T4 Sustainability Ltd

Saint Mary's Community Centre:

Saint Matthew's House Low Carbon and Renewable Energy Technologies Feasibility Study

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Contents

N. B. All costs given in this document are indicative only, to allow early stage comparison of equipment, fuel costs and carbon emissions, with those from other heating plant. They do not constitute detailed costings for this scheme.

1 - Conclusion And Executive Summary

Priority should be given to the insulation of the building to minimise the demand for heat. This reduces the capital cost of the plant required, and the ongoing running costs.

Where it is possible to insulate the building externally, this should be the preferred approach, as it minimises the risk of damage to the building fabric arising from interstitial condensation. Where the use of external insulation is precluded by the listed status of the building, insulation might be applied internally, though this will be complicated by the need to preserve some features of aesthetic value. The floor in the basement should be insulated as well as possible, but it is understood that the thickness of insulation that might be applied is limited by the height of the existing door frames which should be conserved. Spaces between ceilings and the roof should be insulated as well as possible, the choice of insulation being determined by the thickness of insulation it is possible to apply, the cost, and the embedded carbon in the product. Natural insulating products which hold carbon of non-fossil origin should be preferred where space allows the delivery of good U values. Oil-based products with high embedded energy and carbon should be avoided, except where they are necessary to achieve good U values in confined spaces.

In those parts of the building where it is practical, the use of heat recovery ventilation should be considered to further reduce energy consumption.

Windows might be insulated with secondary glazing, but for best aesthetic and thermal effect, bespoke internal frames would be required, assembled by a joiner. These should accommodate double glazing units, in effect triple glazing the windows, while conserving and continuing to use the existing frames and glass.

Having minimised the requirement for heat, a source of space heating should be chosen which is practical, and offers low carbon emissions, and low cost operation. Discussions with the client suggest that simple convector radiators are the preferred choice of heat emitter.

Connection to the district heating system would offer the most compact and simplest plant within the building, but at £70,000 for connection to the system, this is unlikely to be cost effective. The amount of heat that might be available in future may at some point be limited by waste and recycling policies, and the environmental ethical credentials of this option might be questioned, so we suggest this option not be pursued.

A gas boiler would offer the lowest capital cost with only moderate space taken up by plant, but the ongoing use of gas appears to make this an expensive long term option. All energy prices will rise in future, but gas may be at more risk than other energy sources, as in future, more of the gas used in the UK will be imported.
Heat pumps might be considered, but lack of space for heat collection, the need for a

large buffer tank, the cost of boreholes or noise from air source systems, and inefficiency when working with radiators all mitigate against this approach. If used with radiators, a heat pump might offer little carbon or energy cost advantage over natural gas.

Biomass wood pellet heating might be used. Although the necessary plant and fuel store uses a considerable amount of space, this is likely to offer the lowest long term operating costs. It may however, be prudent to fit a gas boiler as backup, so that in the event of a fault on the pellet burner, the gas system could operate automatically so that the building can continue to operate normally.

The space required for the biomass fuel store and plant should be considered with care, but our provisional conclusion is that this may offer the lowest cost and carbon emissions in the long term.

Domestic hot water demand is not expected to be large, and for low volume points of use, it may be acceptable to use point of use resistive electric heaters. We would prefer however, to get the maximum energy contribution from lower carbon sources, and have identified another option based on heating very small water cylinders using the space heating system where possible, perhaps with a solar contribution where this is justified by the demand.

A balance must be struck between the use of highly automated heating and ventilation controls which might save energy and reduce costs, and allowing users of the building the freedom to adjust their own heating and open windows. Although it is tempting to allow users freedom to make manual adjustments to local thermostatic radiator valves, users may turn radiators off during warm afternoons, preventing the warming of parts of the building the following morning. The use of optimising controls which run the heating in the early morning in response to both internal and external temperature might also save significant amounts of fuel if this approach is not thwarted by users turning off radiators. It is suggested that this be discussed further.

Fixed electrical equipment (lights, pumps and control systems), should be chosen to minimise energy use and carbon emissions. Policies should also be put in place to ensure that as far as possible, appliances are purchased with the best energy ratings, and users of the building employ low energy IT equipment and portable devices.

The use of renewable energy sources should be considered where these are practical, though opportunities are limited. There is no hydro resource on site. Wind is not likely to be practical because of limited resource and aerodynamic turbulence, as well as structural and aesthetic issues. The district heating system is expensive to connect to, and the use of waste to energy schemes presents ethical issues relating to disincentivising waste reduction. We are thus unable to recommend this option. Combined heat and power (CHP), has also been considered, but feedback from users of small systems is not encouraging, noise might also be an issue with some units, and the buildings do not have the year round demand for heat that is normally required to make investment in CHP attractive. Biomass CHP has also been considered, but small units are generally not very efficient, and capital costs are very high.

Without a central hot water store, and with limited demand, solar thermal is likely to be difficult to implement and offer poor returns, except perhaps in the cafe kitchen. Hot water demand in the kitchen may not be large if cold fill appliances such as dish washers are used. None the less, with frequent hand washing, and culinary use, it may be worth considering heating water electrically in a local cylinder, but preheating this cylinder using solar energy and biomass or gas heat sources when these are available. This way, the necessary temperature can be guaranteed, but the bulk of the energy used can be delivered from solar energy and lower carbon heat sources. All hot water heaters and cylinders should be selected taking account of the quality of the insulation used.

The government is in the process of reducing the Feed In Tariff rate for photovoltaic systems. Although this is still under review, it is likely that PV will continue to offer a useful rate of return, as the cost of PV systems continues to fall, and energy prices will continue to rise. The un-shaded roof area is likely to limit the size of the system that can usefully be installed.

Although the financial benefits of water use reduction measures and rain water harvesting are limited, and payback times are very long, there are environmental benefits to both, so we urge that these be considered if resources permit. As a rainwater harvesting system will almost certainly require a heavy tank to be installed, presumably at a low level in the building, any structural implications of this should be considered as soon as possible, especially if the tank is to be set into the foundations of the building.

2 - Aims and Objectives

T4 understands that in the process of refurbishing Saint Matthew's House, Saint Matthews PCC aims to create a community facility for artistic activities, including community pottery, art workshops, and art therapy. Spaces will also be provided for occupational therapy, meeting places and a cafe.

The objective is that the building should operate as sustainably as possible, though the concept of Sustainability is taken to have environmental, social and financial aspects, and therefore includes the use of lower carbon and zero carbon (LZC) technologies as part of a bigger picture. Some LZC technologies have already been included in the design.

For the purposes of this document, T4 regards all energy conservation and generation measures, use of the District Energy Network, and water reduction, reuse, and rainwater harvesting, as potential LZC technologies.

As the building is of unique character, and has Grade 2 listed status, it is important to implement measures which, as far as possible, are in keeping with the character and use of the building. A compromise must be struck between the operating cost of the building and conserving its character, and external stakeholders have a say in this, through planning and other consultation processes.

It is hoped that Saint Matthew's House and the adjoining church might share a heating system, and be considered a single unit for energy management purposes, but it is understood that the refurbishment work will largely involve Saint Matthew's House.

3 - Assessing The Space Heating Requirement

It is hoped that heating system will be able to heat both Church House and the church building. It has been estimated by others, and stated in the project brief, on the basis of the areas of the buildings (approximate areas 600m² Church House, and 500m² for the church building), that the space heating required for each building will be around 80kW peak. We have assumed that this would be adequate after the proposed energy efficiency and draught proofing works.

We understand that it is not anticipated that it will be necessary to heat both buildings simultaneously, so it is hoped to use a single plant room, capable of supplying up to 80kW of heat to either building.

The space heating plant might also contribute to domestic hot water heating in some parts of the building, though domestic hot water requirements are likely to be relatively small, except perhaps in the cafe kitchen.

4 - The LZC Option Hierarchy

In seeking to develop a sustainable building, it is important to identify the main issues that should be prioritized. One of these is the use of low greenhouse gas emissions technology.

This document deals with low and zero carbon aspects of the design, and these in turn should be examined to ensure that the effort and investment expended give best value to the community they will serve. In general, reductions in carbon emissions, while requiring some initial investment, will reduce running costs as well as wider environmental impacts.

Emissions will arise from both the construction materials used in the building, and the construction process. Information about the carbon 'embedded' in construction materials is not easy to obtain, but some manufacturers are now able to make this information available, and account should be taken of it when available, taking account of the anticipated life of the product as well as the emissions arising from its manufacture and disposal.

