CENTRE FOR SUSTAINABLE ENERGY

Symes Avenue Community Building Renewable Energy Feasibility Study

Final Version

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Executive Summary

A large scale regeneration scheme is currently going through the planning process for an area around Symes Avenue in Hartcliffe, South Bristol, which will include a new community and library building. The community is represented by the Hartcliffe and Withywood Community Partnership (HWCP), a locally driven and elected body with responsibility for driving regeneration in the area. HWCP will be leasing the building from Bristol City Council at a ‘peppercorn’ rent and would like to examine the opportunities for using the building as a sustainable energy showcase for the area, setting an example for the whole community in the use of renewable energy and energy efficiency.

This report follows a successful funding application to the EDF Green Energy Fund and examines the issues surrounding the integration of renewable energy systems into the design of the building, with the aim of approaching carbon neutrality. The developers aim to achieve ‘Excellent’ status under the BREEAM rating scheme.

The feasibility study was undertaken by the Centre for Sustainable Energy (CSE) and assessed the sustainable energy options for the building, looking in particular at the potential for integration of a ground source heat pump (GSHP) for heating, and a solar photovoltaic (PV) array to provide a proportion of the building’s electricity requirement.

Heat and electricity demand were estimated for the building and, following initial discussions on appropriate technologies, an options appraisal was undertaken on GSHPs, PV, solar water heating (SWH) and roof-mounted wind power. The report gives an overview of each technology and considers design issues, operational aspects and provides an economic assessment based on installer quotes for a suitably-sized system. Comparisons are made with a ‘base case’ scenario of using a condensing gas boiler for 100% space and water heating. Renewable systems considered include a 6m^2 panel SWH system, a 4.5kW$_p$ & 20kW$_p$ PV system, a 1kW roof-mounted wind turbine and a 32kW GSHP with a gas or electricity top-up system. Each technology’s affect on carbon emissions is then assessed and issues surrounding electricity supply and on-site generation are examined. Planning consents, potential for public awareness-raising and funding sources are also covered.

The report concludes that all technologies examined are technically feasible for the proposed building. Each would contribute to some degree in meeting the overall energy demand and there is scope to ‘pick and mix’ between the various technologies and design smaller or larger systems accordingly.

In terms of carbon savings, a GSHP would be most significant, reducing CO_2 emissions by approximately 46%. If all options were implemented, a reduction of 86% could be achieved. The remaining fraction could then be offset by subscription to a 100% renewable ‘green’ electricity tariff, which could then enable the building to claim carbon-neutrality. The wind turbine appeared most favourable in terms of capital cost needed to save one unit of CO_2, with the GSHP ranking second.

The GSHP option also achieved largest savings in total annual heat and power running costs, with a 42% reduction compared to a gas condensing boiler. However, savings enabled by PV or wind depend on the effective value of the power generated, which was assumed to be 6.5p/KWh in the analysis. This could potentially increase to 10.5p/kWh or more with utilities currently offering on-site generation tariffs and the value of Renewable Obligation Certificates. At this higher value, the 20kW$_p$ PV system could potentially achieve a 53% reduction in overall heat and power running costs.

When simple payback on capital costs after grant funding was examined, the wind turbine was found to come out top, with an 8 year period required, followed by the GSHP at 19 years at a 50% grant level. However, site annual average wind speeds need to be taken into account and may decrease the manufacturers’ stated energy yields, which are based on average wind speeds. PV generally has a high capital cost, resulting in long payback periods of 40+ years after grants, but again, the value of generated power is critical and payback

periods will reduce by 30-50% at the 10p/kWh level. Similarly, payback period for the GSHP will reduce in the likely event of mains gas prices increasing.

The GSHP is recommended as the most viable option, although the level of grant funding is critical to payback. With 80% or more capital funding, simple payback decreases to around 5 years, and at 90%, the capital cost is comparable to a gas condensing boiler system. The study suggests that there is a very good chance of achieving these funding levels through the Clear Skies programme and utility green funds. The building is thought particularly suitable for GSHP technology due to its high thermal efficiency and low-temperature underfloor heat distribution system. To save on space required, bore holes are recommended for the ground loop and there will be no visual impact from outside the building. Costings given for borehole installations can vary significantly according to drilling conditions and more accurate quotes should be obtained once building design heat loss is established. A ‘worst case’ scenario might add 50% to borehole costs, increasing payback from 10 to 15 years at a 70% grant level.

Cost-effectiveness for the SHW system will depend on the fuel it will displace i.e. mains gas or electricity. For the latter, payback period will be more attractive, making this a recommended stand-alone option. However, should a GSHP also be considered, the viability of SWH will depend on the contribution of the GSHP to water heating. If this is high, the economics of SHW are not likely to be viable. Carbon savings will be relatively low, again depending on displaced fuel type.

PV systems can be very flexible in design and the Symes building could easily accommodate a 20kW system to supply a significant proportion of electricity demand, or, for example, a 4kW system which would generate a relatively small amount, but would also be highly visible and help raise the profile of the building. The decision will therefore depend on funds available. A larger system would incur higher capital costs, but economy of scale would generally make this option more cost-effective in the long-run. PV is the most expensive of the technologies in terms of capital cost spend per unit of CO_2 saved. However, avoided costs of conventional roofing materials being replaced with PV should be taken into account once details are known and may benefit economics significantly. A GSHP is likely to be more cost-effective and result in higher carbon savings over a PV system. Therefore, it is recommended that PV be given a lower priority than a GSHP in this case.

Roof-mounted wind turbines are recommended on the basis of being a simple, highly visible and relatively cost-effective measure to install. A single turbine would contribute a modest amount to electricity supply and carbon savings, so multiple devices could be considered. However, devices are not fully commercially available at time of writing and are not yet accredited for the DTI’s Clear Skies grant programme. Moreover, little data has been released concerning the performance of these systems at various annual average wind speeds and manufacturer’s claims should be treated with caution.

No planning barriers are foreseen for the technologies considered and recent changes in national and local planning guidance generally encourage the use of renewable energy in new developments. The building will play a high profile role in the local area and will therefore present a good opportunity for users and the local community to experience renewable energy at first hand. The incorporation of renewable energy systems will assist in achieving an ‘Excellent’ rating under the BREEAM assessment and creates potential for the centre to become a regional exemplar in sustainable energy building design and use.

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1 Introduction

1.1 Background

A large scale regeneration scheme is currently going through the planning process for an area around Symes Avenue in Hartcliffe, South Bristol, which will include a new community and library building. The building will play a prominent role in the area, located beside a new superstore, benefits office and new retail outlets. Not only will it draw on the attention of the users of the library and the South Bristol Advice Centre (both to be located within the building), but it will also be a flagship for other organisations using the meeting spaces provided.

The community is represented by the Hartcliffe and Withywood Community Partnership (HWCP), a locally driven and elected body with responsibility for driving regeneration in the area. HWCP will be leasing the building from Bristol City Council at a 'peppercorn' rent and would like to examine the opportunities for using the building as a sustainable energy showcase for the area, setting an example for the whole community in the use of renewable energy and energy efficiency.

This study follows a successful funding application to the EDF Green Energy Fund and examines the issues surrounding the integration of renewable energy systems into the design of the building, with the aim of approaching carbon neutrality.

1.2 Objectives and Scope of Work

This feasibility study assesses the sustainable energy options for the building, in particular looking at the potential for integration of a ground source heat pump for heating, and a solar photovoltaic array to provide a proportion of the building's electricity requirement.

