hot water', though the temperature delivered may not be high enough to ensure control of Legionnaires' disease. A small gas boiler or immersion heaters might be used to eliminate any risk of Legionella build up. Some heat pumps integrate any necessary electric heaters into the same housing as the heat pump, though if the demand for domestic hot water is very small this may not be economically justified.

One of the primary aims of heating the church is the control of humidity. It might be noted that this objective might be achieved most cheaply using a dehumidifier without any space heating at all at temperatures above about 10°C. This would also heat the building slightly from the energy used by the dehumidifiers motor and fan, as well as the latent heat of condensation of the water collected. This might work well if the building were more airtight, but unless this can be addressed, this is unlikely to be practical.

9 - Assessing Hydrology and Spring Water Energy Resources

Site Hydrology

Any practical use of water source heat pumps depends on there being an adequate supply of water at a temperature that makes their use economically viable. A number of water sources are candidates for the provision of heat to the church on this site.

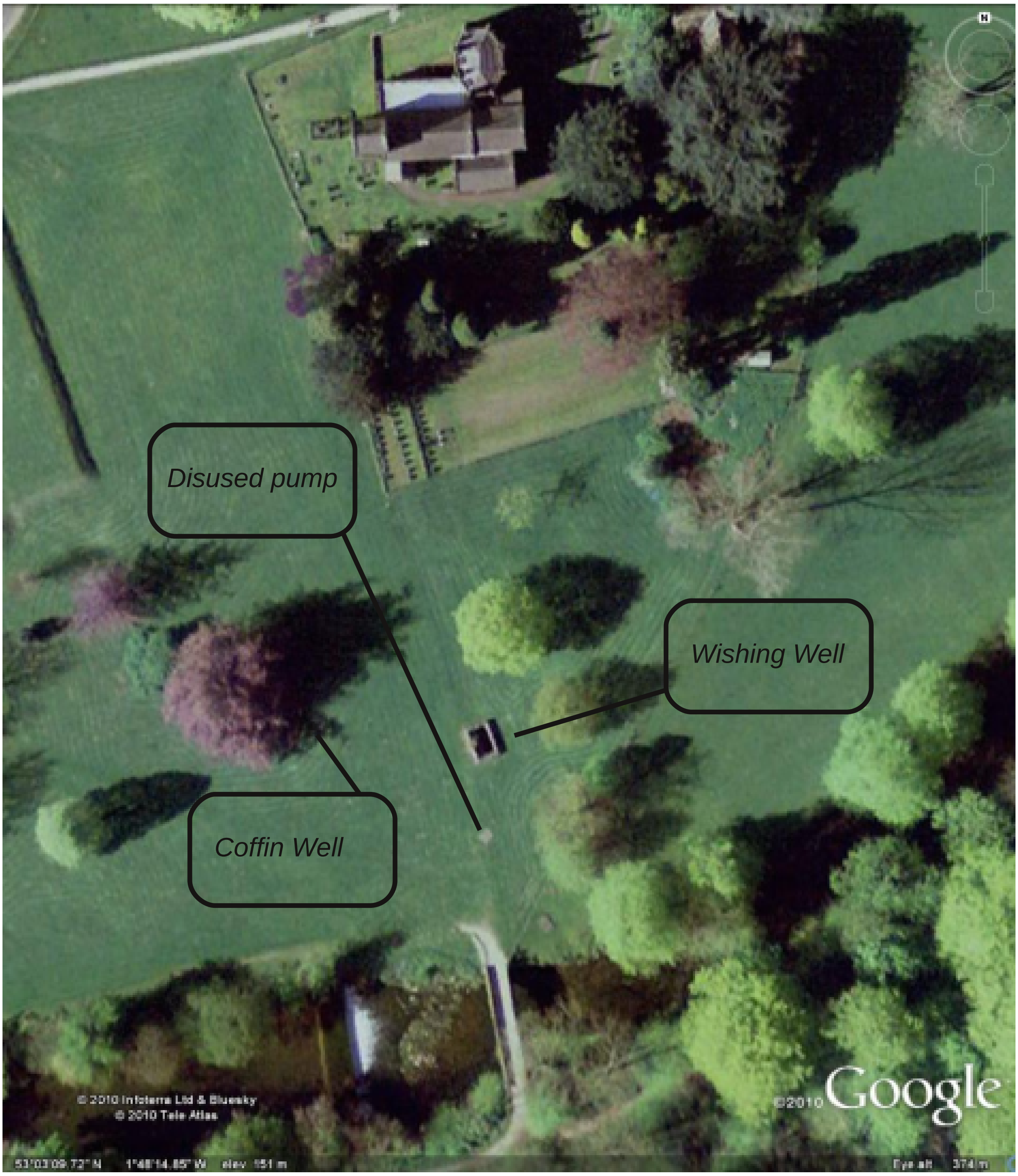
Of these, the river itself might be considered a source of low grade heat, but while this is unlikely to freeze in winter, it might on occasions contain water which is quite cold. In addition to being colder in winter than the springs nearer the church, it is also more remote, and in flood, there is also significant risk to any heat exchangers or other equipment placed in the river.

The 'boil holes' where water rises from underground and flows directly into the River Manifold are the most remote option. These have been dismissed as the length of trench and pipe required to reach them is the greatest of the available sources, and while they are likely to be a very similar temperature to the other wells, the other wells are closer to the church.

The National Trust have said that a drain from Ilam Hall might also be assessed as a source of heat, perhaps in combination with water from the wells. While this might increase the volume of water available, it seems unlikely that there will be any shortage of well water at times of year when use of the heat pump is required. It may also be the case that the drain from Ilam Hall might include melt water from winter snow which could be significantly colder than the spring water entering the wells from underground. This drain water may thus have less value as a source of heat, so might be rejected unless it is later found that the water flows in the wells nearest the church are inadequate.

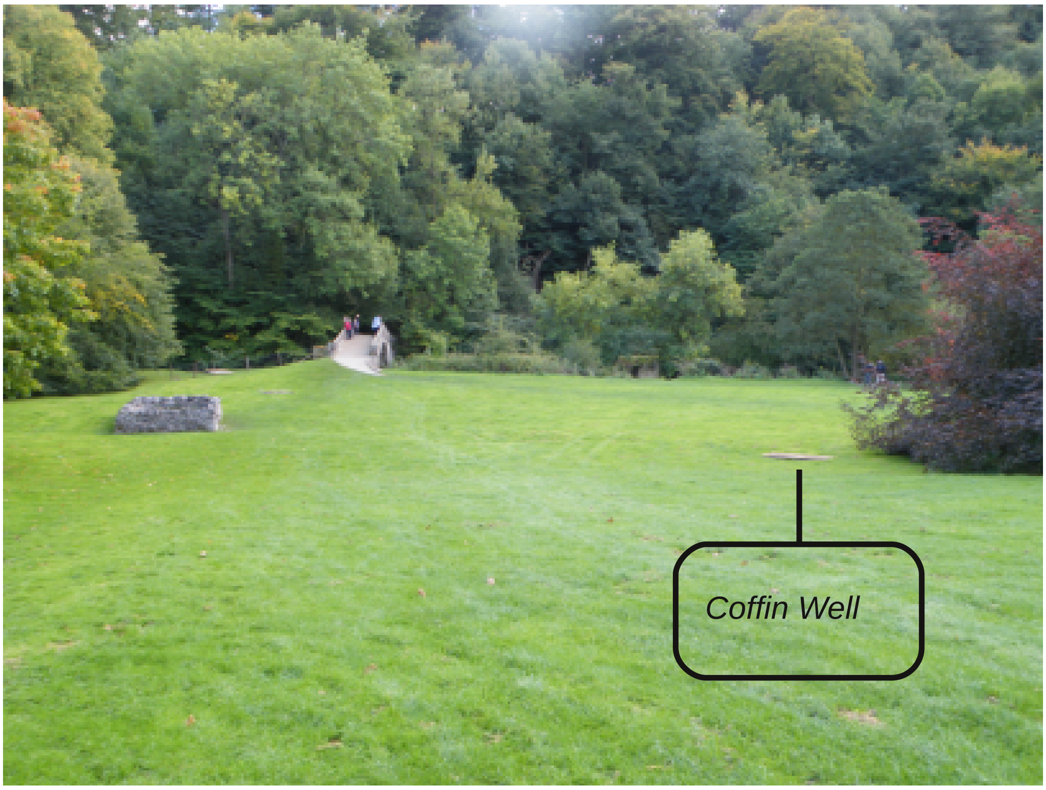
The wells nearest the church are known locally as the Coffin Well (because of its shape) and the Wishing Well. Although neither well ever dries up, the flow of water through them is not thought to be great, if any, between April and October, but is expected to be adequate to run a heat pump over the winter months. Although these wells are the nearest source of warm spring water to the church, both are regarded as historic monuments so it may not be acceptable to place heat exchangers into these to extract heat directly. Although these are referred to as wells, water can be seen to flow thought them during the winter, so they may be thought of as water channels; part of a stream which only runs during the winter months, but below the level of the water table at all times. Discussions with the National Trust suggest that it may be possible to construct a chamber below ground level through which this flow passes, to house a heat exchanger to provide energy for the church heat pump.