The construction process itself should be undertaken in as resource and carbon efficient a way as possible, and the environmental, energy and carbon management policies of contractors might be reviewed as part of the main and subcontractor selection processes.

The bulk of the emissions from the building however will arise from energy use during the life of the building. This can be minimised by the use of insulation, which not only reduces the amount of energy that must be used to heat the building, but also reduces the size and cost of the heating plant required.

Insulation and other measures that are disruptive or costly to retrofit, should be a particular priority when rebuilding or undertaking a major refurbishment, as should items which need to be built into or under the structure of the building.

As far as possible, low carbon technologies should be compared on the basis of life cycle carbon saving per life cycle cost where this information is made available.

Because of manufacturing and disposal processes, no technologies are truly zero carbon, though good quality life cycle data is seldom available.

Despite these limitations, we will offer what information we can, though as things stand, much is 'rules of thumb'. It is likely however, that the best returns will come from reducing the need for space heating by insulating the building as well as possible, by selecting low carbon economical space heating, by minimising the energy used by fixed electrical equipment such as lights, pumps and controls, by the selection of low energy / carbon appliances, and by the generation of all possible energy.

5 - Church House And Church Insulation

5.1 Insulation And Building Regulations - Existing Building

Insulation standards in properties of this age fall far below those currently required under Approved Document L2B (conservation of heat and power in existing buildings) of the Building Regulations. This requires that, if a significant proportion of a “thermal element” is “renovated” (i.e. a heat loss element such as a wall, floor or roof has a layer, e.g. the plaster replaced or added), the replacement should meet reasonably stringent thermal standards set down in Approved document L2B, unless particular circumstances apply.

The effect of insulation can be expressed as a U value. A U value is a measure of heat loss. It is expressed in W/m^2K, and shows the amount of heat lost in watts (W) per square metre of material (for example wall. Roof, glazing, and so on), when the temperature (K) is one degree lower outside. The lower the U Value, the better the insulation provided by the material, (or materials if more than one layer is present).

The current requirements for U values are set out below:

To meet the October 2010 Building Regulations, the following targets apply.

Windows and doors - Windows are required to achieve a U value of 1.8.

Solid Walls - Where solid walls are ‘renovated’, they are required to achieve a U value of 0.30. (The proposed 0.2 for the South gable wall exceeds this requirement significantly). Where no works are carried out to walls, there is no obligation to improve the u value.

Roof - Insulation at ceiling level should achieve 0.16, and insulation at rafter level should achieve 0.18.

Floors - ‘Renovated’ floors are required to achieve a U value of 0.25. (Floor U values are difficult to estimate, as the U value depends on the ratio of area to heat loss perimeter, but a figure of 1 to 2 is normal for an un-insulated floor).

These regulations should be exceeded wherever possible, as the cost of doing so, compared to just meeting the minimum amount required, could be marginal at the time of installation.

The architect has confirmed the following proposed U values except where noted:

Refurbished house:

Floors approx. 0.3
Front (W), rear (E) and church-side (N) walls (left untreated): 1.83
South gable: 0.20
Roof (horizontal surfaces): 0.13
Roof (sloping soffits): 0.27
Window secondary glazing: 2.5 (Estimated based on experience of similar buildings.)
Doors: 3.0 (Estimated based on experience of similar buildings.)

Extension:

Floors: 0.22
Walls: 0.18
Main roof: 0.16
Flat roof: 0.17
Windows: 1.6 (To comply with Regulations.)
Doors: 1.8

Church:

(U values for the church have not been stated. These have been estimated based on our experience of similar buildings.)

Walls approx. 1.8
Roof: approx. 2.0
Windows: approx. 5.0
Doors: approx. 3.0

During the site visit we expressed concern over the proposal to leave three external walls of the church house un-insulated.

From the point of view of running costs and carbon emissions, we do not believe it is tenable in the long term, to run the building with such high heat losses from a large proportion of the external wall area.

Section 5.5 comments on the financial benefits of insulating the building envelope.

Plainly there are considerations relating to the building's Grade 2 listing, but we of the opinion that insulated render (which is already proposed to the South gable) would have no dramatic effect on the aesthetics of the rear and north elevations. Nevertheless we understand that discussions with the Planners suggest that this would be considered beyond the pale, and that internal wall insulation is proposed.

External insulation is by far the best option where this is practicable, allowing the entire thermal mass of the property to be encapsulated in the insulated envelope of the building. This helps to stabilize temperature without cold bridges or condensation risks.

We suggest that internal insulation should be considered to the front elevation of the church house, where external cladding would not be appropriate. Special considerations apply to the internal insulation of external walls, with regard to the potential for interstitial condensation, i.e. the condensation of water behind newly applied insulation, on the old cold surface of the wall. This may cause damage to the building fabric, for example causing rot of the floor joists which rest against the wall on which condensation might occur. Research (Joseph Little, Breaking the Mould, Construction Ireland) indicates that membranes intended to prevent water vapour entering the lay-up of the wall are rarely fully vapour-tight, and may allow vapour into the cold interstices, where it can condense. Insulation manufacturers' condensation risk analyses will normally show that no problems will arise because of the presence of a vapour control layer (VCL). However this assumes that the VCL is 100% effective. This requires huge effort on the part of building operatives not usually highly trained in such fields. Only if you are certain of the builder's expertise in this area should very low U values be sought for internal wall insulation. For this reason a higher (worse) U value of approximately 0.5, still nearly 4 times as good as the un-insulated wall, may be considered to control the risk of condensation.

We have suggested that the U value of the sloping soffits should be improved to a Regulations-compliant 0.18 or better, achievable with approximately 125 - 150mm of polyurethane (Pu) foam board.

We raised the possibility of a relatively low cost well insulated floating floor in the basement.

We agreed to identify areas where insulation could be done at a later stage outside the main contract. This applies to external insulation to the North and East elevations, and to internal insulation to the front (W) elevation. It must be noted, however, that scaffolding would be more complex and costly if external insulation were retro-fitted after construction of the glazed connecting link.

5.2 Windows - Existing Building

We have assumed that complete replacement of windows will not be approved, and that secondary glazing will be permitted. However, instead of the normal single pane of secondary glazing in, say, an aluminium frame, we suggest joiner made secondary frames, with high-specification double glazing and draught-stripping, allowing the original windows effectively to remain aesthetic, while the secondary glazing units achieve a U value close to the Building Regulations requirement.

5.3 New-build Extension

While the proposed insulation values meet or exceed the Building Regulations, we would suggest that consideration be given to further improvement, at relatively low marginal cost, to U values for the roof, floors and windows. We would suggest reduction to approximately 0.1 to the roof, 0.15 to the floors and approximately 1.2 for windows.

5.4 Insulation Materials

We discussed the proposed use of Polyurethane to the south elevation and the sloping soffits, and accept that there is little in the way of sensibly priced or environmentally benign alternatives.

In terms of quilt insulation to apply to the loft areas, the cheapest would undoubtedly be mineral wool, but we would suggest that, in terms of embodied energy and the avoidance of potentially harmful fibres, that consideration be given to the use of Warmcel recycled newspaper, or recycled cotton, hemp or sheep's wool products. Of these, Warmcel and cotton are of plant origin, and may help to retain atmospheric carbon for the life of the building.

By contrast, the environmental footprint of producing sheep's wool insulation, with meat as a co-product is likely to be relatively large, and the product cannot be sourced locally. The development team may however, wish to consider the ethics of using insulation materials that are predicated on there being a meat industry.

5.5 Financial Benefits Of Insulating The Building Envelope

Indicative costs for insulation of South gable wall (approx. 99m^2): £110/m^2 (total £10,890)

Potential savings based on U value 1.83 before works and 0.2 after works, 14 hrs/day heating and average 12 degree internal/external temperature difference. Fuel cost (based on wood pellets) up to 6.59p/kWh: £646 per year.

Approximate pure payback at current fuel costs: 17 years.

Other elevations receiving either internal or external wall insulation may have a longer payback period due to the presence of openings and the need for removal and reinstatement of features and fittings.

6 - Fixed Electrical System And Controls

While the owners of the building may have little choice about the portable equipment that users bring to the building once it is constructed, good quality low energy fixtures and fittings should be specified when the building is under construction.