The specific objectives were as follows:

- To undertake an initial review of the full range of renewable energy options for the proposed building and assess the potential for reaching carbon neutrality
- To undertake a technical options appraisal on ground source heat pumps, solar water heating, photovoltaics and wind power systems that may be appropriate for the current design of the building
- To evaluate the potential role of renewables in minimising running costs of the building
- To undertake an economic assessment of the investment costs and benefits relating to the installation of selected options, including potential sources of funding
- To assess the environmental, social and planning issues that may be associated with each option
- To outline plans for raising the awareness of energy efficiency and renewable energy within the local community and the building's users

1.3 Partners

The various partners and their role in the study are shown in the table below:

Partner	Role	Contact	Address
Centre for Sustainable Energy	Consultants	Martin Holley	Centre for Sustainable Energy The CREATE Centre Smeaton Road Bristol BS1 6XN Tel: 0117 934 0946 Fax: 0117 929 9114 email: martin.holley@cse.org.uk
Hartcliffe & Withywood Community Partnership	Client and funder	Stephen Hewitt	Hartcliffe and Withywood Community Partnership The Gatehouse Centre Hareclive Road Bristol BS13 9JN Tel: (0117) 903 8047 Fax: (0117) 903 8055 E-mail: stephen.hewitt@hwcp.org.uk
AEDAS	Project architects	Darrel Owens	AEDAS Architects Ltd. Norwich Union House High Street Huddersfield HD1 2LF Tel: (01484) 537411 Fax: (01484) 511207 Email: darrel.owens@uk.aedas.com
EDF Energy	Funder	Mark Thompson	EDF Energy PLC 329 Portland Road Hove East Sussex BN3 5SY Tel: (01273) 428641 Email: mark.thompson@edfenergy.com

Table 1.1: Partners involved in study

2 Building Details and Energy Demand

2.1 Description of Proposed Building

Located in Hartcliffe, the building will be part of a new development centred on Symes Avenue, with the building itself adjacent to a block of new-build retail units, next to Morrison's proposed car park.

The structure will be two-storey, comprising a community centre and library, and having a floor area of 877m^2. Included within the centre will be a kitchen, toilets, crèche, offices, lift, meeting rooms and bicycle storage area. Figure 4.6 illustrates the outline design of the building.

2.2 Estimated Energy Demand

During the design phase of the building, the developers have held discussions with BREEAM[1] consultants to explore ways and means of achieving an 'Excellent' standard. Suggestions for measures include rainwater harvesting, heat recovery units, condensing boiler plant, energy efficient lighting controls, external louvers for sun shading, energy management systems, sub-metering and automatic control systems.

[1] Building Research Establishment Environmental Assessment Method.
See http://products.bre.co.uk/breeam

These, and any other energy saving measures applied, such as increased building insulation level and the incorporation of renewable energy systems, will influence the future energy demand of the building.

2.2.1 Heat Demand

At time of writing, plans for the building do not yet specify the level of detail required in terms of building fabric and insulation levels to obtain accurate heat loss parameters. Assumptions are therefore made for heat demand in order to size an appropriate renewable heating system.

Following discussions with several heating installers, a heating plant of around 30-40kW capacity would appear suitable, based on a 'rule of thumb' heat loss rate of 40-50W/m^2 for current building regulation standard buildings. An initial indication of fossil fuel energy (not electricity) consumption may be taken as around 109,600kWh/year, based on a published benchmark for a new design community centre building[1] of 125kWh/m^2/year (upper limit for 'Good Practice').

2.2.2 Electricity Demand

Electricity demand will depend on the occupancy profile and number and type of appliances within the building. Published benchmarks give a figure of 22kWh/m^2/year for electricity consumption in the same category as mentioned in Section 2.2.1, or around 19,300kWh/year for the building as a whole.

3 Initial Review of Renewable Energy Options

Initial discussions with the developers highlighted preferences with regard to renewable technologies to be considered in detail at the site.

The resulting options thought worthy of further consideration were agreed as follows:

- Ground source heat pump
- Solar water heating
- Photovoltaics
- Roof-mounted wind power

4 Options Appraisal

4.1 Options for Heating

4.1.1 Gas Condensing Boiler

The conventional heating plant in this case, and one with which to make comparisons to renewable alternatives, would be a gas condensing boiler with hot water storage cylinder. Although there may be an option to use supplementary electric immersion heating for boosting domestic hot water, the boiler is assumed to provide for all space and water heating for the purpose of the economic evaluation later in this report.

Feedback from installers have indicated that capital cost could be in the range £4-5k.

[1] Energy Efficiency in Buildings; CIBSE Guide F 2004

4.1.2 Ground Source Heat Pump

Overview

Despite increasing use elsewhere, Ground Source Heat Pumps (GSHPs)[1] are a relatively unfamiliar technology in the UK, although the performance of systems is now such that, properly designed and installed, they represent a very carbon-efficient form of space heating. Heat pumps can take low temperature heat and upgrade it to a higher, more useful temperature. A few meters below the surface, the ground maintains a constant year-round temperature of 11-12^{o}C and because of its high thermal mass, heat during the summer is stored and can be pumped into a building. Although the ground temperature may not necessarily be higher than ambient air temperature in winter, it is more stable compared to the wide temperature range of ambient air. This makes system design more robust.

Water (or another fluid) is circulated through pipes buried in the ground and passes through a heat exchanger in the heat pump that extracts heat from the fluid. The heat pump then raises the temperature of the fluid via the compression cycle to supply hot water to the building as from a normal boiler. An electricity supply is required to operate the heat pump unit. Although a GSHP is not completely "renewable" as it uses mains electricity to drive the compressor, it will produce 30-50% less CO_2 emissions than a modern efficient gas or oil boiler.

GSHPs can be used to provide space and water heating (or cooling) to both individual houses and any type of non-domestic building. They cannot be seen from the outside of the building, so aesthetic design is not an issue, and can be a cheaper form of space heating than oil, LPG or electricity in terms of running costs. Although they require an electricity supply, the use of fossil heating fuels is offset, resulting in reduced overall carbon emissions. The measure of efficiency of a heat pump is given by the Coefficient of Performance (CoP), which is defined as the ratio of the heat output, divided by the quantity of electrical energy put in. CoPs of 3 or more should be achievable with GSHP systems, giving good energy and running cost savings. This means that for every unit of electricity used to pump the heat, 3 or more units of heat are produced, resulting in high system efficiencies.

A GSHP system consists of three main elements:

- Ground Loop – this comprises of lengths of plastic pipe buried in the ground, either in a borehole or a horizontal trench. The pipe is a closed circuit and is filled with a mixture of water and antifreeze, which is pumped round the pipe absorbing heat from the ground. With trenches, a coiled pipe network is buried at around two metres depth below ground level, thus requiring a large area of open space depending on the size of the system. For vertical borehole systems, the pipes are placed in holes bored straight into the ground to a depth of 15 to 150m depending on ground conditions and size of system. Vertical systems thus require less ground space but do require access for the drilling rig at the construction stage, though this is unlikely to be greater than for normal construction vehicles.

- Heat Pump – a device which uses the evaporation and condensing of a refrigerant to move heat from one place to another. This works in a similar way to fridges and air-conditioners and uses one or more compressors to transport the heat, hence requiring an electricity supply. Some systems, especially for larger buildings, require a three-phase electrical supply.

- Heat Distribution System – this consists of underfloor heating or radiators for space heating and water storage for hot water supply. It may be possible to combine the use of ground sources for both heating and cooling, using the same mechanical equipment. If the difference in temperature between the source and

[1] For further information see *Good Practice Guide 339: Domestic Ground Source Heat Pumps*; Housing Energy Efficiency Best Practice Programme. Available from: http://www.est.org.uk/bestpractice/

the sink is too great, then this will limit the operational performance of the heat pump. The smaller the temperature difference, the better is the performance. For this reason, systems work best with low-temperature heat distribution systems, such as underfloor heating, with delivery temperatures of around 30-45^{0}C.