Where water flows underground, it is not easy to know where to intercept the flow to extract heat, the three dimensional shape of the path taken by the water. Further, the



Above from Google Earth, top centre, Holy Cross Church. Bottom centre, the bridge over the River Manifold.

The ground slopes down from the church towards the river. The wells and water chanels from which it is hoped to extract heat lie between the two.



Above, view from the north, Wishing Well to the left, Coffin Well with wooden cover over it to the right. Below, Coffin Well viewed from the east with the cover removed.

Above, Wishing Well viewed from the south.

flow rate in any particular part of the path cannot easily be determined from surface observations.

In any water channel it is notoriously hard to judge flow rate. If flow is perceptible in a deep pool or stream, a very considerable number of litres per second are likely to be flowing, but flows underground are largely a matter of guesswork as they can only be examined where the water is accessible from the surface, for example where water flows into Wishing Well.

Flow rates through the Wishing Well were assessed by the community over the winter 2009 / 2010 period, finding typical flow rates of 27 litres per second.

It is impractical to undertake a detailed excavation of the site to reveal where the various springs rise. The location of the heat source heat exchanger then, must be based on the observed locations of the wells, and anything which can be determined about how water flows between them. Although no water flowed during most of the period of this study, experiments were undertaken with drain dye during autumn 2010 once water started to flow through the wells to assess the relationship between the wells and the river.

A strong solution of drain dye was prepared, of approximately 200g of Horobin green drain dye in 10 litres of water, see manufacturers safety data sheet in Appendix 2. Flow rate into Wishing Well was measured by filling a six gallon container (27 litres in

13 seconds) to be approximately 125 litres per minute.

Because water flows into Wishing Well from the direction of Coffin Well, it has generally been assumed that water flows from Coffin to Wishing Well. Coffin Well was thus investigated first.

A few drops of the drain dye solution were introduced at the west end of Coffin Well. Very little water movement was apparent and it took several minutes for the dye to distribute itself into the body of the well indicating that there was little if any flow of water into the west end of the well. The picture below shows the lack of movement of the dye after a about minute. Over time this dye washed through the well, but there was no obvious point at which it became diluted, suggesting that there were no clearly defined points of entry for the water entering Coffin Well.

When a similar few drops of dye were introduced to the east end of Coffin Well, this was quickly diluted and drawn underground in the direction of Wishing Well. It appears then, that while Coffin Well has a distinct outflow at the east end, there is no clear point of entry.

Continuity of flow between Coffin and Wishing Wells was then checked by introducing approximately three quarters of a litre of the drain dye solution into the east end of Coffin Well, and watching the water as it flowed into the Wishing Well.

After about three and a half minutes the water began to show the dye, the intensity of

Above, drain dye placed at the east end of Coffin Well is drawn towards Wishing Well, clearing the water relatively quickly (below), suggesting that this is where most water leaves Coffin Well.

Above, drain dye poured into the east end of Coffin Well.

Below, dyed water washing through to the west side of Wishing Well.

Above, viewed from the north west, drain dye entering Wishing Well from the west, and flowing to the south while the north end remains clear.

Below, viewed from the north west, drain dye carried by water to the exit on the south side, towards the river.

the colour growing and largely fading over the next eight minutes. The dye accumulated at the south end of the Wishing Well, and did not wash up to the north end, suggesting that the bulk of the water leaves Wishing Well via the south end.

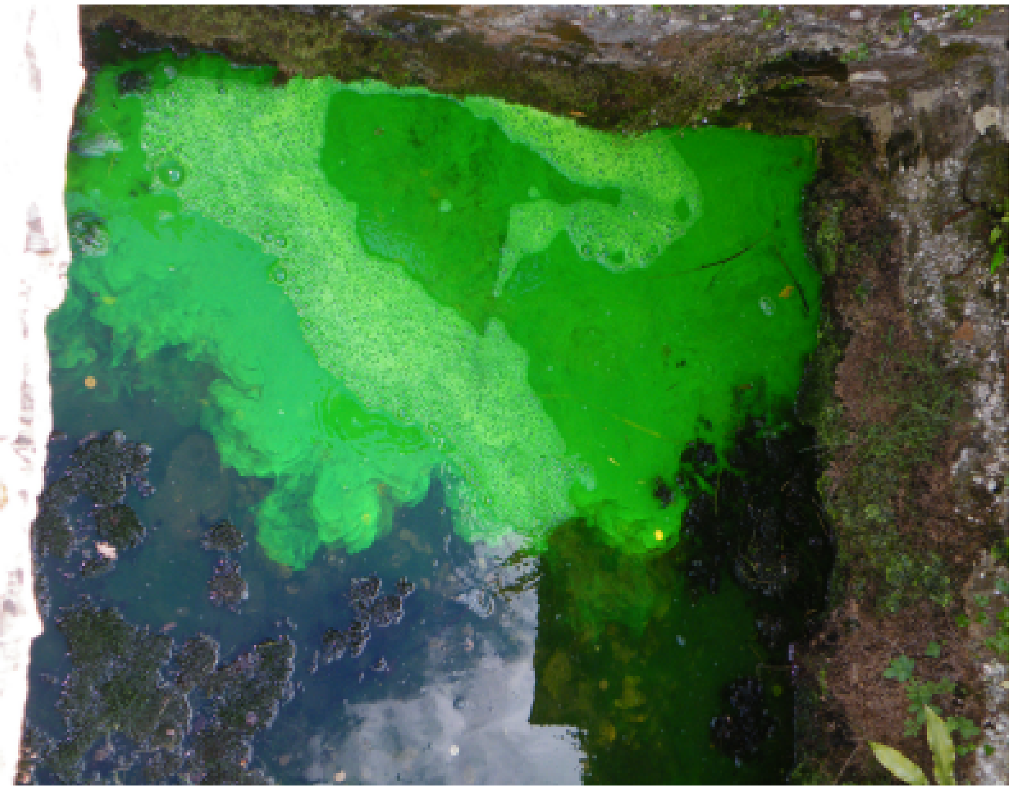
Although dyed water flowed out of Wising Well towards the River Manifold, no dye was observed entering the river at this point, probably because of overwhelming dilution of the dye into the moving river water.

To establish that water from Wishing Well did discharge into the River, a larger quantity of the dye solution, about two and a half litres, was added to the south end of Wishing Well, and a discharge to the river was observed east of the bridge in around 60 seconds.

Some discharge of dye west of the bridge was also observed, though it seemed unclear from which well this dye might have originated. It could have been residual flow of dyed water from Coffin Well, or by a more circuitous path, from Wishing Well.

To determine which of these was most likely, about a litre of the dye solution was added to the south end of Coffin Well, and a discharge to the river was observed West of the bridge shortly afterwards. From the time taken for this to appear, it was concluded that there was probably a link between Coffin Well and the point of discharge to the west of the bridge, but it is not clear if this through a deliberately constructed duct or culvert, or if it is a culvert, the extent to which it might be blocked.

Below, drain dye to be poured into the south side of Wishing Well to verify that it drains into the river.



Above, viewed from the north, drain dye at the south end of Wishing Well drawing into the drain.

Below, the dye emerging in the river east of the bridge, though the exact point of entry is not easy to see.