Daylight should make as big a contribution as possible to lighting within the building, but precautions should be taken to avoid unnecessary glare and overheating, particularly if parts of the building might be used as office space and excessive light levels might make VDU use difficult. Light pipes might be used to bring light to parts of the top floor of the extension which are not near to windows.

No incandescent lighting (including halogen lights) should be used in the refurbished building. Fluorescent and LED lighting are likely to offer the most cost effective options for general purpose lighting, of which the fluorescents are the more mature technology.

Fluorescent tubes come in various lengths and diameters. Vendors generally refer to tube diameter in eights of an inch, identifying one inch diameter tubes as T8, and the newer 5/8^{ths} inch tubes as T5.

Based on our experience in a number of buildings, and experiments undertaken with businesses, I would make the following observations.

In limited comparisons of T8 lights with high frequency electronic ballasts and T5 lighting, we have observed a 30% increase in light output per watt from the T5 tubes. While this is consistent with anecdotes from many sources, it should be noted that the Carbon Trust cite a range of efficiencies for both T8 and T5 lights, and these figures indicate that the best performing T8 lights have efficiencies that exceed the worst performing T5 systems. It should not be assumed then, that selecting T5 fluorescent lighting will automatically deliver better efficiency than installing T8 tubes. To ensure that investment in T5 lighting is more cost effective than T8 lighting, it is important that any T5 lighting should have stated lumens per watt efficiency, which is known to exceed the performance of alternative T8 equipment. Choose lighting then, on the basis of efficiency. It is likely that the best fluorescent option will use T5 tubes, and these will generally offer better returns than T8 units even though the initial capital cost is higher.

To date, our experience with LED lighting has been something of a disappointment. Although LED lighting has the potential for both long life and great efficiency, we have had disappointing experiences with both low cost mass market products, and high end bespoke equipment. In particular, reliability has been overstated.

Another issue of concern is the colour of the light produced by LEDs. Many white LED lights have very high colour temperatures (over 5000K), and we have known sites where these have been installed without the end users seeing them in advance.

After installation, the colour has come as something of a shock, but it is too late to change the installation, as what was promised has been delivered, allowing no redress. We suggest then, that any new lighting (but particularly LED lighting), be viewed prior to acceptance of quotation, to ensure that the end users will be happy with the aesthetic quality of the light. In our experience, end users have generally preferred LED lighting with colour temperatures of around 3800K.

Consideration might also be given to installing good quality sensors to dim or turn off lights when areas are unoccupied or daylight provides enough light. The type of controls required will depend on the lighting technology chosen, so the controls should be purchased as a package with the new lights if the lights are upgraded.

Note that much lighting efficiency can be lost to dirt on emitters, reflective surfaces and diffusers. Cleaning lighting every 6 to 12 months as part of scheduled maintenance would avoid a build up of dirt which would degrade performance over time.

In addition to lighting, the electricity used by thermal control and ventilation systems should be considered.

The efficiency of heat recovery must be evaluated with care, because if it's too low, nearly as much carbon dioxide may be released as a consequence of running fans, as is saved by reducing demand for space heating. There is particular risk of this in buildings that use low carbon space heating, at times when the temperature difference between inside and outside is small. Ventilation controls should be used, so that ventilation increases in response to need. Best performance might be achieved if it were possible to ventilate in response to humidity and the concentration of carbon dioxide and other 'indoor pollutants', though Building Regulations may prescribe a fixed number of air changes per hour.

Circulating pumps should also be chosen with care. Low energy types should be selected. Electronically commutated motors can offer significant energy savings, especially where the pump speed is varied according to the required heat load. The use of this technology need not depend on elaborate control systems such as building management systems. Some pumps are available which vary their speed in response to the heating return temperature, increasing the flow as the return temperature falls, but allowing the pump speed to fall, and energy to be saved, when there is less demand for heat.

7 - Biomass And Heat Pump Options

7.1 Biomass

Principles

The option considered here is to install a biomass (wood chip or wood pellet) boiler, in a boiler room with integral fuel store in the basement area below the proposed new-build rear extension. The boiler would heat both the refurbished house and the adjacent church.

Local Issues

The buildings are in a smoke control area, and to offer environmental benefit, the fuel must be locally sourced, and undergo a minimum of processing.

Equipment

In order to provide reassurance to PCC members who are concerned about the reliability and maintenance obligation for such equipment, feedback has been sought from existing wood pellet boiler users, and this is presented at the end of this section.

In addition, although the biomass boiler would be sized to provide the full peak heating load, a back up gas boiler system could be provided, which would automatically cut in case of shutdown for planned maintenance, or in an emergency.

For the purposes of this study we have based indicative costs on the Froling Turbomatic 85kW boiler, which can run on either wood chips or pellets. Econergy, one of the leading UK biomass boiler suppliers, write:

“The Fröling Turbomatic is a very robust fully automated biomass boiler offering high efficiencies and excellent emissions performance. The TMc includes auto-ignition, lamda control, self-cleaning heat exchanger and grate, automatic ash removal and weather compensated heating controls for up to 18 heating circuits. The fuel feed system is a rotating outfeeder or pellet auger screw. Optional SMS or remote PC control.”

Limitations

Boiler room size may dictate the type of fuel to be used, and the frequency of deliveries.

Existing drawings suggest that the maximum space available for boiler, accumulator (buffer) tank, and fuel store, is approximately 7m x 3m. For the Froling 85kW boiler approximately 3m x 4m of this space will be required for the boiler and plant room itself, leaving 3m x 3m for fuel storage.

The size of the boiler and accumulator, and the limited access available, would require that the system components be put in place and protected after demolition of the existing extension, and before construction of the new extension.

The photographs on the previous page give an idea of the size and appearance of a biomass system, a wood chip fuel store and boiler. The right hand side of the top left picture shows the pipe through which fuel may be blown into the store. The top right picture shows the fuel store, a fabric bag, and the pipe at the bottom that allows fuel to be withdrawn by an Archimedean screw. The picture bottom left shows the fuel feed pipe and motor that drives the screw. The bottom right photograph shows the final fuel feed, air blower, and boiler (orange).

Fuel

A critical consideration for users installing biomass systems is the degree of automation. Would the use of a biomass system leave behind the ‘switch on and go’ convenience of gas, and return the user to the days of coal fired boilers, with dedicated ‘janitorial’ staff ?

For this reason a log boiler is not proposed in this case, and consideration is given to wood pellets and wood chips as a fuel source.

Wood chips have the advantage of potential local supply, either from a specialist chip provider, or by bringing in a contract chipper to locally managed woodland.

Wood chips have a far higher moisture content, and thus a lower calorific value, than wood pellets, which are made from dried sawdust.

Typical moisture and energy contents and densities are:

> Wood pellets: 6 to 10% moisture content. Approx 650 kg/m^3.
> Approx 4,695 kWh/tonne.
>
> Wood chips: 25 to 30% moisture content. Approx 200 kg/m^3.
> Approx 3,000 kWh/tonne.

It is likely, in the light of the small size of the fuel store, that pellets will prove more feasible than chips.

Some suppliers are able to blow pellets or chips from a tanker into fuel stores, and the store can be designed for this. 'Blown-in' delivery is generally more flexible as a long pipeline can be used, potentially causing less road congestion than if a loader were required to empty a lorry by ‘top-loading’ the fuel store.

The small size of the proposed fuel store, in this case (potentially only 18m^3), may mean that tanker delivery is not available, with delivery in bulk bags being the alternative option. This would however involving manual handling of the bags.

If a fuel store of the volume suggested above were available (and the figure of 18m^3 makes no allowance for the fuel feed machinery within the store, or any air space), then using wood pellets, at approximately 650 kg/m^3 and 4,695 kWh/tonne, would provide space for 11.7 tonnes of pellets, providing a maximum energy store of around 55,000kWh.

Given that the fuel store cannot be allowed to empty, this would suggest refuelling every two to three months in the main space heating season.

If wood chips were used at 200 kg/m^3, and approximately 3,000 kWh/tonne, maximum storage would be 3.6 tonnes, or 10,800 kWh, with two to three weekly refuelling required in the main space heating season.

Specific negotiations with potential fuel suppliers would be required to establish realistic fuel supply intervals, but it is clear that a ‘buffer’ of several days’ supply is prudent, since times of peak load may coincide with icy weather conditions which could make delivery impossible.

Local suppliers are generally reluctant to deliver less than 10 tonnes of wood chip in any one delivery, so the unit cost would increase if smaller volumes were required.