Figure 4.1 shows a schematic of a typical system:

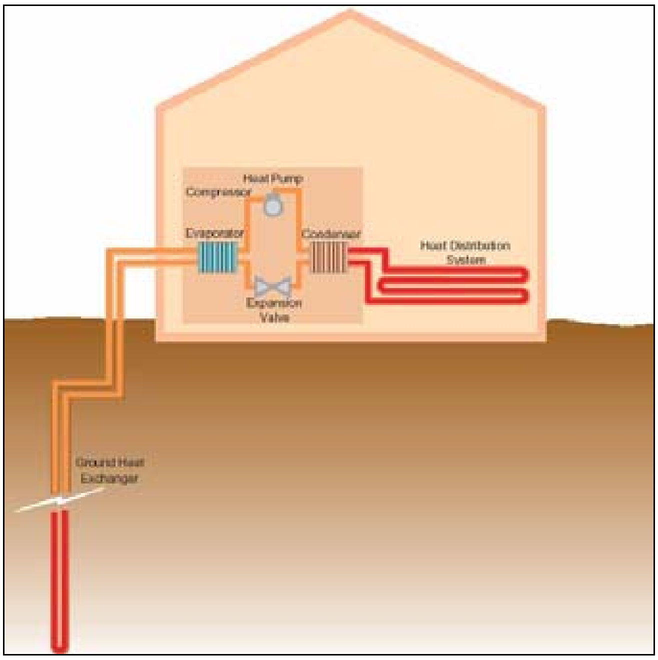


Figure 4.1: A typical GSHP system

Capital costs of GSHP installations typically range from £800 to £1,200/kW[1] of thermal output, with a large part of this needed for the installation of the ground loop. Longer pipe runs, deeper bore holes and ground type will all affect costs. System sizing, and hence cost, is highly dependent on accurate assessments of heating loads and the technology is usually most viable for highly insulated buildings. In order to reduce capital outlay, systems are often sized to supply a proportion of the total heat load (e.g. 50 – 80%), with a back-up system such as electrical heating to meet peak loads.

Figures 4.2 & 4.3: Borehole drilling rig (above); heat pump unit (right)

[1] Good Practice Guide No 339; Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems. Housing Energy Efficiency Best Practice Programme.

Design Issues

Symes Community and Library building may be suitable for a GSHP for the following reasons:

- The building will be highly insulated and is likely to exceed current Part L Building Regulations in this respect
- Installation of the ground loop can be undertaken during or prior to building construction
- A low-temperature underfloor heating system has already been specified for the heat distribution system
- GSHPs and ground loops are not visible from the building exterior and will therefore have no bearing on 'visual impact' planning issues
- A 3-phase electricity supply can be made available

Heat Pump Unit

GSHP suppliers are generally unable to provide detailed designs without in-depth information on heat loads, ground types and patterns of heat use within a building. Sizing software is usually used in heat pump design and there are often a number of design options with different configurations. A number of installers were consulted on the design configuration and various systems were discussed, ranging from a single heat pump unit with electrical top-up to a modular system using 2 heat pumps to meet 100% load. Unfortunately, it is difficult to make a valid comparison between systems in terms of performance and cost without detailed designs first being undertaken.

The choice of using a modular system with two separate heat pumps, or using a single unit will again depend on detailed design work being undertaken. Single heat pump units are rarely sized to meet 100% of heating load. Generally, a modular design may have lower running costs where 100% of the heat load is to be met, but is likely to have higher capital costs than a single heat pump unit with a conventional supplementary heat source for top-up. Differences in running costs will depend on the type and amount of supplementary heating used. Although a more expensive option in terms of capital cost, the use of 2 x 20kW units, for example would tend to have lower running costs than a single 40kW unit, as it would work more efficiently. The twin units may then work with 2 compressors each, for example, and have a modular output of 10, 20, 30 or 40kW as opposed to a 20 or 40kW output of the single unit with 2 compressors. The twin units would also have the added advantage of redundancy should one fail.

In the absence of detailed heat loss figures for the building, a general heating load of 50W/m^2 is assumed. Considering the building's floor area, this would result in around 44kW of heating requirement at worst-day conditions. However, worst-day conditions only account for a small percentage of the annual heating load and sizing a single heat pump to meet 100% load would result in an inefficient and costly system. For example, with domestic applications, a heat pump sized to meet 50% of design heating load is likely to meet 80-85% of the annual heating energy requirements. A supplementary heating system is therefore recommended to top-up the heat pump supply. This would typically be supplied by electric immersion heaters although, as mains gas will be readily available on site, a small gas boiler may also be an option to provide supplementary heating and domestic hot water (DHW).

Where specific heat zones are required, as likely to be the case with Symes Community Building, a buffer tank is normally used with the GSHP. This would be in addition to the tank used for domestic hot water.

Maximum water delivery temperature depends on the type of pump used, but is usually around 55^0C. However, CoP values will vary according to the delivery temperature output, with typical values as follows:

Temperature Output [DegC]	Operating CoP
35	4.5
45	3.7
55	3.0

Table 4.1: Typical GSHP delivery temps and CoPs

The buffer tank is likely to be kept at 40-45^{0}C for supplying the underfloor heating system. However, higher temperatures are required for domestic hot water and electric immersion heating is often used. The cost of using this form of top-up is usually less than running the heat pump at a higher CoP to gain higher temperatures. The electric top-up can then be used periodically to pasteurise the water at 55-60^{0}C.

For cooling purposes, a GSHP would need specifying as such and is likely to be a more costly option. This is not recommended as units with facility for cooling are not currently eligible under the Clear Skies grant scheme. Also, plans for the building incorporate a ventilation system which may have a cooling facility.

Ground Loop

Heat pumps are supplied in a variety of sizes e.g. 28kW, 32kW or 40kW with capital cost increasing significantly with size. A 40kW system would typically require either 10 x 70m boreholes or 10 trenches each 50 metres long. The trench option would require an area of at least 50m x 50m – which could be provided by the proposed superstore car park nearby.

Boreholes are around 100mm in diameter and can be arranged in a line or grid formation, but need to be a certain distance apart – typically 5m or more. Although these can be accommodated within the building's footprint beneath the ground floor, this is not generally recommended as future access would then be difficult (although a maintenance requirement in this respect would be highly unlikely). If the boreholes were located outside the building footprint, connections can be hidden underground in order to ensure zero visual impact of the ground loop from the outside.

Generally, a trench based system should work out cheaper than boreholes depending upon the nature of the site. However, discussions with the developers have indicated that problems with scheduling and arranging ground works in relation to the surrounding development may render this option impractical. For this reason, the borehole option only is considered below. It is advisable to contact the local planning authority to inform them of the intent to drill boreholes. Checks for any underground pipes, cables and ground type are normally undertaken by the drilling contractor.

GSHP case studies are presented in Appendix B.

Operation and Maintenance

Operation of a GSHP system is fully automatic and usually includes weather compensation to adjust for external temperature variations. Although less responsive than a conventional system, controlled heat delivery via an underfloor distribution system results in an even spread of heat, with no peaks or hot-spots. Manual adjustment is possible but should be used with care to ensure efficient operation of the system.

No maintenance is required for the ground pipes, which should last for 40+ years and be a once-only cost during the lifetime of the building. The heat pumps themselves require no annual routine maintenance. Heat pumps should have a longer life than a traditional boiler (20-25 years) although replacement costs will be higher than an oil or gas boiler.

If a small gas boiler is used as supplementary heating, there will be a small annual maintenance fee for boiler servicing.

Tariffs

Heat pumps tend to be operational for relatively long periods throughout a 24 hour period and the electricity tariff used to power the pump is therefore important in relation to running costs, with a mixture of on-peak/off-peak tariffs generally used. The proportion of time a system may operate on each part of a dual tariff is difficult to predict and will vary according to external temperature and use of supplementary heating. Tariff availability may vary geographically and at least one utility is now offering a tariff specifically for heat pump installations (Guernsey Electricity Ltd. -5.95p/kWh). Scottish and Southern are also currently examining the suitability of such tariffs, which will clearly affect running costs. Table 4.2 below lists examples of currently available domestic dual tariffs:

Utility	Standing Charge [p/day excl. VAT]	On-peak [p/kWh excl. VAT]	Off-peak [p/kWh excl. VAT]
Southern Electric	8.11	7.39	2.73
npower	-	18.62 (1st 728 units/year) 6.55 (thereafter)	2.81
Good Energy[1]	14.29	8.70	2.95

Table 4.2: Examples of dual-rate electricity tariffs

[1] Also a 'green' tariff – see Section 6.3.

The proportion of time a system is using an off-peak supply to an on-peak supply will obviously affect running costs. Unfortunately, it is very difficult to predict such a split as many factors are involved. In the analysis below, a split of 65% off-peak to 35% on-peak has been assumed. The presence of a solar PV system (see Section 4.2.1) would be advantageous in this respect as the more expensive daytime imported electricity could then be offset with the PV system output.