Above, viewed from the east, drain dye poured into Coffin Well to see if this has a direct link to the river.

Below, the dye emerging in the river west of the bridge, though again, the exact point of entry is not easy to see.

Above in more detail, the dye emerging in the river west of the bridge, though the exact point of entry is not easy to see.
Below, the water around the site of what is assumed to be an old pump remained clear at all times, suggesting it is isolated from the surrounding culverts and ground water.

The aim of this exercise was to identify the best location to site a chamber to house the heat exchanger to source heat for the heat pump used to heat the church. To minimise disruption to the site it would be an advantage to select a location where the flow is significant and measurable. Based on the behavour of the dye, the flow to the west of the bridge (the 'dash dot dot' line in the diagram below), appears to be relatively weak, and there is little certainty as to the path taken by this water underground. Unless this is a man made culvert, the flow may also run deep under the surface. Given that the river bank is deep and the flow emerges under the surface, this seems likely for at least part of this flow.

There is similar uncertainty about the flow to the east of bridge (the 'dash dot' line in the diagram below), though the flow rate appears subjectively to be somewhat higher.

The flow from Coffin to Wishing Well (the dashed line in the diagram below), appears to have the best and certainly the most measurable flow, especially if intercepted at the Wishing Well end. There is more certainty here about the path of the stream underground, and its depth, as the endpoint can be seen clearly. A proposed location has been marked as a blue square on the diagram below (not to scale) which has the advantage of being relatively close to the church building.

The Energy Resource

There are a number of sites in the Peak District where warm springs rise to the surface. The temperature of these varies very little with the season, and for all practical purposes the spring outlet temperature at a given site can be regarded as constant. For example, Bakewell had a spring which delivered water at 15°C, Matlock delivers water at 20°C, and Buxton at 25°C. Although Ilam only achieves a constant 10°C, this is a perfectly adequate temperature for a water source heat pump, and avoids the potential difficulty that temperatures over 15°C can be too high an inlet temperature for the sustained operation of some heat pumps.

These springs then, offer a source of heat energy, albeit low grade heat, and have aroused considerable curiosity over the years as to their potential as an energy source.

Low temperatures have generally precluded the use of these springs as a direct heat source, but the increasing availability and deployment of heat pumps in the UK is now making the use of this heat a possibility, with technology which while expensive compared to a simple gas boiler, is 'off the shelf', and tried and tested in other parts of Europe.

Perhaps because the UK has had access to cheap natural gas from the North Sea, where as European countries have mostly had relatively high energy prices, the uptake of heat pumps in the UK has been relatively poor until recent times, and we are now only slowly catching up with our European and Scandinavian neighbours. This may have been reinforced by the relatively widespread availability of three phase domestic electrical supplies in Europe.

At a time when the need for sustainable consumption of locally sourced energy has never been more clear, options to use renewable energy in the Peak District National Park are constrained by the need to conserve the visual environment. This precludes many opportunities to exploit wind power and solar resources, but heat pumps have the advantage that in many circumstances, little or no infrastructure need be visible or prominent in the landscape. Further, for the significant amounts of thermal energy obtained, carbon emissions can be significantly lower than would arise from the burning of even natural gas, which is widely seen as the current benchmark for efficient space heating. As natural gas is not available on this site, the heat pump should be judged against the use of propane and electricity, both of which are more carbon intensive and expensive than natural gas.

The amount of energy available from a stream of water depends on the specific heat capacity of water, the flow rate, and the amount by which it can be cooled by the heat pump.

The specific heat capacity of water can be assumed to be fixed over the range of temperatures of interest. The amount by which the heat source water can be cooled by is constrained by the requirement that the water must never be permitted to freeze. Many heat pumps also have a maximum amount by which they can cool water, typically between 4°C and 6°C, so starting from 10°C, there should be little risk of freezing.

A spreadsheet has been provided with this report to allow the user to explore the amount of energy that can be extracted from a heat pump given the cold side flow and return temperatures and flow rate.

The spreadsheet deals with the energy that thermodynamics predicts might be extracted from a stream of water at a given temperature without taking account of the practical constraints imposed by particular machines. It does not do detailed design calculations which must include parameters specific to each model of heat pump. For example it can take no account of the practical constraints imposed by some products, e.g. minimum flow rates, heat source ΔT values, and switch on surge currents which should be addressed as the detailed design is undertaken.

If it is used to calculate heat transfers using water / antifreeze mixtures, the specific heat capacity of the fluid must be adjusted accordingly.

This .xls file will run on Microsoft Excel 2000, but should this not be available, it works just as well on the OpenOffice.org Calc program which is part of the Open Office suite. This excellent open source software is available as a free download from the http://www.openoffice.org/ web site.

The first page of the second tab of the spreadsheet is used to see how much energy a given flow of water falling in temperature by a given number of degrees can contribute to the heat in a building on winter days.

This takes data entered in the blue shaded cells of the spreadsheet, and derives a number of results. Subsequent rows are colour coded as follows.

> Green lines are constants. Note however that as the fuels burned to generate electricity in the UK change over time, the figure for carbon dioxide emitted per kilowatt hour of electricity used may require adjustment. At the moment it is rising sharply as coal is being substituted for natural gas in the 'UK generating mix' as natural gas prices rise. The accepted figure has gone from 0.43 to 0.54 kg of carbon dioxide per kWh of electricity delivered in the last two years.
>
> Yellow lines are intermediate calculated results which may be of interest.
>
> Red lines are significant outputs that you'll need to know to size your system

or negotiate with external agencies.

Brown lines refer to the emissions and cost performance of an alternative (or existing) heating system and fuel, based on the delivery of the same amount of thermal energy as the heat pump.

Note that all significant numbers are shown in the column B of the spreadsheet. Selecting cells in this column will show the values or formulae that calculate cell values near the top of the spreadsheet window.

The core calculation takes the heat pump source flow and return temperatures, and calculates a quantity, sometimes referred to as 'delta T', written as ΔT. This is multiplied by the thermal capacity of the fluid (4.187 kJ per litre per degree centigrade for water,) or that of the water / antifreeze mixture, and the number of litres of water flowing from the source per second, to give the amount of power available from the water when the heat pump is running (not including the electrical input). The amount of power available is used to calculate the amount of energy that might be available per hour. The number of hours per day that heating will be required (the daily operating period) is input by the user so that the amount of energy that might be extracted from spring water per working day can be calculated.

The number of cubic meters of water per day is calculated by the spreadsheet.

Should an open loop heat pump be considered, this figure may be requested by the Environment Agency who may require the purchase of a water Abstraction License if significant amounts of water are withdrawn from a well or watercourse, for example for an open loop heat pump.

The COP of the heat pump may be input by the user. This figure, typically in the range 3 to 8 for warm water source systems, will depend on the properties of the heat pump, and the difference between the heat source and sink temperatures. This figure should be taken from tables or graphs provided by the heat pump manufacturer. If a manufacturer is reluctant to discuss the COPs of their products, be very suspicious, and ask how performance can be assessed and compared with other products. Entering the COP for the conditions under which the heat pump will typically be working into the spreadsheet, allows the amount of electricity that will be used to extract the energy from the spring water to be calculated. This in turn allows the calculation of the total amount of energy available to the heat sink (building), and the financial cost of delivering that energy.

The carbon emissions arising from the use of the heat pump are also calculated to allow the environmental benefit of using the heat pump to be assessed.

Where appropriate, the estimated performance of the heat pump can be compared with alternative fuels by entering the cost and carbon emissions per kilowatt hour for the selected alternatives. This facility may also be used to compare the use of a heat pump to existing heating systems.

On the following page of the second tab of the spreadsheet, annual figures are estimated. These are based on the assumption that the figures entered on the first page refer to a typical winter day, and that consumption on a typical winter day will be twice that of the year round average consumption. This is however only intended to give a very crude estimate of a years consumption, provided to give an 'order of magnitude' idea of likely performance. These results should not be used to prepare budgets or calculate operating costs.

When comparing different heating systems, it should be kept in mind that those with well chosen emitters of heat (compact finned pipe radiators, under floor heating etc), will deliver additional benefits because the emitters will be close to the congregation. This proximity matters just as much as the amount of heat emitted.