For this reason the use of wood chips may be considered to be impracticable, as deliveries would be too frequent, and an insufficient ‘buffer’ would be available in the event of delivery problems.

From an environmental point of view, local supply is preferable, but even a local supplier of pellets is likely to source them from further afield. Wood chips are far more likely to be sourced locally.

Fuel Supply Contracts

Fuel can be purchased by the tonne which, particularly in the case of wood chips with variable moisture content, may lead effectively to the purchase of some expensive water. Alternatively suppliers may enter into contracts to supply heat. In this approach, the heat provided by the boiler is measured, and fuel is charged for, at an agreed price per kWh of heat produced, (see picture top of next page, of a heat meter installed on a biomass system at a school in Fife). In this way, if a particularly moist batch of fuel is delivered, the customer pays only for the heat which that fuel (with a reduced net energy content) can provide.

Wood fuel suppliers in the area are able to provide reliable long term pellet/chip fuel supply contracts using timber from sustainably managed local sources. Initial discussions have taken place with one of the area’s leading suppliers.

Carbon Impacts

The carbon emissions arising from producing 111,690 kWh of heat (see under ‘potential costs and incentives, below), from natural gas (at 0.1836 kg CO_2 per kWh, Defra emissions factor), with a 95% efficient boiler, is 21.59 tonnes per year.

A change to wood pellet or wood chip burning (at 0.039 kgCO_2/kWh, emissions factor from Nottingham Energy Partnership), could reduce the mass of carbon dioxide emitted to 4.84 tonnes per year (assuming a 90% efficient boiler), a reduction of 16.75 tonnes per year, or 335 tonnes over the assumed 20 year life span of the boiler.

Indicative Costs

Note: costs of the heat distribution systems (radiators, pumps, pipework, insulation, controls, and maintenance costs), are not included.

The Fröling 85kW boiler could, with heat meters, heat main, and a 1,000 litre accumulator tank, cost an estimated £45,000 installed (see attached indicative cost estimate for included and excluded items), excluding the cost of any work to the boiler house and fuel store. This estimated cost does not include annual servicing and planned maintenance.

The Renewable Heat Incentive

See

http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/incentive/incentive.aspx

This incentive allows, for boilers of under 200kW, a payment of 7.6p per kWh based on 1,314 peak load hours per year. Above 1,314 hours p.a. the tariff drops to 1.9p per kWh.

In the case of the Fröling Turbomatic 85kW boiler, the tariff would (only if the actual heat-load in use meets or exceeds this level), pay 85 (kW) x 1,314 hours (111,690 kWh p.a) x7.6p ('Tier 1') (£8488) per annum for 20 years at today's prices (a total of £169,760 over 20 years), with any heat generated above 111,690 kWh being paid at 1.9p/kWh ('Tier 2'), though these rates have yet to be finalised.

Nottingham Energy Partnership's Energy Cost Comparison web-site (http://www.nottenergy.com/energy_cost_comparison), suggests a cost per kWh of heat of 6.59p for wood pellets, and 4.74p for natural gas. No cost is given for wood chips, so the stated price for seasoned wood (4.28p/kWh) has been used as a proxy.

However,
http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,59188&_dad=portal
Suggests a price for pellets of 4.8p/kWh, and approximately 3.5p/kWh for woodchip.

Thus pellet costs for 111,690kWh per year would be between £5,361 and £7,360 per year if all heat were supplied by the pellet boiler.

Mains gas would cost only £5,562 per year, but the use of a pellet boiler would give rise to a RHI income of £8,488 per year, whereas the gas boiler would give rise to no heat incentive at all.

Notwithstanding very different capital costs, the pellet boiler (based on current fuel prices) would give rise to an index linked net income of between £1,128 and £3,127 per year for 20 years.

For wood chips, the RHI income would be the same, and the chip costs between £3,909 and £4,780, giving rise to a net income per year after fuel costs of between £3,708 and £4,579.

Note however, that all energy prices are likely to rise in general, and that as gas prices increase, more users are likely to adopt wood based fuels. The resulting competition for the available wood, is likely to link the cost of wood fuel to that of other fuels.

Other Issues

A biomass boiler will undoubtedly have greater maintenance requirements than a heat pump, and maintenance of and repairs to the fuel feed system must also be factored in at around £1,000 to £1,500 per year.

Scientists are engaged in much debate as to the true carbon costs of biomass arising from the use of fossil fuels in planting, harvesting, processing and transporting wood, and these are likely to vary greatly with location, so local availability and fuel quality must be taken into account. Even if one does not dispute the figures we have used (from Nottingham Energy Partnership, an excellent source of quality data), there are undoubtedly other contaminants produced during burning, including tars and small quantities of dioxins.

Concerns over greatly increased use of biomass in urban areas have been expressed, and the risk of future smog has been mooted if wood based fuels are widely adopted. It is however, clear that a Defra approved biomass appliance, well maintained and run on good quality fuel, will keep these issues to a minimum, and ultimately, the limited supply of wood is likely to prevent the use of biomass coming to dominate the urban heating market.

7.2 Heat Pump Options

a) Ground Source Heat Pump (GSHP)

Ground source heat pumps draw heat from the ground, and use refrigeration technology to increase the temperature at which that heat is available, so it can be used for space, possibly water heating.

When used for heating, the ratio of kW of heat out to kW of electricity in, is known as the coefficient of performance or CoP, and depends on the temperature of the heat source, and on the flow temperature.

Where large areas of land are available, trenches can be dug to accommodate the ‘ground loop’ pipes which capture low grade heat. Where (as in this case) there is insufficient land for trenching, deep boreholes can be drilled to accommodate the loops.

In view of the lack of land available, the only possible site for boreholes is within the footprint of the extension. Although a full specification has not been drawn up, it remains unclear whether sufficient space will be available to allow a sufficient number of boreholes with enough separation to prevent each borehole ‘robbing’ heat from its neighbour. Extrapolation based on a recent project suggests that up to 1,300m of boreholes would be required for 80kW output. Since each borehole (probably max 100 – 150m deep) needs to be 5m from its neighbour, it suggests that ground source on this site would be impossible if the boreholes were drilled vertically, but if these were to diverge underground, heat could be drawn from a greater volume of rock, though the legality of this would have to be checked.

Equipment

A GSHP installation would be likely to involve two 40 kW heat pumps and a buffer tank which ensures that the heat pumps will not switch on and off too frequently, by providing a large volume of water to heat each time a heat pump is started. The picture below shows two Stiebel Eltron WPF40 ground source units.

Limitations

Heat pumps are low flow-temperature appliances, usually operating at a maximum flow temperature of around 55°C, compared with gas boilers which may run at flow temperatures of up to 80°C.

Heat pumps work most efficiently (with the highest CoP) when delivering water at low flow temperatures. When a GSHP is providing water at 30-35°C, for example, running through under-floor heating pipes, a CoP of over 4.0 might be achieved. With higher flow temperatures (of 45-55°C, when running radiators, for example) CoPs will typically drop to as little as 2.5 (with perhaps as much as 3.0 available if flow temperatures are kept nearer to 45°C).

Where under floor heating is not available, to achieve adequate room temperatures with flow temperatures of only 45-55°C, larger radiators are usually chosen than might be used in a conventional heating system where a fuel is burned at a high temperature. Fan assisted radiators might also be used, but these can be relatively noisy, and might be particularly inappropriate in a church.

If the emitters are undersized, the effect of the low flow temperatures is to make the heating system slow to warm up, and slow to ‘recover’ when temperature has dropped, and less able to fully heat the building in very cold conditions.

This might be less of a problem in the church house, where a normal working temperature will be required for up to 14 hours per day, but in the case of the church itself, which is used mainly on Sunday, and very sporadically at other times, it could be very hard to heat the building quickly, and it would be plainly absurd to have to keep the building warm at all times simply because it cannot be warmed up quickly.

If the heating was only able to heat Church House slowly, it would be particularly important to use controls that would start to heat the building in time to bring it up to the desired temperature by the time the building opens in the morning. Alternatively, the heating might not be turned off completely at night, but ‘set-back’ (a reduction of temperature by 3-5°C overnight) might be used. This second approach should be avoided if possible however, due to the increase in energy use. If aesthetically and financially acceptable, the better approach would be to use large finned double radiators as emitters, at the lowest possible working temperature.