Economics

Discussions with a number of installers were held to obtain quotes for capital costs of a GSHP system. None were willing to provide more detailed costings without further information on the final building design regarding construction and heat loads, and especially in relation to ground loop installation costs and the ground works that may be required. The depth and number of boreholes will depend on their layout (grid or line), ground type and on the heat pump rating. Therefore, building heat loss calculations are required before any detailed costing can be achieved.

In assessing the economic and environmental aspects of a GSHP, a comparison is made below with a gas condensing boiler system. Table 4.3 compares capital and running costs, and gives simple payback periods where relevant. Assumptions and figures used are provided in Appendix A.

Two scenarios are compared:

A. 32kW GSHP with 6 to 8 x 70m boreholes plus 10kW top-up gas condensing boiler for buffer tank and domestic hot water

B. 44kW gas condensing boiler for 100% space and water heating

System type	Capital cost – heat pump installation[1] [£]	Capital cost – borehole installation [£]	Capital grant level for GSHP [%]	Marginal net capital cost[2] [£]	Annual running cost (fuel + maintenance) [£]	Proportion of space & water heating load met by GSHP [%]	Simple payback period compared to 'B' [Years]	Annual CO_2 emissions [Tonnes]
A	18k	26k	0	39,500	1,492	94	42	13.4
			50	20,250			19	
			70	12,550			10	
			90	4,850			<1	
B	N/A	N/A	N/A	(4,500)	2,316	N/A	N/A	23.1

Table 4.3: Economic Comparison of Scenarios – the GSHP system is assumed to use gas supplementary heating. If electric immersion was used instead, the payback period would be marginally higher.

[1] Includes supplementary gas heating system. GSHP quote provided by GeoScience Ltd. http://www.earthenergy.co.uk
[2] Net additional cost of GSHP over and above gas condensing boiler cost, at specified grant level. Does not include heat distribution system.

At grant levels below around 60%, a GSHP is not particularly cost-effective in terms of payback when compared to a gas condensing boiler at current gas prices. However, if further funding is secured to increase capital grant level, payback periods would reduce significantly as shown above. It is also worth noting that payback period is sensitive to gas price. For example, if the gas price used in the analysis increased by 20%, payback period would reduce from 19 to 13 years, at a 50% grant level. However, fluctuations in electricity prices will also have an effect.

It is also important to note that costs stated for the borehole work can vary significantly according to drilling conditions. Geoscience Ltd. has said that a 'worst case' scenario could add 50% to the borehole costs. At a 70% grant level, this would increase simple payback from around 10 years to 15 years. A more accurate quote can be obtained once the building design heat loss is known. Geoscience would then size the heat pump and boreholes and quote after researching the area's geology based on postcode and site plans.

4.1.3 Solar Hot Water

Overview

Solar water heating systems gather energy radiated by the sun and convert it into useful heat in the form of hot water. Systems have been available in the UK since the 1970's and the technology is now well developed with a large choice of equipment to suit many applications.

Solar water heating systems normally work alongside a conventional water heater to ensure year round hot water. A well-designed domestic system should provide almost all hot water requirements during the summer months and about 50% over a year.

A solar water heating system would typically comprise three main components:

- solar collectors – absorb and retain heat from the sun's rays and transfer this heat to a fluid
- hot water cylinder – stores the hot water that is heated during the day and supplies it for use later

- plumbing system - made up of simple piping and sometimes a pump, which moves the heated fluid around the system and through the hot water cylinder

The two main types of collectors are flat plate (Figure 4.4) and evacuated tube (Figure 4.5). The latter type is more efficient and hence occupies a smaller area, but can be more expensive. Collectors can be mounted on, or integrated within, an existing roof.

Figure 4.4: Flat plate collectors

Figure 4.5: Evacuated tube collectors

Design Issues

The roof of the proposed building has both flat and sloping areas with potential for solar technologies, the details of which are shown in Table 4.4 and locations in Figure 4.6. Ideally, solar panels should be orientated between south-east and south-west to maximise energy capture.

Roof Type	Description	Orientation	Approx. tilt angle from horizontal [Deg]	Approx. area [m^2]	Approx. area[1] available for solar panels [m^2]
A	Main roof area	Flat	0	500	250
B	Sloping roof over lift	15^0 west of due south	30	45	41
C	Sloping roof over plant room	15^o south of due east	30	36	36

Table 4.4: Roof details

[1] accounts for shaded areas and rooflights

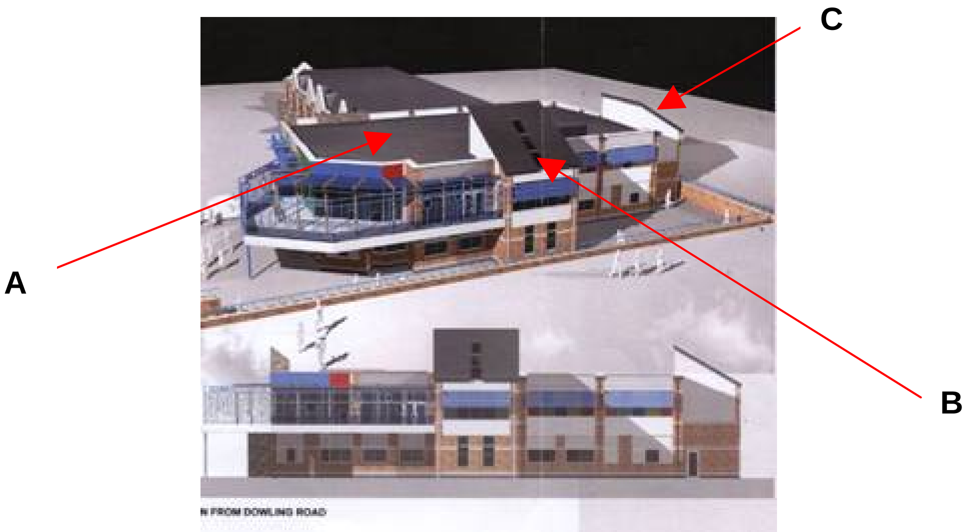


Figure 4.6: Symes Community and Library Building - proposed design showing roof areas

Hot water demand for the building is expected to be relatively small, with outlets in the kitchen and toilets. For sizing purposes, the heat demand of a large domestic property has been assumed i.e. around 6,000kWh per year. The system would typically be used to heat the domestic hot water tank, which would have an electric immersion top-up. However, a system could be designed to integrate with a GSHP and provide pre-heat to a buffer tank and/or DHW tank. Such a system would be costly, requiring specialist tanks and the additional need for a supplementary top-up heating system such as gas or electric immersion. Carbon savings will depend on which fuel the solar hot water system will displace. This may be gas or electricity used for the supplementary heating system.

Following discussions with developers, bolt-on systems are more likely to be implemented than roof-integrated due to the current stage of the development process. Roof B is the most optimum position in terms of solar energy capture and would easily accommodate the panel area required for a 6,000kWh demand i.e. around 6m^2. Location on the flat roof area would need angled console mounts in order to achieve a sufficient tilt angle to improve energy capture. The effect of shading from nearby obstacles has not been quantified, but is expected to be minimal considering the heights of the surrounding buildings.

Due to the adequate roof areas available, flat plate collectors are assumed to be more cost-effective than tubes. However, a photovoltaic system (see Section 4.2.1) may also be considered for certain roof areas.

Operation and Maintenance

Maintenance requirements are minimal; with a simple annual check required, and a 5-year replacement of antifreeze. Digital controls and display units are available for most systems allowing ease of monitoring and control. Annual cleaning of panels may be required but the tilt angles will promote a degree of cleaning from rainfall.

Economics

A standard system designed to supply around 50% of an annual 6,000kWh domestic hot water demand will need around 6m^2 of flat plate collector and is likely to cost in the region of £4,000-£6,000 (including standard storage cylinder).

Assuming that the system offset mains gas (at 1.6p/kWh) used in water heating, annual savings of around £48 would result. The simple payback period on capital cost, assuming a 50% grant (see Section 9), would be between 40 – 60 years.

CO_2 savings from avoided gas use would be around 0.57 tonnes/yr. If electricity (at 6.5p/kWh) was offset, the saving would be £195/yr. In this case, simple payback would be 10 – 15 years, with 1.29 tonnes/yr of CO_2 saved.