10 - Some Design Constraints and Sizing of the Heat Pump

The demand for spring water on the site will be highest in winter, so the availability of spring water should generally map well onto the demand.

In the case of this building it is know from the prior use of the electric heating that the input of several kW of heat in winter makes it more comfortable, but does not bring it up to a normal room temperature (of 20°C or so). There is however no aspiration to heat the building to this extent.

The amount of heat that can be delivered to the church depends on

> the supply of water from the well (volume and temperature),
>
> the performance of the heat exchanger that extracts heat from the spring water if a closed loop system is used,
>
> the temperature and size of the emitters in the church, and
>
> the amount that can be spent on electricity to run the heat pump.

For example, assuming that the heat pump achieves a COP of 5, a 5kW heat pump would draw 4kW of low grade heat from the environment, and would have an electrical power consumption of 1kW while in operation.

If this was left to run continuously, it would deliver

> 24 X 5 = 120 kWh of heat per day
>
> for the consumption of 24 kWh of electricity.

If electricity costs 10p per kWh, this would cost £2.40 per day using the heat pump, but would have cost £12 using resistive electric heaters.

The use of a larger heat pump would require more water which might preclude operation in dry winters, and while it would heat the church more, this would also increase the operating cost.

The emitters which might be used in the church include steel radiators, finned pipe heaters, trench heaters and under floor heating, see sample manufacturers documentation enclosed with this report. Radiators dissipate little heat at the low operating temperatures which are necessary for efficient heat pump operation, and this will also limit the use of finned tube and trench heaters.

Given that best heat pump efficiency and lower operating cost will be achieved by the use of under floor heating, this might be considered in the parts of the church where the floor needs replacing under the pews.

While this is a limited area offering the opportunity to deliver about 6kW of heat to the building with a floor temperature of 35°C, it heats the congregation directly, and should not generate strong plumes of hot air which will quickly rise to the roof of the building. Unless it is decided to add some additional emitters, the heat pump should be sized to match the area of floor which can be used to provide under floor heating. See Appendix 3.

11 - Off The Shelf Heat Pump Options

A number of manufacturers have water source heat pumps available, but many of these are open loop designs where care must be taken to ensure that the spring water available is compatible with the machines considered.

Few machines appear to be marketed for specifically for closed loop water source applications, but machines intended for ground source operation may generally be operated in this role, with the ground source heat exchanger immersed in a large body of still water, or a moving stream of water.

This heat exchanger has the disadvantage that the temperature of fluid available to the heat pump will be reduced. This in turn will reduce the COP. A benefit however, is that that a greater range of heat pumps may be available as the market for machines intended for ground source operation is much larger. These however are likely to require the use of a glycol based antifreeze in the pipes between the heat exchanger and the heat pump, if only to meet the requirements of the warranty. The heat exchanger should be used in a contraflow configuration (see Appendix 1) to minimise the temperature drop between the spring water and the water / antifreeze mixture circulating between the heat exchanger and heat pump.

Note that in translation, many foreign manufacturers refer to antifreeze as "brine". This is <u>not</u> a salt solution, see reference to chloride ion concentration below. Putting salt in a system will cause rapid corrosion and failure out of warranty. The material normally used as antifreeze is ethylene glycol (much the same as one of the antifreezes commonly used in car engines), though generally we prefer to use propylene glycol because of its much lower human toxicity. Such a substitution should be checked with the manufacturer of the equipment on a case by case basis.

Left, high surface area heat exchange coil. This offers superior performance compared to the heat exchangers generally fitted to domestic hot water cylinders, and could just as easily be installed in a length of pipe through which a stream of water flows, to make a contraflow heat exchanger.

Pipe of this type has a cost of roughly £19 per metre.

Water Quality and Flood Issues

If an open loop system is used, the mineral content, chloride ion concentration, and pH of the spring water should be checked by analysis to ensure compatibility with the manufacturers specifications. If the necessary water quality requirement cannot be met directly by the spring water, an intermediate heat exchanger might be used between the spring water and the heat pump. Topologically, a closed loop system would be created.

For a closed loop system, the heat exchanger material must not be corroded in the ground or water course. In ground source systems heat is collected from a very large volume of soil through a very large surface area of heat exchange pipe, and black plastic MDPE pipe is commonly used. In closed loop water source systems the heat exchanger is more compact, and a high surface area of metal pipe is generally used to form the heat exchanger. This needs to be mechanically robust enough to tolerate peak water flows, and if mounted in a stream or river, must be able to withstand the impacts of any rocks or boulders washed down-stream in flood conditions.

Electrical Issues

As a general rule, heat pumps with a single compressor and heat outputs larger than 10 to 15kW require a three phase electrical supply. Although the electrical requirements of a heat pump may be relatively modest while it is running, the 'switch on surge' current may impose severe stress on electrical systems.

As an example, one small single phase heat pump with only 1.2kW thermal output, that draws a current of 1.66 amps when running, draws a switch on surge current of over 90 amps for less than a second as it is switched on. As most domestic electrical supplies are fused at 60 or 100 amps single phase, larger machines require the use of either three phase power supplies or 'soft start' technologies.

Soft start technologies include mechanical, refrigerant bypass, and electrical techniques. One of the most beneficial is electronic inverter drive which also allows variation in the speed of the heat pump motor. This offers the possibility of continuously modulated operation with variable heat output from a heat pump, rather than controlling energy output by simply switching the machine on and off to give a variable duty cycle of operation. Where multiple heat pump compressors are installed, it is normal practice to start them a few seconds apart to reduce the peak current requirement, but on this site, the use of more than one compressor is unlikely to be necessary.

Before installing a large heat pump system, it is advisable to contact the local electricity District Network Operator (DNO) to ensure that the local electricity distribution system can withstand the peak load associated with the starting of the heat pump. It is most unlikely that any difficulty would be caused by a small machine used to heat the church, especially if a three phase machine is used.

For a building such as the church which has a three phase supply, a three phase heat pump should be used if there is a choice. Three phase motors tend to be slightly more efficient than single phase and do not require capacitors to start and run. This simplifies the design and is 'one less thing to go wrong'.

While a modern heat pump with soft start systems ought to pose no challenge when grid connected, it should be noted that it is unlikely to be able to start if linked to grid isolated micro-generation equipment. While for example a small hydro system might easily be able to provide the 1kW of electricity required to run a heat pump with 5kW thermal output, it would be unlikely to be able to deliver the starting current without tripping protection devices. Further, matching the two would be difficult if the generator and load had different numbers of phases.

The simplest way to deal with these problems is to connect both systems to the grid. This allows the income generating export of excess energy, allowing all of the energy generated to be used productively. It also permits the import of any electricity shortfall.

Other System Design Issues

For larger systems it may be necessary to use more than one heat pump. Even where it is not necessary to use more than one heat pump, some designers and users of systems may choose to do this in order to reduce the number of 'single points of failure' in a system. Two smaller heat pumps may cost more than one larger unit with the same total power however, and the system controls will also be more complex as they will need to include load sharing and sequencing capabilities to ensure equal use of all the installed pumps. In an application such as this, in a non residential building where alternatives such as propane heaters are available in an emergency, it is suggested that a single heat pump is used to keep the system simple and minimise cost.

Given that it is desirable to dissipate the maximum amount of heat into the church as cheaply as possible, it seems appropriate to use a heat pump to power wet underfloor heating if aesthetic and conservation constraints permit.

The use of radiators seems undesirable because they would need to be large and highly visible to work adequately at low temperatures, and much of the heat they release would rise directly to the top of the building. Trench heaters (finned pipes recessed into the floor) would give rise to limited air movement, and not be very effective at low temperatures. Finned pipe radiators under pews would have limited effects at low temperatures, and if accidentally kicked would become damaged over time and might leak. Fan assisted radiators may be thermally effective in these situations, but might be too noisy to use in services, too big to fit under the pews, and would not heat the users of the building directly.

There is some risk that in dry years it will not be possible to heat the building for as many months as might be desired over winter. In general it is possible to make heating systems that use a heat pump and another type of boiler, for example a propane gas unit with balanced flue, though the energy cost of using this would be higher than a heat pump. Note though that condensing gas boilers may work more efficiently than usual at the low system temperatures associated with underfloor heating. This is because the exceptionally low return temperatures found in systems based around under floor heating (UFH) for heat pumps, may facilitate more efficient condensing of water in the combustion gasses. If this is of interest, it might be discussed with any proposed suppliers if a gas boiler is considered further, but for the time being it will be assumed that there will be no backup from a permanently installed propane heater.