Fuel

For the purpose of running cost calculations we have assumed an electricity cost of 15p per kWh, and have assumed that it is not possible to run the heat pump on night-rate electricity (unless space can be found for a very large accumulator tank so that accumulator heating times can be de-coupled from space-heating times). This may result in a slightly pessimistic calculation as some energy might be used at night rate, but the selection of cheap night time electricity generally increases the day time energy cost, and the ‘lions share’ of energy consumption is likely to be during the day.

Carbon Impacts

Defra gives a carbon emission of 0.525kg per kWh of electricity. Therefore the following emissions would result:

CoP 2.5: 23.46 tonnes per annum

CoP 3.0: 19.55 tonnes per annum

Potential Costs And Incentives

Note: costs of the heat distribution systems (radiators, pumps, pipework, insulation, controls, and maintenance costs), are not included.

A GSHP system, including boreholes, would have an indicative cost of £88,700 (£44,500 for a pair of heat pumps and associated equipment, and £44,200 for boreholes). As the Church and the Church House are to be heated by radiators, the best CoP likely to be achievable is 3.0. We have carried out two calculations, one based on a CoP of 3.0, and one on a CoP of 2.5.

To provide 111,690 kWh with a GSHP with a CoP of 2.5, and an electricity cost of 15p/kWh would cost £6,307 per year. (125,120/2.5 x 15p)

To provide 111,690 kWh with a GSHP with a CoP of 3.0, and an electricity cost of 15p/kWh would cost £5256 per year. (105,120/3.0 x 15p)

The Renewable Heat Incentive (RHI) would pay 4.3p per kWh for heat generated by a GSHP, or £4802.67 per annum.

*NB: The figure of 111,690kWh p.a. is based on the biomass tier 1 threshold at this stage (see definition in the biomass costs and incentives section above), and is not based on a detailed heat loss calculation.

b) Air Source Heat Pump (ASHP)

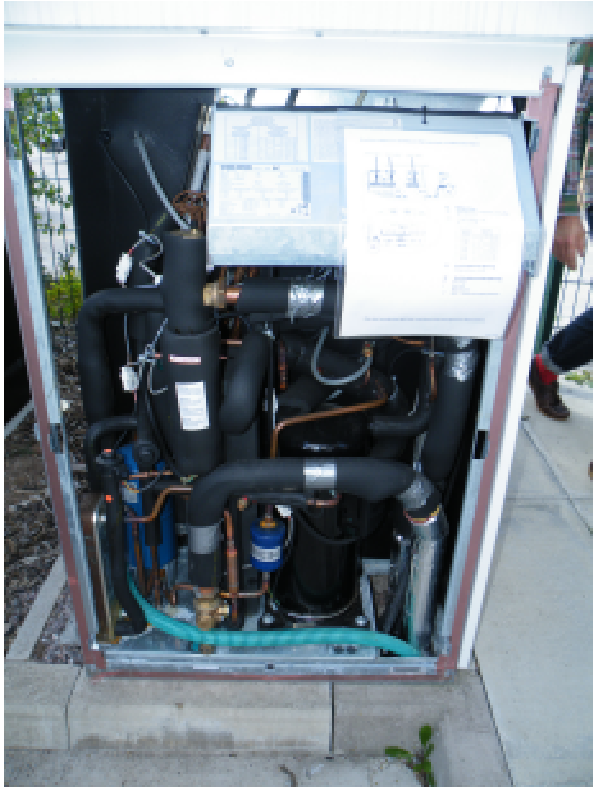
Air source heat pumps draw heat from the external air, and use refrigeration technology to increase the temperature at which that heat is available, so it can be used for space, possibly water heating.

When used for heating, the ratio of kW of heat out to kW of electricity in, is known as the coefficient of performance or CoP, and depends on the temperature of the heat source, and on the flow temperature.

No land is required; simply an external wall on which to site the heat pumps, or an area of exposed ground on which the equipment may stand. Some, though not all systems look similar to air-conditioning units.

Equipment

An ASHP installation would be likely to involve two or three heat pumps, and a buffer tank which ensures that the heat pumps will not switch on and off too frequently, by providing a large volume of water to heat each time the heat pump or pumps start. The pictures above show the outline of a Stiebel Eltron WPL 57 A, and a similar



machine with the covers removed. The A4 paper towards the top right of the right hand picture gives an idea of scale.

Limitations

Just like GSHPs, ASHPs are low flow-temperature appliances, usually operating at a maximum flow temperature of around 55°C, but with greater efficiency at lower temperatures.

Heat pumps work most efficiently (with the highest CoP) when delivering water at low flow temperatures. When an ASHP is providing water at 30-35°C, for example, running through under-floor heating pipes, a CoP as high as 3.0 to 3.5 might be achieved. With a higher flow temperature (of 45-55°C, when running radiators, for example) CoPs will drop to as little as 2.0 (with perhaps around 2.5+ available if flow temperatures are kept nearer 45 degrees).

The issues relating to the sizing of emitters are similar to those encountered with ground source heat pumps, but an additional issue arises with air source systems, in that on the days that most heat is required, outside temperatures tend to be at their lowest, and this increase in the difference between inlet and flow temperatures reduces the CoP. Air source systems then will be at their least efficient on the coldest days. If sized correctly, ground source systems by contrast should experience little fall in ground temperature, either in cold weather, or during the heating season.

Fuel

For the purpose of running cost calculations we have assumed an electricity rate of 15p per kWh, and have assumed that it is not generally possible to run the HP on night-rate electricity because of the lack of space for a very large accumulator tank.

Carbon Impacts

Defra gives a carbon emission of 0.525kg per kWh of electricity. Therefore the following emissions would result:

CoP 2.0: 29.32 tonnes.

CoP 2.5: 23.46 tonnes.

Potential Costs And Incentives

Note: costs of the heat distribution systems (radiators, pumps, pipework, insulation, controls, and maintenance costs), are not included.

Based on the use of three Stiebel Eltron WPF 57 A heat pumps, an ASHP system would have an indicative cost of £76,300. While cheaper machines could be purchased, the client would need to satisfy themselves that the machines were quiet enough to be used near a church, and that the noise levels would stay within acceptable limits as the machines aged.

As the church and the church house are to be heated by radiators, the best CoP likely to be achievable is 3.0. We have carried out two calculations, one based on a CoP of 2.5, and one on a CoP of 2.0, based on COP figures from ‘Getting warmer – a field trial of heat pumps’ produced by the Energy Saving Trust.

To provide 105,120 kWh with an ASHP with a CoP of 2.5 and an electricity cost of 15p/kWh would cost £6,307 per year (125,120/2.5 x 15p).

To provide 105,120 kWh with an ASHP with a CoP of 2.0 and an electricity cost of 15p/kWh would cost £7,884 per year (105,120/3.0 x 15p).

The Renewable Heat Incentive (RHI) does not currently cover ASHPs, and no incentive would be payable unless this policy changes.

Other Issues

Despite the claims of some salespeople, Heat Pumps do not provide wholly renewable energy. While the heat drawn from ground or air is arguably renewable, the system as a whole only becomes wholly renewable when run from renewable electricity. The potential area available for the installation of PV panels (even if the proposed adjoining development does not compromise it) would be wholly inadequate to provide a significant proportion of the electricity required to run heat pumps, so if a renewable supply is required, it would be a question of subscribing to a ‘green’ tariff. Very few of these provide energy from 100% renewable sources, and even those that claim to are ethically compromised by the sale of Renewable Obligation Certificates.

7.3 Making The Decision: Criteria For Choice

Firstly, it must be noted that all the cost estimates for heating do not include radiators or other elements of the heat distribution system, or controls.

Undoubtedly the cheapest heating system in terms of capital costs would be a gas-fired system, and whatever fuel is chosen, it may be that a gas boiler might be retained as an emergency back up element of the system.

Recent estimates for a replacement boiler system for another Sheffield church suggest a price in the range of £15 - £20,000 with no annual incentive payment, and fuel costs of approximately £5,562 per year for 111,690 kWh at current prices.

Of the more sustainable options, the ground source system has a high capital cost, and some uncertainty about the legality of allowing the boreholes to diverge underground. The air source system gains no RHI income, so is a poor financial contender, and might also give rise to noise issues. While the ground source system in particular might be worthy of further research, our provisional conclusion is that the wood pellet system is most likely to offer a good financial return with only moderate environmental impact.

The ball-park estimate for the pellet boiler installation is around £45,000. Fuel costs could be around £5,360 to £7,360 per year, and RHI income would be £8,488 per year, or £169,760 over 20 years.