4.2 Options for On-site Electricity Generation

4.2.1 Photovoltaics

Overview

Photovoltaic (PV) systems utilise sunlight to provide electricity. Linked PV cells are encapsulated into modular panels - often a rectangular shape about a metre long. These are then interconnected to provide electrical power, which can be harmonised with grid electricity and fed back into the network.

There are two main elements to a solar PV system: the solar PV array and the Balance of System (BOS) components. The array consists of modules connected together. A module is the name used for a unit consisting of individual PV cells, e.g. a single panel or tile is referred to as a module. Currently the most common and commercially available solar cells are:

- **Monocrystalline Silicon Cells**
  Made from wafer thin slices cut from a single cylindrical crystal of silicon, these cells have typical efficiencies of around 15%. The manufacturing process is complicated and therefore expensive.

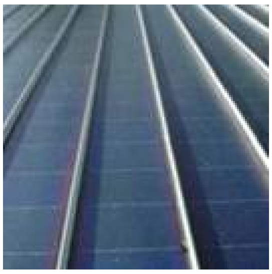
- **Polycrystalline Silicon Cells**
  These cells are made from wafer thin slices cut from an ingot of melted and recrystallised silicon. Typical efficiencies are around 12%. The manufacturing process is less complicated resulting in a cheaper product than monocrystalline.

- **Thin Film Cells**
  The vast majority of thin film is comprised of amorphous silicon. This is composed of silicon atoms in a thin homogenous layer deposited on a rigid or flexible metal plate. Although typical efficiencies are around 7%, these cells have a better efficiency than monocrystalline or polycrystalline cells in diffuse light and tend to have a greater yield per kW installed, depending on geographical location. This may be a good option if area is not a constraint. The manufacturing process is least complicated, normally resulting in the cheapest PV product available.

- **"Hybrid" Silicon Cells**
  This technology combines both monocrystalline and thin-film silicon to produce cells with the best features of both technologies. Typical efficiencies are around 18% - giving a greater yield per m^2. The manufacturing process is complicated and therefore results in a relatively expensive product.

Figures 4.7 to 4.13 below illustrate PV types:

Figure 4.7 - console mounted panels on flat (monocrystalline)



Figures 4.8 & 4.9 – 'AluPlusSolar' standing seam PV (amorphous)

Figure 4.10 (left) & 4.11 (above) – translucent BIPV for rooflights/flat roofs

Figures 4.12 & 4.13 – C21 BIPV roof tiles (polycrystalline)

Cells are rated in W_p - the power they will generate under standard test conditions: 25 °C with a light intensity of $1000W/m^2$. Such a light intensity is only achieved on clear, sunny days during certain times of the year.

Other types of 'thin film' cells also exist, such as CIS (copper indium diselenide), which recently came out top in a comparison study on different PV types. This study[1] compared energy yields at a UK site over a one-year period for identically-rated systems, and concluded that the best performing technologies yield up to 20% more energy per kW_p than conventional crystalline silicon PV. Value for money, in terms of installed cost per kWh generated, is therefore a more useful parameter than installed cost per system kW_p.

PV systems can be grid-connected or stand-alone, with the latter type normally using a battery facility to charge as required. The community building will clearly have a grid connection so it is only necessary to consider grid-connected systems in this instance. The balance of system components may consist of an inverter (to convert the DC electricity generated to AC), isolation switches, a combination of import/export/total generation kWh meters and possibly a display unit to show how much electricity the system is generating.

Studies have shown that PV systems in the UK will generate an amount of energy equal to that used in their manufacture (energy payback) within about 4-5 years[2], depending on PV type.

Design Issues

Note - the points mentioned in Section 4.1.3.2 regarding optimum orientation, preference for bolt-on systems and available roof area also apply to PV.

Using high efficiency PV (i.e. monocrystalline), the total available roof areas shown in Table 4.4 could potentially accommodate sufficient PV to meet more than the building's normal annual electricity requirements (not including GSHP). However, this is likely to involve excessive cost. In designing a system, a balance would therefore be needed between cost and energy yield, as well as aesthetics.

Positioning PV on the flat roof would need to avoid areas shaded by the sloping roof on the south elevation and by any other obstacles that may be incorporated in the final building design. Building-integrated photovoltaic (BIPV) options for flat roofs include 'glass' roofs or skylights using translucent PV laminates, or 'sawtooth' designs in order to achieve a tilt angle to increase yield. In costing BIPV, avoided costs of conventional roofing materials should also be taken into account. Bolt-on systems will use console mounts to achieve a tilt, with adequate spacing needed to avoid modules overshading each other. See Appendix X for illustrations.

The sloping roof areas could also incorporate integrated PV, allowing translucent materials to be used for natural daylighting. Alternatively a bolt-on array could be used in conjunction with conventional rooflights. Roof B is favourably orientated to the south and will receive around 99% of energy compared to optimum positioning. As Roof C faces more to the east, it will receive around 90% of optimum. In terms of appearance, PV will be more visible on the sloping roofs and, if thoughtfully designed, will be more aesthetically pleasing than a console-mounted array on the flat roof. However, the smaller areas involved will result in decreased energy yield.

Vandalism (also applies to solar thermal)

There are certain types of solar panels that are less-prone to damage by vandalism but a well-aimed projectile would be likely to cause some degree of damage. Individual panels or vacuum tubes can easily be replaced although the same model may not necessarily be available a few years down the line. Protective measures such as wire meshes can offer

[1] *Photovoltaics in the UK: An introductory guide for new consumers*. Environmental Change Institute/University of Oxford. 2003.
[2] *Energy viability of photovoltaic systems*, Alsema & Nieuwlaar, Energy Policy Vol 28 Issue 14, Nov 2000

protection but most suppliers are of the view that system efficiency will be adversely affected from shading effects. A PV installation at the York Eco Centre[1] incorporated UV stabilised polycarbonate sheets above the PV modules to provide protection against vandalism. It has been estimated that this reduces the output of the PV array by approx 5%.

'Photovoltaics in Buildings' No 5 (Newsletter of the DTI's Domestic Field Trial) states that most projects in areas of deprivation, often undergoing regeneration, have found that once ownership of the systems is recognised, i.e. once tenants have moved in, then there are few problems with vandalism and theft. Suitable positioning of panels will lessen the risk e.g. roof-mounted panels are less visible than wall-mounted and are likely to attract less attention.

Operation and Maintenance

PV systems have no operational requirements apart from occasional checks on performance. Maintenance is normally limited to annual cleaning of panels, although there is a degree of self-cleaning by virtue of the panel tilt.

Economics

Costs of PV are currently in the range £5k-10k/kW$_p$ for bolt-on grid-connected systems up to 10kW$_p$, with BIPV systems within this scale generally ranging up to £13k/kW$_p$, before avoided roofing costs are taken into account. To give an indication of costs and yields, a number of quotes have been obtained from PV suppliers, based on the roof types and areas for the proposed community centre.

There are many types and system sizes that can be considered. Four systems are compared in Table 4.5 below, ranging from a 4kW$_p$ system on the sloping roof area to a 20kW$_p$ system for the flat roof area. Roof C is similar in size and shape to Roof B so similar figures will apply, although energy yields will be lower due to orientation.

	PV module type	Installed capacity (kWp)	Approx. Area of Array (m^2)	Estimated installed cost (£) [1]	Approx. annual energy output (kWh)	Cost to output ratio (£/kWh/yr)	Value of annual energy output (£) [2]	Annual CO2 saving (tonnes)[3]	Simple Payback period (yr)
Roof A – main flat roof	Sanyo HIT – hybrid (console mounted)	20	240 (flat roof area)	49,600	18,000	2.8	1,170	7.7	42
	Sharp – polycrystalline (console mounted)	20	300 (flat roof area)	45,200	15,000	3.0	975	6.5	46
Roof B – sloping roof over lift	C21 roof tile – polycrystalline (BIPV)	4	40	32,600	3,200	10.2	208	1.4	157
	Shell – polycrystalline (BIPV or bolt-on)	4.5	36	13,925	3,600	3.9	234	1.5	60

Table 4.5: Comparison of PV Systems

Notes:

1. Costs provided by Solar Century Ltd. www.solarcentury.co.uk and PV Systems Ltd. www.pvsystems.com . VAT not included (usually charged at 5%). Offset costs for conventional roofing materials are excluded.