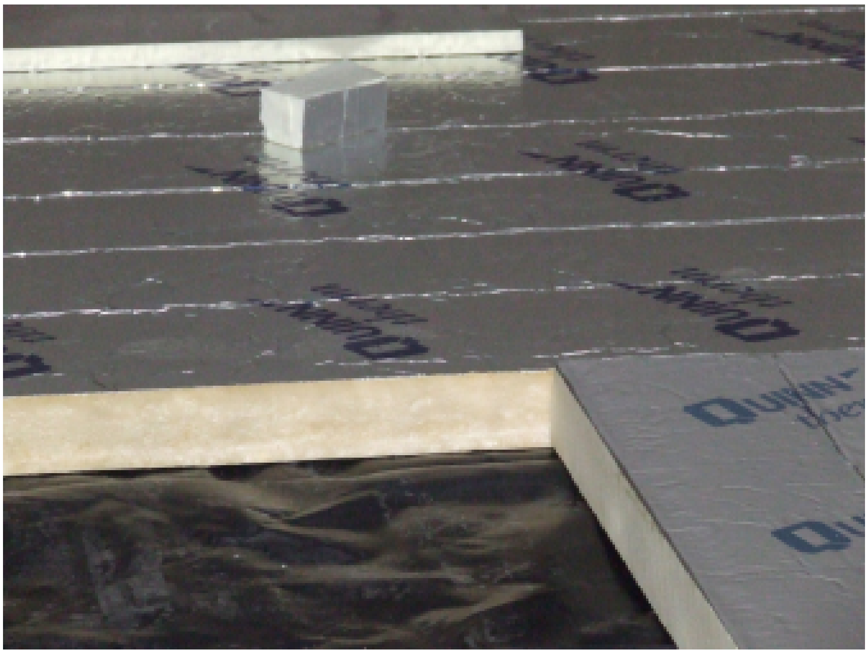
When a heating system uses radiators and a heat pump, the efficiency of the heat pump depends critically on the radiators operating at the lowest possible temperature, but the heat emitted by the radiator depends critically on temperature.

Where high temperature boilers are used to heat water for underfloor heating systems, it is common practice to use a three port thermostatic mixing valve and a circulating pump to deliver large flows of water at a constant but lower temperature. While the large flow rate is always desirable to help achieve a uniform temperature distribution over the whole floor area, where heat pumps are used to power UFH, the regulation of temperature by dilution with water from the UFH return is undesirable as it is predicated on the assumption that the heat source produces water at a higher temperature than is required in the floor that it is heating.

Where a heat pump is used, greater system efficiency is achieved with a good flow rate through the under floor heating, but without restricting the temperature with a three port mixing valve. Further, it may be desirable to install the under floor heating pipes closer together than normal when heat pumps are used, perhaps on 150mm to 200mm centres rather than 300mm centres. The floor may then be heated with water at a slightly lower temperature. This gives the same heat output, a more uniform floor slab temperature, and allows better heat pump efficiency to be achieved.

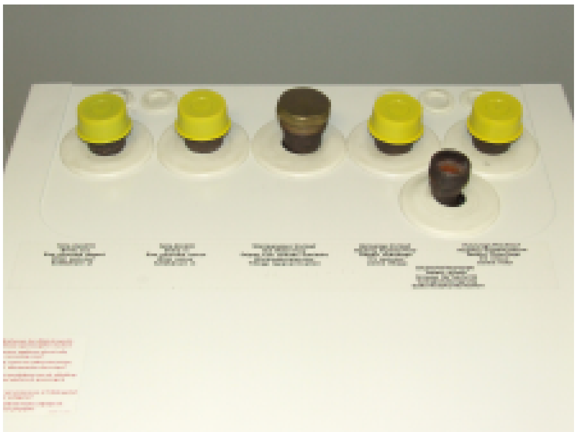
Note that in some buildings the demand for heat may be significantly less than the maximum output of the heat pump, a buffer tank (heat store) may be required to add thermal capacity to the heat distribution system to avoid frequent switching of the heat pump. The use of such a heat store can be avoided, reducing the cost, complexity and space required for equipment, by heating all of the available floor slab whenever the system is switched on.

As an example, let us now consider a heat pump with a water inlet temperature of 8°C, driving either under floor heating at 35°C, or radiators at 55°C. An inlet temperature of 8°C has been selected because the water / antifreeze mixture from the source heat exchanger can never reach the temperature of the surrounding spring water, but with good heat exchanger design, it should be able to get within a small number of degrees of the available 10°C spring water.



Above, regulations require the installation of a damp proof membrane and thick insulation beneath under floor heating. This should be installed to prevent the loss of heat to the ground under the church.

Below, insulation with underfloor heating pipe on 150m centres, stapled on to it prior to pouring the concrete screed to form the floor. The pipes were spaced for use with a heat pump.



A typical Stiebel Eltron heat pump.

Above left, the plumbing connections, back row from left to right, heat source water out, heat source water in, hot water flow to DHW cylinder or calorifier, space heating flow, and the return which is shared between space and water heating. The pipe to the front is connected to internal safety devices. Right, internal electrical connections and control electronics.

Below left, the casing as seen from the outside. Right, inside the unit, the compressor module (large black cylinder) on vibration reducing mounts, insulated pipes, and soundproofing foam.

Example - The Use of a Stiebel Eltron WPF 5 Heat Pump

The WPF 5 heat pump is an established member of the Stiebel Eltron heat pump product range, which can be used in ground source or closed loop water source applications. It is the smallest model, the others including the WPF 7, WPF 10 and WPF 13. All are available as three phase machines, and the WPF 5, WPF 7 and WPF 10 have single phase versions. These all have the same external appearance, similar to the housing displayed on the previous page, but the compressor module is larger and heavier in the more powerful units.

The 8°C To 35°C Case

From the manufacturers data, the WPF 5 machine will achieve a COP of 5.25 when operated with an inlet temperature of 8°C and an outlet temperature of 35°C. It will deliver an output of 7 kW for an electrical input of 1.33 kW, and require 1.5 m^3 of water / antifreeze mixture per hour. If electricity costs 10p per kWh, this suggests an electricity cost of about 1.9p per kWh of heat delivered, or 13.3p per hour, or £3.19 per day of continuous operation.

The 8°C To 60°C Case

From the manufacturers data, the WPF 5 machine will achieve a COP of 2.6 when operated with an inlet temperature of 8°C and an outlet temperature of 60°C. It will deliver an output of 6.33 kW for an electrical input of 2.45 kW, and require 1.5 m^3 of water / antifreeze mixture per hour. If electricity costs 10p per kWh, this suggests an electricity cost of about 3.85p per kWh of heat delivered, or 24.4p per hour, or £5.86 per day of continuous operation.

This indicates that the cost of heating the church using a heat pump and radiators is likely to be nearly twice as much as using the heat pump to heat under floor heating.

Comparison With Existing Heat Sources

Because the use of the existing propane and butane heaters causes damage to the fabric of the church, their use must be seen as a failed experiment. In the long run, some form of dry heating must be used. If restored to use, at 10p per kWh, the continuous operation of 7kW of electric heaters would cost £16.80 per day, though this might be reduced if an optimal tariff was chosen for this load.

Indicative Price of Heat Pump System with Under Floor Heating

The following are indicative prices for the main elements of the system.

The end user price of the WPF 5 heat pump:	£4,681
Cost of underfloor heating (see Appendix 3): (Assumes ground is prepared by the community.)	£6,325
Estimated cost of water source heat exchanger and 2 X 200m of MDPE pipe to reach it: (Assumes ground works carried out by the community.)	£1,250
Electrical isolating switches, cable and connection: (Subject to inspection by an electrician.)	£500
Estimated Total ex VAT:	**£12,756**

Note that if the two pipes to the water source heat exchanger are run in the same trench, one of the pipes will need to be insulated, and provision will need to be made to prevent the insulation from being crushed by the surrounding soil. Assuming a WPF 5 is run during the six month winter heating season (mid October to mid April), into an underfloor heating system, for 18 hours per day, it will deliver about 23,000 kWh of heat per year, about 125 kWh per day of the heating season. This comfortably exceeds the winter daily energy consumption estimates in section 4, and the energy should be directed to where the congregation sit.