Assuming current costs (and forgetting for a moment the imminent near 20% gas price rises), 20 year costs excluding maintenance and parts could be as follows:

Gas:

Capital cost: £20,000
Gas cost: £111,240
Total: £131,240

Wood pellet:

Capital cost: £45,000
Fuel cost: £147,200
Total: £192,200
RHI income: 20 years at -£8,488 per year = -£169,760
Balance: £22,440

Even taking a very pessimistic view, and installing a back up gas boiler sized to provide 100% of heating load, the total cost after RHI would still be only £42,440.

Factoring in estimated servicing costs at £750 per year for gas and £1,500 per year for pellets has the following effect.

Gas boiler costs brought forward:

£131,240
Plus 20 year x £750 (£15,000)
Total: £146,240

Pellet boiler (with gas back-up) costs brought forward:
£42,440 (net of RHI)
Plus 20 years x £1,500 (pellet boiler service) and
20 year x £750 (gas boiler service) (£45,000)
Total: £87,440

From the point of view of a whole-life costing the pellet boiler is clearly the best financial choice, in addition to its carbon benefits.

We have not included back up gas costs, since the emergency use of gas should be sufficiently rare as to have a relatively insignificant effect on cost, and on the RHI receivable.

Wood Pellet Boilers: User Experience

On 15th of September, I (Nick) spoke to Sally Rylance, of the Forestry Commission in Pickering. They have had a 60kW Fröling Turbomatic, supplied by Econergy, for about 18 months.

She described the Fröling Turbomatic as a technically sophisticated boiler, and summed it up as easy to use, surprisingly clean, and ‘great when it works’.

They had a fault with the fuel feed mechanism in the depths of last winter, with temperatures as low as -14°C. The bad weather and the understandable call on Econergy’s resources delayed a service call for a whole month, during which time they had no heat at all.

She is, understandably, strongly of the view that an emergency back up system is prudent. However, apart from that fault and another one which occurred last week, she had not even had to phone the supplier in 18 months.

Interestingly, their fuel use for the last year was approximately 22 tonnes. At approximately 4,700 kWh/tonne, that would have provided 103,400 kWh, very similar to the heat provision estimated within this report.

Diarmuid Egan, at Sheffield City council's SHAW team, would be happy to speak to PCC members about their experiences with biomass. Although these are bigger, 'district heating' boilers, which run on chips rather than pellets, many of the issues encountered are similar.

The key issue would appear to be the 'belt and braces' provision of a back up heat source.

Appliance	Approx capital cost excl VAT	Annual fuel cost (low estimate)	Annual fuel cost (high estimate)	Estimated heat delivery p.a. (kWh)	RHI rate/kWh	RHI payment p.a.	Possible surplus p.a. after fuel costs	CO_2: Tonnes p.a.	CO_2: Tonnes over 20 year life
Wood chip boiler	£45,000	£3,909	£5,294	111,690	7.6p	£8,488	+£3,194	4.36	87.2
Wood pellet boiler	£45,000	£5,361	£7,360	111,690	7.6p	£8,488	+£1,128	4.36	87.2
GSHP (elec @ 15p/kWh)	£88,700								
CoP 2.5		N/A	£6,701	111,690	4.3p	£4,803	-£1,898	23.46	469.2
CoP 3.0		N/A	£5,585	111,690	4.3p	£4,803	-£782	19.55	391
ASHP (elec @ 15p/kWh)	£76,300								
CoP 2.0		N/A	£8,377	111,690	0p	£0	N/A	29.32	586.40
CoP 2.5		N/A	£6,701	111,690	0p	£0	N/A	23.46	469.2

8 - Domestic Hot Water

Domestic hot water requirements are likely to be relatively small, with water only used on a small scale in kitchen areas and for hand washing in toilets. It is further understood that the points of domestic hot water use will be distributed throughout the building.

An exception to this might be the kitchen for the cafe, though even in this area, consumption may be small if for example all dishes are washed in a low water use cold fill dishwasher. The consumption in this area should be assessed with the help of the staff who will be running the kitchen.

In a building with low hot water use and scattered points of consumption, the use of centralised domestic water heating plant poses a number of problems. Distribution of hot water through long pipes is unlikely to be effective because of the length of time it takes the hot water to arrive, and most of the thermal energy in the hot water is likely to be lost without benefit to the user while the water stands in the pipes.

This might be addressed by circulating the water through the hot water distribution pipes (a pumped loop), though as these pipes are then constantly hot, energy losses from the pipework, however well insulated, are likely to be significantly greater than the small amount of energy usefully delivered to end users.

This has given rise to the suggestion that domestic water heating might be delivered by point of use resistive electric water heaters. While these are compact, electricity is the most carbon intensive fuel that might be used.

A compromise might be to use very small hot water cylinders which have a heat exchanger to allow the transfer of heat from the space heating system when it is on to preheat the domestic hot water, but which also incorporate an immersion heater which will ensure that all water is delivered at between 60 and 65°C to control the risk of Legionnaires' disease. Hot water cylinders can be fabricated in more or less any size, and can be made to fit under work surfaces.

Any electric water heaters should be controlled by time switches so that energy is not wasted keeping water up to temperature over night. They should also be chosen for the quality of the thermal insulation offered as this determines the heat loss that will occur even when there is no hot water consumption.

While the lack of centralised domestic hot water plant makes the use of solar water heating difficult, consideration might be given to using it in the supply for the cafe kitchen if this has high enough hot water demand in a single location.

Domestic hot water for a kitchen and toilet heated primarily via an indirect heat exchanger, but with a 3kW immersion heater to maintaining a Legionella safe temperature, and provide back-up heat.

9 - Heating Controls

It is understood that the view has been taken that the control system should be as simple as possible.

While in general terms this seems sound, as it allows end users of the building to use the heating system more easily, a simple system which cannot be overridden by automated controls does pose some problems.

In winter, it is normal practice to start to heat a building some hours before staff arrive in the morning. This allows it to reach an acceptable temperature before they arrive.

This can be achieved with a simple time switch, but can be improved on by using temperature compensators which adjust the heating start time in response to internal and external temperatures. This heats the building up just in time, saving money, fuel, and reducing carbon emissions.

Either of these can be compromised if users are in the habit of adjusting radiator valves, turning them fully off when rooms overheat, or fully on when it is cold.

In parts of the building that are occupied by full time staff, it should be possible to set thermostatic radiator valves (TRVs) to a comfortable temperature and leave them at that setting.

In public parts of the building however, it may be necessary to fit tamper proof controls to avoid thermostatic radiator valves being left fully closed or fully open overnight. Alternatively, a member of staff might be tasked with setting all radiator vales appropriately at the end of the day.

In principle, a building management system (BMS) might be used. Such a system would control the temperature of each room individually, allowing users to specify a range of temperatures which they find acceptable, and allowing these to be boosted for a while if desired. User settings however could be overridden, avoiding the problems of turned off TRVs preventing rooms from being heated on cold mornings. A BMS might also be integrated with a room booking system, allowing unused rooms to cool when not in use, but bringing them up to temperature in time for booked use.

While the BMS option sounds attractive, feedback from users suggests that they are expensive to install, configure and maintain, and that product life cycles may be short, necessitating periodic upgrades or replacement.

Although these factors preclude our recommending a BMS system at this time, as the value of the energy that it might save increases, and the cost of BMS technology decreases over time, it should be noted that the installation of a BMS may become economically viable at some point in the future.

10 - Solar Thermal And Photovoltaic Systems

10.1 - Solar Thermal

The use of a solar thermal system is likely to be worthwhile if a part of the building can be identified which has a high enough water consumption. Subject to an assessment of hot water demand, the likely site appears to be the cafe kitchen.

The hot water requirement for a site such as this, differs from a domestic setting because in a cafe, there is likely to be a demand for hot water throughout the day, and possibly all day. In a domestic setting, demand on many days of the week is largely in the early morning and the evening, so water which is being heated must be stored until the end of the day. This requires a large hot water cylinder to be used (typically 170 litres for a family of three). These differences in mode of use render many simplistic design tools inappropriate for situations such as a cafe.

Should the cafe have a solar thermal system installed, this will require a backup form of heating, and the cylinder might include an indirect heat exchanger connected to the space heating system to provide auxiliary heat when there is insufficient solar energy available to meet the demand.

An immersion heater should also be fitted to provide auxiliary water heating when the space heating system is switched off.