2. Costs assume capital grants of 60% for roof A; 48% for roof B C21 (£4,250/kW$_p$); 50% for roof B polycrystalline

[1] http://www.windandsun.demon.co.uk/projects_yorkeco.htm

3. Assumes all PV-generated electricity will offset imported electricity at 6.5p/kWh

4. CO_2 factor assumed is 0.43kgCO_2/kWh for grid electricity

It should be noted that the value of on-site electricity generated may be greater than assumed in the above table. For example, if all the power generated by the PV system is consumed on-site i.e. zero export, the combined value of avoided electricity imports and renewable generation tariffs (see Section 6), could be around 10-11p/kWh. This would have the effect of reducing simple payback periods by around one third, and could decrease further accounting for the value of Renewable Obligation Certificates (ROCs) and Levy Exemption Certificates (LECs).

Avoided costs of conventional roofing materials being replaced with PV should be taken into account once details are known and may benefit economics significantly.

4.2.2 Roof-mounted Wind Power

Overview

Urban locations have lower wind speeds than rural areas and can give rise to areas of increased turbulence due to the high number of obstacles present. Excessively turbulent wind flows can exert increased stresses on turbine components which may lead to noisier operation and premature wear and tear. Add to this the sensitivities surrounding visual impact and it is understandable why the urban environment is less suitable for conventional wind power technologies.

More recently, however, urban markets are potentially opening up with the introduction of technologies compatible with limited spaces on roof tops and small real estate footprints. Specifically, small-scale roof-mounted turbines have now been developed to cope better with lower wind speed and higher turbulence, whilst operating with minimal noise and vibration. Owing to the early stage of development, choice is limited with such roof-top devices. The following are two examples of Horizontal Axis Wind Turbines (HAWTs) at 'near market' status pitched at the domestic sector:

- SWIFT- Manufactured by a Scottish company, this device has a power output of 1.5kW. An annual energy yield of 4200kW is claimed by the manufacturers, although the annual average wind speed on which this figure is based is unspecified. Large scale production is expected to start in June/July 2005. http://www.renewabledevices.com/swift.htm

Figure 4.14: SWIFT turbine

- WINDSAVE – Also Scottish manufactured, the WindSave has a power output of 1kW at a rated wind speed of 12m/s, with a start-up speed of 3m/s. The device is claimed to generate 43.68kWh per week with an average annual wind speed of 6.2m/s. http://www.windsave.com

Figure 4.15: WindSave turbine

Novel designs in roof-top Vertical Axis Wind Turbines (VAWTs) are currently in development although little information currently exists on their status. The 'Wind Dam' is one such device that incorporates a directional wind concentrator to increase the relative wind speed. Development is still at the prototype stage at time of writing.[1] More ambitious designs for building-integrated wind power involve enhancing wind flows by virtue of the building design itself.

Design Issues

Roof-top installation is reasonably straightforward, with the output wired into the grid as with PV systems. To optimise energy yield, the turbine should be located on the south west side of the building, facing the prevailing wind direction, and be relatively unobstructed by nearby obstacles such as tall buildings or trees. Annual average wind speeds for the area are likely to be around 4 to 5m/s at 10m elevation.[2] which should be taken into account when estimating annual energy yield. More than one turbine could potentially be installed on the same roof to increase output. The potential for vandalism should also be assessed when choosing a location.

In the case of Symes Community and Library building, although installation of the domestic-scale devices mentioned above are not likely to generate large amounts of electricity, they will certainly be high profile due to their visibility. For this reason, it is useful to evaluate the 'start-up' and 'cut-in' wind speeds of the turbine i.e. the wind speeds at which the rotor will begin turning and the turbine begin generating. Estimates can be made of the proportion of the year during which the rotor will be turning – e.g. wind speeds below 2.5m/s are likely to occur for around 1,818 hours (21%) of the year for typical UK sites with an annual average wind speed of 4.5 m/s. This will be particularly important for installations where raising public awareness is a key objective.

[1] See http://www.exmoor-nationalpark.gov.uk/Projects/Sustainable_DevFund/Wind Dam.pdf for further information
[2] The DTI's NOABL wind speed database gives an annual average wind speed for the site of 4.7m/s at 10m above ground.

The turbine weight, mounting equipment, vibration and potential for noise disturbance should all be assessed for roof-mounted wind turbines. The two turbines mentioned above are claimed by the manufacturers to be acceptable in these respects due to their domestic application. At time of writing, neither device is accredited by the Clear Skies grant programme (see Section 9).

Operation and Maintenance

Roof-top wind turbines are generally designed to require zero routine maintenance and are fully automatic in operation.

Economics

The two roof-top devices that are most likely to be available in the near future are compared below:

Name	Rated power (kW)	Rated wind speed (m/s)	Annual energy yield at stated annual average wind speed [1]	Cut-in speed (m/s)	Installed Cost (£)[2]	Simple payback period [yrs]	CO_2 saving [t/yr][3]
Swift	1.5	Not specified	4,200kWh (wind speed not specified)	Not specified	1,700	6.2	1.8
WindSave	1	12	2,271kWh at 6.2m/s	3	1,200	8.1	1.0

Table 4.6: Economic comparison of roof-top wind turbines

[1] Value of electricity generated taken as 6.5p/kWh
[2] Prices quoted by suppliers do not include installation costs – hence an additional £200 is assumed here
[3] Carbon factor assumed is 0.43kgCO_2/kWh

Note – annual outputs given are those claimed by manufacturers and will vary depending on local conditions. For the typical urban wind speeds expected at the proposed site, annual energy yields are likely to be lower, and hence payback periods longer than the values stated above.

5 Carbon Emissions

Approximate carbon emissions for each technology considered are outlined in Section 4 and are summarised below in Figure 5.1:

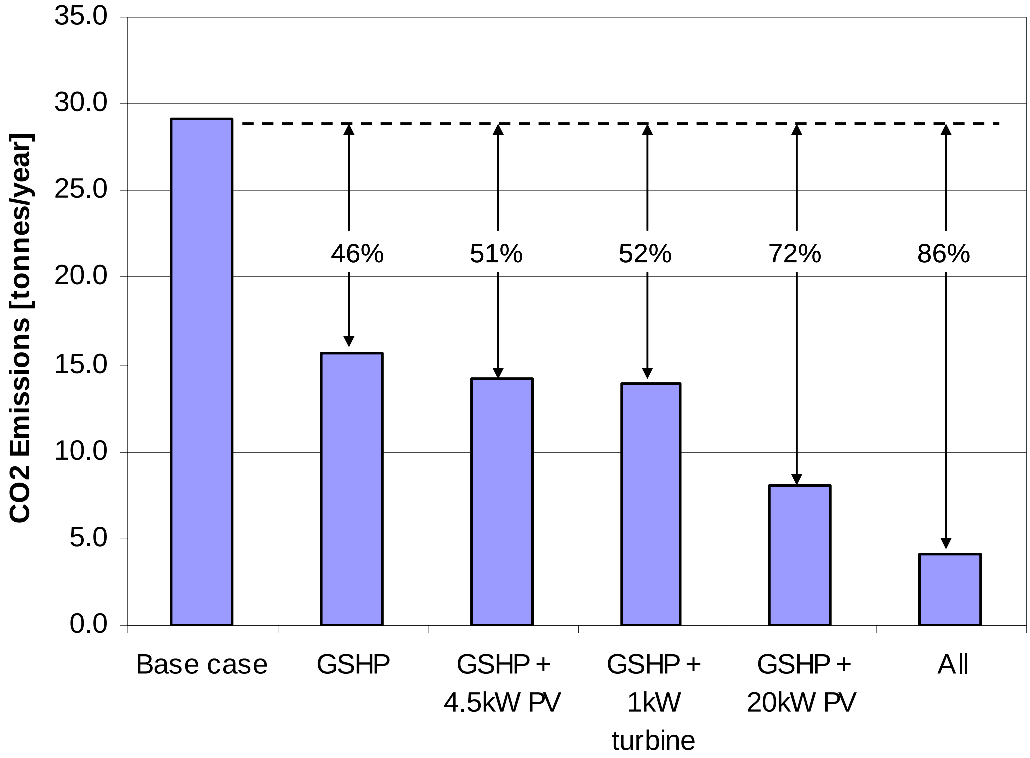


Figure 5.1: CO_2 emissions for various scenarios showing resulting % reduction from base case