CSEP Heat Pump Benchmark

For the purposes of Community Sustainable Energy Programme, this must be benchmarked in pounds per tonne of carbon dioxide emissions avoided.

This will not give a realistic figure for this heat pump because we are required to assume a COP of 3.2 which is lower than anticipated for this heat pump under these conditions, an emissions factor of 0.43 kg CO_2e per kWh of electricity which is out of date (too low), and no account is taken of how effectively the heat is delivered. None the less, it offers a standard way to assess the cost of avoiding future carbon dioxide emissions by the use of a heat pump, as opposed to some other sort of heating.

Using this COP, it will be assumed that 7,188 kWh of electricity must be used to generate the 23,000 kWh per year of heat.

Using the CSEP benchmark calculation for heat pumps against resistive electric heating, over the anticipated twenty year life of a heat pump, this indicates a pounds per tonne of carbon dioxide figure of

(£12,756 X 1000) / ((23,000 kWh X 0.43 - 7188 kWh X 0.43) X 20)
= £93.81 per tonne of carbon dioxide, against a BRE bench mark figure of £180.

As this is significantly lower than the BRE benchmark, it is acceptable.

12 - Hydro Generation Issues and Possible Way Forward

For general information about hydro power in the Peak District National Park, see the following report to which T4 made significant contributions.

http://www.friendsofthepeak.org.uk/download/files/HYDRO/PEAKPOWERMainreportAppA.pdf

Attempts to develop a hydro scheme on this site date back some decades. It is understood that the project reached the point where a leat was dug, and equipment delivered to site. The system was never installed however, and the equipment was later claimed for the war effort. More recent efforts to develop a scheme are detailed on page 42 of the above report.

Above, the leat which runs parallel to the footpath on the south side of the river to the west of the bridge. This is now silted up and overgrown, but the community has expressed an interest in using it.

In recent years the community has investigated a system offered by Derwent Hydro, but it is understood that this was rejected by the National Trust on the grounds that a turbine house (little more than a shed), would have needed to be located adjacent to the river to house equipment.

While it is understood from the work undertaken by Derwent Hydro, that the site might deliver in excess of 8 kW, the CPRE / Friends of the Peak District report identifies "Significant constraints - cultural heritage and river environment". This is consistent with the experience of the community while attempting to explore hydro power project options.

A particular problem with this site is the very low head available. There are two weirs in the vicinity of the site, both west of the bridge, but neither is high, and they are over 150m apart.

The Community have suggested that a new leat, culvert or pipe might be dug to 'cut the corner' from west of the top weir to below the bridge, but it is not clear if this would work well because of its great length, or be acceptable to other stakeholders including the Environment Agency.

Given the range of stakeholders involved in any hydro project decision making process, it seems unlikely that a major project will come to fruition quickly, and superficially an impasse appears to have been reached.

Given however that the aim of the project is primarily to provide energy to heat the church, and the amount of energy required is small, the community might wish to consider the use of a very low head Archimedean screw turbine which might look rather like the system shown below.

Above, the east of the two weirs, though this has been restored increasing the height since this photograph was taken. Below, the west of the two weirs.

This is still not free of visual impact, and might require some change of level along the bank-top adjacent to the weir, but until detailed design work is done, it is unclear how far this type of system can be optimised for this site.

The information about Archimedean screw turbine was provided by Mann Power Hydro. If the community is still interested in exploring options for hydro power, it is suggested that Dave Mann be invited to visit the site to discuss the minimum visual impact options. These might then be discussed with the National Trust and other stakeholders.

Mann Power hydro has tested this turbine with a range of fish, and independent experts have confirmed that they do them little or no damage. More details are available from Mann Power Hydro. While this design clearly addresses some environmental concerns, the Noise from a hydro system should also be considered when evaluating environmental and aesthetic aspects.

Archimedean Screw Indicative Costing

Mann Power Hydro indicate that the screw, gearing, generator and break for their systems normally cost around 3,000 per kW for 20 kW systems and above.

This relationship breaks down for small systems however, for which they cite the following indicative prices,

10 kW	£40,000
8 kW	£40,000
5 kW	£33,000
3 kW	£27,000
1.5 kW	£23,000.

As a rule of thumb, Mann Power Hydro suggest that an installed system typically costs three times the cost of the components identified above, so an 8 kW system would typically cost around £120,000 and a 3 kW system would cost around £69,000. Given that the community might undertake some of the work, and the proximity of a connection to the national grid, this estimate may be on the high side however.

A Note re Mechanical Coupling of Hydro to Heat Pumps

It has been asked by the Community if might be possible to drive a heat pump directly from the mechanical output of a hydro system.

Discussions with heat pump engineers indicate that while it is mechanically possible, the environmental benefits will be confounded by the release of refrigerant gases which may be toxic, deplete stratospheric ozone, and / or contribute to climate change.

An electric refrigerant compressor uses conductors with static seals to convey electricity to a motor located within the compressor housing. Such an arrangement can withstand considerable pressure and vibration. A mechanically driven pump however, must have a seal around a rotating shaft which is much more prone to leak, especially as the seal become worn. (Note that for example, that belt driven car air conditioning needs to be topped up periodically. By contrast, electric fridges are sealed for life.) This seal reduces the pressures which can be used internally, and I understand it is this constraint which makes mechanically driven heat pumps less efficient than electrical ones, even if the environmental impact of refrigerant leaks is set aside.

It has further been suggested that a sealed compressor might be driven hydraulically from an external energy source such as a hydro system, the hydraulic pipes being welded as they pass through the outer envelope of the compressor to avoid the need for a rotating seal.

This is interesting because Mann Power hydro have looked at the hydraulic coupling of screw turbines to generators.

While this might address the need to avoid a rotating seal in the compressor envelope, the seals of both the hydraulic motor and refrigerant compressor will have to be enclosed inside the same housing if they are to be coupled by the same mechanical shaft. As the internal refrigerant and hydraulic seals become worn, it is thus likely that refrigerant would escape by dissolving into the compressor oil, then escape via the hydraulic system. This then, seems unlikely to offer a route to a practical and efficient leak free mechanically driven heat pump.

13 - Project Concept and Design Information

Overall Project Concept and Establishing Need

The project seeks to conserve the heritage value of the church and increase its value to the local and wider community by sustainable means.

In practice this has come to mean reducing operating costs at Holy Cross Church Ilam, by seeking to reduce their energy requirements, and using natural sources of sustainable energy in the vicinity of the church. The Community understands that this will contribute to reducing national dependence on imported fuels, and reduce carbon emissions.

The existing electric heating system is failing, and is prohibitively expensive to operate. This adversely affects levels of comfort for users of the building, and precludes many community activities in winter, sometimes including worship.

The use of unflued propane and butane heaters in the church has already caused damage to the fabric of this listed historic building, and must cease to avoid further harm.

Energy Efficiency and Energy Performance

It is not anticipated that it will be possible to reduce heat loss from the building by a large percentage. None the less, reducing drafts and adding some secondary glazing might be achieved without compromising the character of the building.

Outcomes

The project will have succeeded if the operating costs of the building are reduced, allowing improved levels of comfort and community use, and halting further damage to the fabric of the building.

Options Appraisal

Energy saving measures and renewable energy technologies have been considered in sections 2 to 7, and the suggested energy conservation measures should be investigated. Of the sustainable energy options, only the heat pump has insignificant impact on visual amenity, and this has examined in more detail.

It may also be possible to develop a hydro scheme near the church, though stakeholders have yet to reach agreement about the size of the scheme, and the extent to which any loss of amenity and change of character of the site might be acceptable.

Energy Yield and Value for Money

Energy yield and carbon savings for the proposed heat pump system are discussed in section 11, and indicate an energy yield of close to 23,000 kWh per year, with a CSEP benchmark carbon reduction price of £93.81 per tonne of carbon dioxide.

Project Management and Project Team

The project would be managed by the Holy Cross Church community, and other stakeholders form the village of Ilam and the surrounding area.