The control system should allow solar energy to heat the cylinder at any time with a standard solar differential temperature controller, but only use the auxiliary energy sources on occasions when the cafe is open, or will opened in the next few hours.

The cylinder might be vented if the refurbished building has a cold water header tank, or could be unvented. If the cylinder is unvented, the manually resettable high limit thermostat must be wired in such a way as to cut off energy supplies to the cylinder in the event of the cylinder overheating.

The panels used might be flat plate or evacuated tube. Evacuated tubes might be more efficient in cold weather conditions, but is arguable that flat plate collectors are typically more efficient when heating cooler water, so we are reluctant to make a generalisation that either technology is thermally superior. Particularly given the listed status of the building then, the choice of collectors might be made on aesthetic grounds.

The picture at the top of the next page, shows a typical evacuated tube collector. These are almost always mounted above the tiles of a roof, and can stand several inches proud of the roof. The picture below shows a flat plate collector mounted 'on roof' on brackets, again above the tiles. While this type of installation is relatively quick to undertake, a better aesthetic outcome might be achieved by mounting the collector 'in roof'.

The above picture shows a flat plate collector mounted 'in roof', mounted with a flashing kit so that it sits directly over the laths.

Mounting collectors 'on roof' allows the free movement of cool air behind the collector. By contrast, mounting 'in roof' exposes the rear of the collector to the relatively warm and still air that it typically found in loft spaces. This can reach temperatures of more than 40°C in warm weather, and reduces heat loss from the

rear of the collector.

If two such collectors are mounted together, a flashing kit is available to fit neatly between them. This has the additional benefit of allowing the panels to be mounted closer together. See picture at bottom of the previous page. (Note this system had a solarimeter temporarily installed. This device and its wiring would not normally be present).

Feedback from the owners of solar water heating systems is usually good. Reliability is generally high as long as systems are correctly installed in accord with best practice. We have had experience of somebody buying a house with an old solar thermal system installed, and being sufficiently impressed with its performance to upgrade it to a modern system with larger collector area.

Based on our experience of repairing solar thermal systems, the main threats are corrosion causing blocking of the pump and narrow pipes, failure of the controller, and freezing in winter. As a consequence, we normally recommend that bronze pumps be used to minimise corrosion over the life of the system. We further recommend the use of variable speed controllers and low energy pumps to reduce the 'parasitic' electrical energy use.

Maintenance requirements are modest, though antifreeze should be changed every five years. If this is not carried out, damage may result as the glycol in the antifreeze oxidises to form acids (which also promotes corrosion), and the antifreeze tends to polymerise and solidify. The antifreezes used in solar thermal systems should be based on propylene glycol which is significantly less toxic than ethylene glycol (the antifreeze typically used in cars). As long as antifreeze or other freeze prevention measures are used correctly, the risk of freezing can be controlled, even in the most exceptional of winters.

Without knowing the demand for hot water from the cafe kitchen, it is not easy to predict the financial or carbon savings that might be made. In a domestic situation however, a pair of the Zen 2.75m^2 collectors shown on the previous page might contribute 1,015 kWh per year, though the energy yield would be expected to increase significantly if hot water consumption was higher than in the domestic scenario.

Taking the figure of 1,015 kWh per year, compared to electricity (the proposed alternative fuel), a solar thermal system might save over £150 per year (at 15p per kWh), and the emission of about 553 kg of carbon dioxide per year. An additional payment might be made under the Renewable Heat Incentive at a rate of £0.085 per kWh, adding £86 per year to the value of the system. If the system has a life of twenty years, this would yield an income of £3,755 though this figure is likely to increase as the RHI payments will be adjusted in line with inflation, and energy prices will inevitably increase.

Such an installation might add £5,500 excluding VAT to the cost of the refurbishment.

While the economic case is not compelling, if hot water demand is significant, or grants might fund all or part of the capital cost of the system, this technology might make a financial as well as an environmental contribution to the project.

10.1 - Solar Photovoltaic

Unlike hot water which must be used on site, any surplus of electricity can be exported into the national grid so no energy generated is wasted, and none need be stored locally.

A number of types of photovoltaic panels are available, but as roof area will be limited, it is important to optimise the performance in terms of watts per square meter, as well as pounds per watt.

Again panels may be mounted either in roof (see below) or on roof (see top of next page).

While 'in roof' mounting might be seen as an aesthetic advantage, the performance of photovoltaic cells decreases with temperature, so for photovoltaic panels, 'in roof' mounting gives a performance disadvantage. We do not recommend it, unless it is absolutely necessary from the point of view of planners of other stakeholders with a

duty to minimise visual impact.

Electrical energy is generally worth more per kWh than thermal energy, though if electricity is used for water heating on this site, this will be less true than on a site where natural gas is used to heat water.

PV panels are much less efficient than solar thermal collectors at converting light and radiant heat into useful electrical energy, so arrays of PV collectors tend to be larger than those used by solar thermal systems. PV is extremely sensitive to shadowing, so the amount of energy that can be generated is likely to depend on the amount of un-shadowed roof area available, or the amount that it is deemed aesthetically acceptable to use. While still worth considering, it is unlikely then that any PV system that can be installed will be very large.

Based on ten YingLi 260W panels, a 2.6 kW PV system might cost approximately £7,350 ex VAT, assuming scaffolding is provided by others.

Based on an electricity cost of 15p per kWh, such a system should generate approximately 2,232 kWh per year which would displace 1,216 of fossil carbon emissions from electricity production per year. Using the revised (post December the 12th 2011) Feed In Tariff rate, would generate an income of £671 per year including Feed In Tariff, bill reduction, and export tariff.

11 - Rainwater Harvesting And Water Conservation

Initial calculations for the roofs of the church house and the extension suggest an annual rainwater yield of 152,400 litres, and a maximum tank size of 7,620 litres, giving up to 91,000 litres per annum. (Although over-sizing the tanks may seem tempting, BS8515 sets limits on the size of rain-harvesting tanks in order to avoid stagnation and Legionella or other bacterial contamination).

Rainwater harvesting not only reduces the amount of potable water used to flush WCs, but by reducing run-off to main drainage reduces the risk of over-burdening the main drainage system, acting as an element of sustainable drainage. This is sometimes referred to as water attenuation.

Assuming the use of very water efficient WCs, an estimated average of 100 WC flushes per day with 50% low flush and 50% full flush suggests a WC consumption of 300 litres per day.

Over a full year (assuming 340 days use per year, allowing for partial use only on Sundays), the expected yield would roughly match the consumption for flushing.

As the site has no external land area, the tank could potentially be accommodated within the footings of the extension, subject to structural engineer's recommendation.

The photograph at the bottom of the previous page shows access to an underground tank, and to the left of the picture, a submersible pump and the tank cover. Access to the tank need not take up a large footprint within the building, but access may be required periodically to clean filters or strainers, and to service or replace the submersible pump.

One approach to making water available without running the pump constantly, is to pump water up to a small low weight tank in the loft space. From here water can flow down to WCs etc under gravity. The picture top left of the next page shows such a tank. The submersible pump delivers water via the filter (blue) to the right of the picture.

A controller is required to manage the operation of the submersible pump, and this can also manage fall back to the rising main supply in the event of drought, or failure of the submersible pump. Many companies supply controllers with a wide range of features. The picture at the top left of the next page shows one that T4 make to manage the submersible pump and rising main supply.

We recommend that any WC replacements should use very low-flush units such as the 4 litre dual flush WCs offered by Ifo and Armitage Shanks, among others.

Estimated Water Saving

In terms of savings it is important to note that while rainwater harvesting makes savings on the supply side (at approximately £1.20 per m^3), water conservation measures (overall reduction in consumption) make savings both on the supply side, and in terms of disposal (at around £1.30 per m^3).

Based on the flushing rate estimated above (100 flushes per day for 340 days per year), annual consumption for flushing could be as high as 204,000 litres if a 6 litre single flush cistern were to be used.

Changing the specification to a 4 litre/2litre dual flush WC and assuming 50% use of the low flush facility would save nearly 102m^3, at approximately £1.20 per m^3 (supply) and £1.30 per m^3 (disposal), a total of £255 per year.

If, in addition, the entire flush volume of the 4/2 litre WCs were to be provided from rainwater, this would reduce potable water consumption by approximately 102m^3, saving approximately £127.50 per year.