The scenarios shown in Figure 5.1 are as follows:

a) **Base Case**: *Gas condensing boiler providing 100% space and water heating with standard electricity import tariff (6.5p/kWh)*

b) **GSHP**: *GSHP providing 94% space and water heating with gas boiler top-up*

c) **GSHP + 4.5kW PV**: *(b) plus 4.5kW polycrystalline PV system*

d) **GSHP + 1kW turbine**: *(b) plus 1kW roof-mounted wind turbine*

e) **GSHP + 20kW PV**: *(b) plus 20kW hybrid PV system*

f) **All**: *all system mentioned in (b) to (e) plus 6m^2 solar water heating system*

The base case of a gas condensing boiler heating system and a standard electricity supply would result in annual CO_2 emissions of around 29 tonnes. Should all measures be implemented, this would reduce to approximately 4 tonnes. Further measures would therefore be required to achieve a carbon-neutral building. To avoid excessive cost, the easiest way to achieve this is to subscribe to a 'green' electricity tariff, where all electricity supplied by a utility is matched by renewable energy generation. In this case, the top-up heating for the GSHP option would need to be switched from gas to electric immersion heating in order to achieve zero net carbon emissions. Carbon factors used in calculating emissions are 0.43kgC/kWh for electricity and 0.19kgC/kWh for mains gas.

Green tariffs are described further in Section 6.

6 Electricity Supply & Generation

6.1 Grid Connection Issues

In the case of wind power and solar photovoltaics, there are two main options for connecting the power from the system. The first is grid-connection, where any surplus electricity that is not used immediately on-site is exported to the local grid. The second is stand-alone battery storage, where the energy generated is used to charge a battery bank, which, in turn, supplies power for the site.

As the building will have a mains electricity supply, grid connection should be straightforward, making this a cheaper option than battery storage. Battery banks also require a secure area for storage and additional maintenance.

The size of the generator will dictate which guideline will apply to the grid-connection element of the installation. The G83/1 Engineering Recommendations were introduced for connections up to 16 amps per phase on 230V or multiphase 400V. This replaced the previous ER G77/1 and ER G83 and allows for, effectively, installations up to around 4 kW for low voltage single phase and 12 kW for low voltage 3-phase, referred to as the Small Scale Third Party Generating Limit (SSTPGL). Anything above this, such as a larger PV system or wind turbine, needed to comply with G59, and was likely to require greater connection costs using half-hourly metering.

‘Modification P81’ was recently introduced to allow small-scale generators, such as those conforming to G83/1, to use non-half hourly metering, which is a much cheaper option than half-hourly metering. However, in November 2004, Ofgem announced that the SSTPGL will be raised to 30kW. Subsequently, the scale of the PV and wind systems considered suitable for the Symes building will not require half-hourly metering.

Installers will typically include the installation of cabling and conditioning equipment within their scope of work. If a grid connected generator produces electricity surplus to the site’s requirements, an export agreement can be arranged with the distribution company (District Network Operator or DNO) and a supply agreement arranged with a supply company i.e. utility. This may or may not be economically attractive depending on the tariff offered.

Note – if renewable on-site generation is included in the building design for the Symes building, the incorporation of a suitable export meter should be considered in the electrical design if appropriate.

6.2 Value of Electricity Generated

A key support mechanism to help deliver government renewable energy targets is the Renewables Obligation, which came into force in April, 2002, and will remain in place until 2027. This is an obligation the Government has placed (in England and Wales) on electricity suppliers that a certain percentage of their electricity supply each year should come from renewable sources. This is currently about 4%, and will increase up to 10% by 2010, and 15% by 2015.

In order to demonstrate compliance, the suppliers need to have a sufficient number of Renewables Obligation Certificates (ROCs). A generator earns 1 ROC for every MWh (a 1000 kWh, or “units” of electricity) of renewable electricity generated. These ROCs may be traded, eventually to be bought by those electricity supply companies who don’t own enough renewable generation capacity of their own to meet their obligation. In short, this mechanism means that there is now a strong market for the development of electricity generation from renewable sources, with generators being offered attractive prices for the electricity they generate, as there is currently a shortage of supply of renewable electricity. As from 1st April 2004, all renewables generators, independent of size, are now entitled to receive the ROCs.

If the Symes building were to generate electricity from a PV or wind system, it is likely that most, if not all, of the power would be used on site – particularly if the electricity demand was increased by installation of a GSHP. Therefore, this on-site generation would offset imported electricity, giving each generated kWh the value, in savings, of the import tariff.

Some companies are now offering to 'buy' renewable electricity from generators in order to 'sell' on to purchasers of green energy. For example, Good Energy Ltd.[1] are currently offering 4p/kWh on total generation (on systems up to 30kW capacity) regardless of whether the renewable electricity is all used on site or exported. If all generated electricity was used to offset imports at e.g. 6.5p/kWh, this would increase the value of the renewable electricity to 10.5p/kWh. In addition to this, ROCs can be earned on the electricity generated.

As well as the Renewables Obligation, in April 2001, the Climate Change Levy came into force, which includes a levy on non-domestic users of electricity of 0.43p/kWh. Renewable electricity is exempt from the levy. Therefore, every MWh of renewable electricity generated also earns a Levy Exemption Certificate (LEC), which again can be traded, and which can be purchased by large users of electricity to avoid paying the levy.

6.3 Green Tariffs

Green electricity tariffs are offered by a number of utilities and are normally more expensive than ordinary tariffs, with the premium being used to benefit in some way the development of renewable energy. Being on a green tariff does not necessarily mean that the electricity you are using is coming from a wind turbine in Scotland. Many companies that offer green tariffs to their customers may not be generating from a renewable energy source at all. The majority of companies offering green tariffs support the funding of renewable energy projects through the tariff you pay them (i.e. a Green Fund). Although some companies do supply electricity from one or more renewable sources (i.e. a Green Power Supply), they may not generate over their legal obligation set by government targets. There are some green tariffs that do not generate from renewable energy sources nor contribute to renewable energy funds, but may pledge their support to renewable technology.

It is important therefore to look closely at the various tariffs and decide on priorities. For example, once all economically feasible measures have been implemented to reduce a building's CO_2 emissions, 100% renewable supply green tariffs are often used to bridge the gap to carbon neutrality.

The table below shows examples of green tariffs available and how they support renewables.

[1] http://www.good-energy.co.uk/homegenfaq.asp

Company Name	Tariff Name	Comments
Green Power Supplies		
Good Energy	Good Energy	Ensures renewable electricity is supplied above the company's legal obligation
Green Energy	Green Energy 10 and Green Energy 100	Does not generate more than the company's legal obligation
Ecotricity	Ecotricity	Does not generate more than the company's legal obligation, although directly invests proceeds into building new wind power
Green Funds		
London Electricity/SWEB	Green Tariff	Premium portion of tariff will be put into a fund and matched by an equivalent amount by SWEB/London Electricity to support new renewable energy projects. However, customer will not be buying electricity generated from renewable energy sources.
Powergen	Greenplan	As for SWEB's Green Tariff
Scottish power	Green Energy	Premium portion of tariff goes to a trust fund for renewable energy development, but customer will not be buying electricity generated from renewable energy sources.
Other		
npower	Juice	No 'premium' charged, but tariff has been developed by npower in conjunction with Greenpeace, who aim to encourage public support for off-shore wind farms. Customer will not be supporting any additional electricity being generated above that which the company will obtain to meet its legal obligation.

Table 6.1: Examples of Green Tariffs

See www.greenelectricity.org for up-to-date prices on each tariff and contact information.

7 Planning Consents

Being invisible to outside observers, a GSHP will normally require no specific planning consents. However, the local planning authority should be made aware of the intention to drill boreholes. Although more visible, PV and solar water heating will rarely require specific consents for a new-build project.

Roof-mounted wind turbines are in their infancy so there are few case studies to examine and no specific references are made in current planning guidance regarding this technology. However, significant emphasis on encouraging renewable generation in buildings is now generally given and small roof-mounted turbines are unlikely to be a barrier to planning.