Community Involvement, Public Profile and Promotion

The community in Ilam has been involved in a number of environmental initiatives over the last few years. The hydro project was part of the Ilam Community Initiative agenda, and has very broad support in the community. So did the light bulb change project which had national press and television publicity. Since then, follow up projects have tended to support individual needs, though many ideas are impossible to develop in the Peak Park, in listed buildings, or in a conservation area. This has caused significant frustration. A shared project which can be undertaken in such a locale would help to refresh the enthusiasm of the Community. There is some feeling that something concrete needs to be achieved to maintain enthusiasm, now that the awareness of the Community has been raised.

The Community aims to promote their projects using local media such as the parish magazine and local press, as well as the wider media, and also to involve visitors to the church and estate. There is also an Ilam web site which would very likely be used to disseminate information about the hardware and performance of the project. This might incorporate real time performance displays which might be inappropriate in a historic church.

Given their track record, I anticipate that publicity would be forthcoming if it is possible to bring this project to fruition.

The local community is involved through the Ilam Community Initiative (original umbrella organisation), the Church, School, National Trust, and YHA. All these are interconnected by their memberships. In a small community such as this, most people assume more than one role.

The National Trust will be involved as they own the land surrounding the church, and the community had some support from Local Government in the early stages of the project. The Lichfield Diocesan Advisory Council are involved, and in some degree act as 'gatekeeper' as well as adviser on behalf of the church.

Project Longevity and Sustainability

Both heat pump and hydro systems should last twenty years or more. The heat pump should offer the community reduced heating costs over that period, which would contribute to the viability of the church and community. The Community might also be able to receive payments under the Renewable Heat Incentive (RHI) as of April 2011.

Should a hydro scheme also be developed, the project would produce a net energy surplus, and would generate income for the Community from the Feed In Tariff and energy sales. Any financial surplus could be used to build a contingency fund for the replacement of equipment, the dissemination of information, or other Community activities.

The project has environmental, social and financial benefits - 'triple bottom line' benefits.

Building Integration

Integration of renewable energy systems into a historic listed church building would be deemed inappropriate by many stakeholders.

While the community intends to make it known how energy is conserved and the building is heated, these measures must not conflict with the character of the building and its surroundings. As far possible, there should be a clear demarcation between original features and recently installed equipment, and recently installed equipment should not impose visually.

The project should be undertaken in such a way that any new equipment can be installed and removed, without damage or change to the original structure, features, fixtures and fittings of the building.

Structural Design

If the heat pump is installed in the cellar, and the use of a buffer tank can be avoided, these are unlikely to have any impact on the structure of the building. If underfloor heating is installed over the roof of the cellar however, a structural engineer should ensure that the cellar roof is in good condition, that the bricks and mortar are sound, and re the under-floor heating, that the necessary thickness of concrete and any necessary re-enforcing is used.

Electrical Design

The heat pump should be connected via a D type breaker to avoid tripping on start up, and an isolating switch should be installed in the power supply cable to allow isolation at the site of the machine, as well as at the three phase consumer unit.

As the size of any hydro scheme that may be developed cannot be known at this time, detailed design is not possible, but if this exceeds 16 amps per phase (approximately 10.8 kW), G59 protection relays will be required unless the District Network Operator agrees that G83 is adequate for the agreed maximum power output.

Electrical earthing in the building may need to be upgraded in accordance with current wiring regulations.

Legal issues

The Community understands the regulatory and stakeholder constraints within which it operates. It aims to work with the Church, local and national government agencies, and the institutional stakeholders on the estate, to reach an outcome where a reasonable compromise can be reached between the sustainable development of the Community, and the conservation of heritage.

Uncertainties

Some uncertainty remains about the water source heat exchanger. The detailed design of this element can only be undertaken when it is clear where the unit will be installed, and what shape this culvert or chamber be. For the time being, a contingency sum has been included which it is anticipated will cover this cost.

Details of the under floor heating design may not be finalised until the pews and flooring have been removed, and the ducts to the cellar and cellar vaulting examined. This should include checks to ensure that the bricks and mortar are in adequate condition. (A few bricks have already fallen out of the cellar roof.) A structural engineer may need to be consulted to establish that the cellar roof can withstand the weight of the under floor heating system.

The temperature of the spring water and the ground at a depth of at least a metre should be monitored during this process, logging temperature over a period of time. T4 would be pleased to discuss a range of very low cost temperature data logging options.

As climate changes and demand for water increases, changes to the level of the water table may occur, either due to reduced rainfall (climate change), or abstraction at other locations.

Other stakeholders may object to the interception of the water flow between Coffin and Wishing Wells.

Stakeholder consultation will be required before covering any archaeology under the pews with insulation and screed. Subsequent action may then be required to document or excavate any finds prior to continuing the project.

14 - What Next ? Summary of Recommendations

If this has not been done already, a list of significant stakeholders and consultees should be drawn up so that all relevant bodies that should be involved in the decision making process are identified and approached.

The energy conservation work should be costed and undertaken by the community once stakeholders in the building have been consulted.

Some of the uncertainties listed in Section 13 can only be resolved by starting to look under the floor that pews are mounted on. As the floor is rotting in places it may be difficult to restore to its current condition once it has been taken up. The condition of this floor, and what is under it needs to be known as soon as possible however, so that detailed design of under floor or trench heating can be undertaken, and the locations of the ducts which might be used to run pipes discovered. It would be prudent and interesting to photograph and document whatever structures are found.

The hydrology of the site might be investigated further. In particular it would be useful to know where the flow from the Hall runs. It would be unfortunate if for example it entered Coffin Well, and could thus carry melt water from snow to the heat pump. The National Trust should be consulted to see where this runs, and this should be verified with drain dye. Further dye has been left with the community to facilitate more experiments.

Should an insurmountable problem be discovered with the heat pump project, a 'Plan B' might be the heating of the church with flued radiant propane heaters, but the running cost of this solution would have to be checked carefully to ensure that it can meet the needs of the community. The heat pump based system should deliver heat more efficiently and cheaply however, and offers the possibility of being powered entirely from renewable electricity, either from local micro-hydro generation, or purchased though the grid.

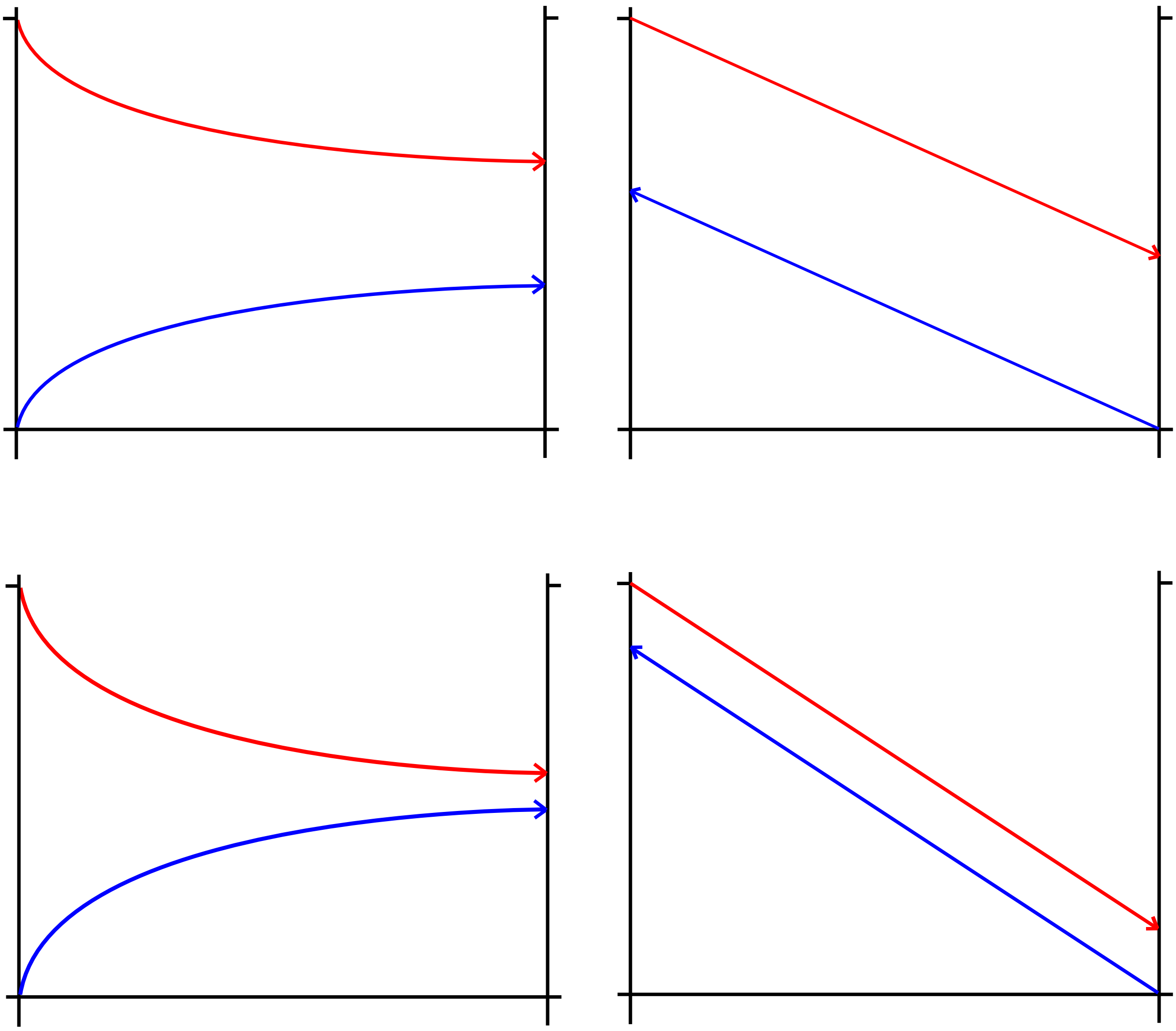
Opinion should be sought from a hydro engineer to identify the quietest and least visually intrusive Archimedean screw turbine design, and if this appears to be economical in the long term, this should be discussed with relevant stakeholders to see if the project might be taken forward.