If urinals are to be installed, consideration should be given to the use of waterless urinals, even if rain harvesting is used. Although rain water can also be used to flush urinals, and sensors can be used so that urinals are only flushed when they have been used, the use of waterless urinals significantly reduces the load on mains drainage, and would reduce the proabablity of mains water being required during dry periods.

Estimated Carbon Saving

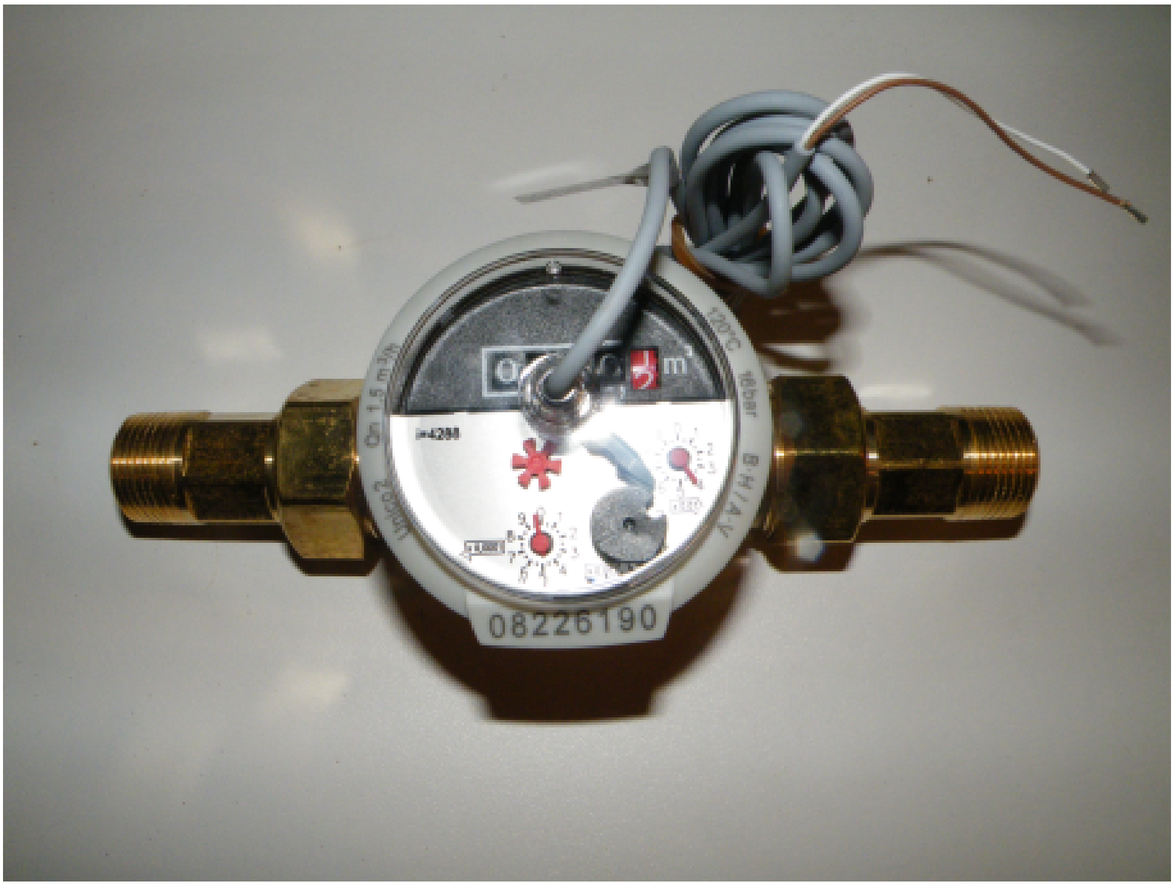
The carbon reduction that might arise from the proposed reductions in water use, and the use of rainwater harvesting, would be approximately 129kg per year.

Wider Environmental Strategy

While rain water harvesting (at approximately £7,500 to £10,000 capital cost) is not going to pay back in even 50 years at current water costs, the environmental benefits of reducing the waste of natural resources, and reducing peak loads on main drains are important.

We would suggest that a target for water consumption per person be set, exceeding even that required to achieve a BREEAM 'Very Good' score, and that performance in use be monitored closely against this target. To facilitate this monitoring, we would suggest water sub-meters, possibly using a data logging facility if this is also put in place to record energy consumption. See picture of a pulse output water meter costing around £130 at the top of the next page. This type of meter can also be read manually.

Further savings can be made by introducing a degree of automation to the taps.



Percussion taps at the most basic, though in the long term these may prove unreliable, with a tendency to stick and leak.

Subject to budget, we would recommend the use of infrared controlled taps with spray heads to minimise water use.

In terms of appliances, special care should be taken to ensure that appliances with the lowest possible water and energy use are chosen.

12 - Inappropriate Technologies

12.1 - Hydro Power

Of the systems commonly regarded as renewable energy technologies, hydro is clearly inappropriate as there is no access to moving water from the site.

12.2 - Wind Power

Micro wind would be problematic on a number of grounds. Energy yeilds would be lower than might be anticipated from data in the NOABL national wind speed database, because air that swirls around rooftops is turbulent. This turbulence applies rapidly changing forces to horizontal axis wind turbines, causing unproductive mechanical stress, rather than the delivery of useful energy for electricity generation.

This might be addressed, at least in part, by the use of vertical access turbine which would develop useful torque regardless of the direction from which the wind blows in the horizontal plane. Vertical axis machines however tend to be more expensive, perhaps as much as twice the price of horizontal axis machines of the same power.

In either case however, the more important issues would be the dynamic structural loadings that even a small wind turbine would impose on the building in high winds, vibration that might cause structural damage, noise that might be stressful and irritating to the users of both buildings, incompatability with the listed status of the buildings, and the lack of space for any exclusion zone around the turbine. The combination of the above issues renders the use of wind power inappropriate.

12.3 - Connection to the Veolia District Energy System

Discussions with Martin Simpson and Richard Barker at Veolia Environmental Services (UK) Plc has confirmed the current situation with regard to new connections to the District Energy System.

An indicative cost has been given which is subject to a full survey, of £71,000 for connection, plus an annual standing charge of approx £1,100, plus a unit energy charge of around £32.50 per MWh.

The situation is further complicated by the ethics of using energy from the combustion of waste. While it is accepted that for the foreseeable future waste disposal will be a necessary evil, our actions should ideally not incentivise the production of waste, albeit to provide fuel for 'waste to energy' plant. Further, only a portion of the energy in waste is from non fossil sources, and some, such as plastics, will be from fossil carbon sources. Considering the cost, uncertainty about connection and the ethical issues, we are reluctant to recommend this technology.

12.4 - Combined Heat And Power (CHP)

Combined Heat and Power is a technology which burns a fuel, and uses the heat both to generate electricity, and deliver useful heat. Although CHP systems are expensive, where there is continuous demand for heat and electricity, high utilisation can make them competitive.

In theory any fuel might be used, and depending on scale, a range of systems based on turbines, internal combustion engines, Stirling engines (an external combustion engine), and fuel cells are available.

Although the generation of electricity and heat by CHP makes more productive and profitable use of the fuel, it makes most sense when there is a simultaneous demand for both electricity and heat. Excess electricity can be sold profitably, but in summer in many building, it may not be possible to use all, or indeed any of the heat produced. CHP systems then, make most sense where there is a year round baseload demand for heat, and this will not be the case in this building. It is unlikely that running a CHP system to produce electricity alone would make financial or environmental sense.

CHP can attract payments under the RHI if the fuel used is eligible. Many CHP systems however are gas powered. Because of a lack of RHI income, these would not be financially competitive compared to pellet boilers, and because of the emission of fossil carbon, neither would they be environmentally competitive.

Discussions with Derby City Council indicate that of three gas powered internal combustion CHP systems that were installed a few years ago, one has never functioned correctly, and one proved too noisy for the residents of the building. They do not regard the experiment as a success.

A biomass CHP system such as the Talbott BG25 TCS Biomass to Power System might be a solution if space were available, and ought to be eligible for the RHI. This gives 25kW of electricity and 80kW of heat, and has a pellet fuel option. Such a boiler would deplete fuel stocks even more quickly than a conventional pellet boiler however, raising further questions about the timely delivery of fuel, and at 2.25 x 3.75 x 3.85m high excluding fuel store, it is difficult to see how it might be assembled in the available space.

Given the above, we cannot recommend any CHP solution.

Appendix 1 - Project Contacts

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