Appendix 1 - Contraflow Heat Exchange

In a 'contraflow' configuration, the fluids between which heat is being transferred pass in opposing directions. This is much more efficient, as the heated fluid leaving the heat exchanger can attain a temperature very nearly as high as heating fluid where it enters the heat exchanger.

The graphs below indicate the relative performance of better (bottom row), and worse (top row) heat exchangers, used in parallel flow (left column), and contraflow (right column) configurations. The y axis indicates temperature, and the x axis indicates location within the heat exchanger. The arrows on the lines indicate the direction of fluid flow.

While it is important to use a good quality and adequately sized heat exchanger, parallel flow, (both fluids passing the same way), will greatly limit the performance that can be attained.



Appendix 2 - Drain Dye Safety Data Sheet

HOROBIN™

Midacre, Willenhall Trading Estate,
Willenhall WV13 2JW, UK
Telephone: +44 1902 60 40 60
Fax Number: +44 1902 60 33 66
Email: sales@horobin.co.uk
Web Site: www.horobin.co.uk

TECHNICAL INFORMATION
HEALTH & SAFETY INFORMATION
DRAIN TRACING DYE

DESCRIPTION	A water-soluble dye for use in the detection of leaks from drains/sewers etc

COLOURS AVAILABLE	RED, GREEN, BLUE, YELLOW, VIOLET, ORANGE

COMPOSITION	12.5% FOOD COLOUR 87.5% DEXTRENE [BULK FILLER]

PHYSICAL & CHEMICAL PROPERTIES

APPEARANCE	An odorless, free flowing powder, packed in 200 gms & 100 gms plastic jars

HEALTH & HAZARDS

TOXICITY	This product is not considered to present any significant hazard in normal use.
SKIN IRRITATION	NONE
EYE IRRITATION	NONE

FIRE HAZARDS

FLASH POINT	N/A
IGNITION TEMPERATURE	N/A
EXTINGUISHING MEDIA	CO2, water mist, foam
SPECIAL FIRE PRECAUTIONS	This powder will not ignite easily in bulk, but may burn or smolder and may evolve flammable or noxious fumes if involved in a fire.

SPECIAL FIRE & EXPLOSION PRECAUTION	In common with other powdered organic products including the vast majority of Dyestuffs, this product can form dust clouds in air which could be spontaneously explosive.

STORAGE PRECAUTIONS

SPECIAL PRECAUITONS	NONE
PROTECTIVE MEASURES	If the dust is a problem, wear dust masks and gloves
SPILLAGE	Sweep up the bulk(without creating dust)and dispose of safely, swill down the site spillage with water
DISPOSAL	Subject to local regulations, bury in an approved land fill site or burn under carefully controlled condition.

TRANSPORT PRECAUTIONS

SPECIAL PRECAUITONS	None Not restricted by road, rail, air or sea

HANDLING USE PRECAUITONS

GENERAL	Hazard due to casual contact is negligible and there is no reason to suppose that any abnormal toxic hazard arises from handling under normal conditions of use. However, good conditions of industrial hygiene and safe working practices should be observed, and as with all organic chemicals, exposure should be kept to a minimum by using appropriate protective clothing where dust is a problem. I.e. Dusk mask, rubber gloves.

FIRST AID PROCEDURES

SKIN	Wash with soap and water or propriety skin cleanser
EYES & EARS	Irrigate promptly with copious amounts of clean water, seek medical attention
INGESTION	Seek medical attention – symptomatic treatment

Appendix 3 - Outline Underfloor Heating Design

Assume three areas of underfloor heating, currently under pews, with areas of

9.2 X 2.55 m,
8.2 X 3.1 m, and
8.2 X 2.15 m.

This gives three heating pipe loops at 15cm spacing, of 16mm multi layer composite pipework (with oxygen barrier, 14mm internal diameter).

With heating pipe loops spiralling in and out, allowing 20m for tails to the location of the manifold, this gives rise to the following pipe lengths (including tails),

loop 1 142m,
loop 2 156m, and
loop 3 109m,

and will require the use of a three way manifold with flow adjusters to allow the balancing of the heat flow to each block of seating.

The heat pump should be switched on in response to low temperature or high relative humidity whenever heat source water is available. Floor temperature should be controlled by reducing the heat pump output temperature. There is no requirement for a three port mixing valve. The floor will run at lowest possible heat pump temperature.

Outline Bill of Quantities

Parts for underfloor heating:
Insulation 2.4m X 1.2m sheets, 24 sheets:
Estimated 8 man-days to install:
Dry Screed, 6 cubic metres £90 per cubic meter:
Estimated 2 man-days to lay screed:

Estimated total ex VAT cost: £6,325

Heat Output From Standard Tables

30°C mean water temperature and 18°C ambient: 4.2kW
40°C mean water temperature and 18°C ambient: 7.8kW

Notes

It is envisaged that the concrete screed of any under floor heating would be poured over insulation and a damp proof membrane. These would prevent the screed binding to the structure of the building, allowing the screed to be broken up and removed without causing damage to the pre-existing structure at the end of its life.

The thickness of the insulation under the screed will need to be determined once the pews have been removed, and may not be uniform.

Appendix 4 - Project Contacts

Holy Cross Church Community:

Main Contact:

Holy Cross Church,
c/o Mr. Robert White,
Paddock House,
Castern,
Ilam,
Ashbourne.
DE6 2BA

Phone: 01335 310344

Secretary:

Miss Ellen Clewes,
2 Orchard View,
Ilam,
Ashbourne.
DE6 2AZ

Phone: 01335 350437

T4 Sustainability Limited:

John Beardmore, Managing Director,
MSc EDM (Open), B.A. Chem (Oxon), CMIOSH, CEnv, MIEMA, MEI.

Paul Chandler, Development Director, MEng, MSc, PgCert, MIET.

Simon Townsend, Technical Director, BSc, HND.

T4 Sustainability Limited,
181 Belper Road,
Stanley Common,
Ilkeston,
Derbyshire.
DE7 6FT

Email:	info@T4sLtd.co.uk
Phone:	0845 4561332
Web site:	http://www.T4sLtd.co.uk
Company number:	04441097.
VAT number:	797 2239 85.
Data Protection Registration:	PZ8412476.

Microgeneration Certification Scheme number: ELC54087

Renewable Energy Assurance Listing number: 00015524