PPS22, the national Planning Policy Statement on renewable energy,[1] states that:

"Local planning authorities and developers should consider the opportunity for incorporating renewable energy projects in all new developments. Small scale renewable energy schemes utilising technologies such as solar panels, biomass heating, small scale wind turbines, photovoltaic cells and combined heat and power schemes can be incorporated both into new

[1] http://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/source/odpm_plan_source_030334.doc

developments and some existing buildings. Local planning authorities should specifically encourage such schemes through positively expressed policies in local development documents."

On a local level, one of the goals of Bristol's Community Strategy is to create and develop a carbon-neutral city by tackling the causes of climate change. Bristol Climate Protection and Sustainable Energy Strategy Action Plan 2004/6 highlights the potential role of renewables, and the Bristol Sustainable Development Guide for Construction specifically encourages their use.

8 Potential for Education & Awareness Raising

The building will play a high profile role in the local area and is likely to accommodate a variety of occupants ranging from the general public using the library to community groups holding evening meetings. In fulfilling this role as a community facility, the centre will therefore present a good opportunity for users and the local community to experience renewable energy at first hand. As an 'Excellent' rating is already planned under the BREEAM assessment, the addition of renewable energy systems creates potential for the centre to become a regional exemplar in sustainable energy building design and use.

Visibility of systems in action will, of course, vary with types installed. For example, a GSHP will not be visible to building users, whereas solar thermal or PV panels located on the sloping roof faces will. A roof-mounted wind turbine would have the largest visual impact, but care will be needed with its exact location as it may be vulnerable to vandalism.

Inexpensive display boards in the building reception area can easily be incorporated to explain the technologies installed in simple terms. For PV and wind, real-time LED display boards are often used to indicate the instantaneous power and energy generated to date.

9 Sources of Funding

Grant funding for the project can potentially be sourced from the following schemes:

Name of Initiative	Clear Skies
Description and main criteria	Fixed grants are available on a range of renewable installations, with separate conditions for household and community applications. Technologies supported include solar water heating, micro-wind, micro-hydro, ground source heat pumps powered by renewable electricity, automated wood pellet fuel stoves and wood fuelled boiler systems. Community applications are invited from not-for-profit organisations registered as a legal entity – e.g. community/environmental groups, local authorities and public service organisations. SMEs are not eligible. Applicants must demonstrate evidence of real community involvement and engagement and the installation must enhance public awareness/ understanding of renewable energy. Preference is shown for schemes that; are located in an area of social need; can demonstrate cross-community involvement; have evidence of match funding. The following conditions apply to both community and household applications: schemes must use components **on the DTI's approved product list**; all measures must be professionally installed; grant applications can not be retrospective.
Funder	DTI
Funding type	Capital funding available
Amount of Funding per project & Leverage	Household - fixed grants vary from £500 to £5000 depending on the technology Community - Maximum of 50% of total capital and installation costs or £100,000, whichever is smaller.

Date of next call	Household grant applications can be made at any time Community capital funding applications – Four competitive funding rounds will be held per year. At time of writing, application deadlines for 2005 have yet to be announced. Funding for feasibility studies has now expired. Application forms available from the Clear Skies website – www.clear-skies.org

Name of Initiative	**Regional Electricity Supplier Funds – Powergen Green Plan (in collaboration with WWF)**
Description and main criteria	Open to community groups and not for profit orgs. (Local Authorities may be considered, but cannot lead the application). Projects must have environmental and community benefits whilst using the greenest energy supply. Bid must provide sponsorship opportunities for Powergen and WWF. There are no geographical restrictions, and Powergen are actively looking for bids outside their traditional patch of East Midlands.
Funder	Powergen Green Plan
Funding type	Development and Capital funds
Amount of Funding per project & Leverage	Development and capital funding considered for between £2.5 and 25K. Can match fund with public sector funds (and this will be smiled upon) although not absolutely necessary. 80% of funds awarded are given up-front, with the remaining 20% on project completion,
Date of next call	Applications usually considered twice yearly. Next deadline – 31/12/04. Successful projects are not revealed until approx. 3 months after deadline.
Contact for more information	Tel: 0870 419 1521 www.powergen.co.uk

Name of Initiative	**Regional Electricity Supplier Funds – EDF Green Energy Fund**
Description and main criteria	Green funds are set up by electricity suppliers which have fund-based green electricity tariffs. The premium paid by customers contributes to the fund to support the development of new renewable energy projects. All projects funded under the scheme must be located within the SWEB or LE supply areas, and be for the installation of a renewable energy generation plant. Limited funds are available for feasibility studies. Preference is given to projects that with demonstrable community engagement and benefits.
Funder	EDF Energy
Funding type	Development and capital funding
Amount of Funding per project & Leverage	A maximum of £30,000 capital funding, or £5000 toward cost of feasibility studies. Partnerships are not essential.
Date of next call	Submissions are invited at any time, and funding decisions are made approximately every 3-6 months, depending on the number of applications received.
Contact for more information	Mark Thompson 01273 428641

Name of Initiative	Regional Electricity Supplier Funds – Scottish Power's Green Energy Trust
Description and main criteria	Green funds are set up by electricity suppliers which have fund-based green electricity tariffs. The premium paid by customers contributes to the fund to support the development of new renewable energy projects. Usually projects funded under the scheme must be located within the supplier's traditional supply area. Npower's renewable energy product 'Juice' is for green supply and currently has no fund attached to it for project work. **Scottish Power's Green Energy Trust**, does not restrict applications by geographical area. The fund aims to create new renewable energy sources; encourage R&D in renewable electricity; promote education in the community on renewable energy generation
Funder	Scottish Power (Green Energy Trust)
Funding type	Development and Capital funds
Amount of Funding per project & Leverage	The Green Energy Trust will fund up to 50% of total project costs
Date of next call	Applications are considered at least 3 times a year. See contact below for application deadlines.
Contact for more information	(0141) 568 4615 Claire.Doherty@scottishpower.com

Name of Initiative	Major Photovoltaics Demonstration Programme
Description and main criteria	In May 2002 the Department of Trade and Industry introduced the first phase of it's major photovoltaic (PV) demonstration programme. The £20 million of the first, 3 year phase of funding is for grants of between 40 and 60% of total installation costs for householders, businesses and social housing groups. There are 4 types of grant, the aim of which is to stimulate the demand for solar electricity.
Funder	DTI
Funding type	Capital funds
Amount of Funding per project & Leverage	Small-scale applications (0.5–5 kWp) – Stream 1 – These grants are available for: owners of domestic dwellings, organisations with less than 250 employees and less than £25 million annual turnover, public bodies for use on public buildings (e.g. schools, health centres, etc), voluntary/ charitable organisations and community groups. Bolt-on systems are eligible for a capped grants of the lesser of £3,000/kWp or 50%. Integrated systems will be eligible for a capped grant of the lesser of £4,250/kWp or 50%. Approval is on a rolling basis and grants are fairly automatic, provided applications meet certain criteria. You have six months from grant approval to finish the work, and once the installation is complete and the required paperwork filled in, the grant is paid over to you. 2. Large and medium-scale applications for social housing groups and larger-scale public authority building projects (5-100 kWp) – Stream 2 - Grants for up to 60% of the total installation costs. Applications are made on a quarterly competitive call basis. An independent panel consider the applications and if the application is approved you have 12 months to complete the installation. The grants are paid in 2 stages: up to 70% at approval and 30% on completion. 3. Large and medium-scale applications for commercial organisations (5-100 kWp) – Stream 2 - For commercial organisations the funding is up to 40%. Applications are made on a quarterly competitive call basis. An independent panel consider the applications and if the application is approved you have 12 months to complete the installation. The grants are paid in 2 stages: up to 70% at approval and 30% on completion.

	4. Off-grid PV applications – Both Stream 1 and Stream 2 – Off-grid projects have a separate application form with different criteria. The grant will cover all eligible costs currently covered in the grid connected grant (i.e. modules, inverters, installation, reasonable other costs including scaffolding, roofing and structural work). However, the funding will not cover batteries or complex charge controllers and only building related off-grid applications will be eligible for funding (i.e. no boats or caravans). The same levels of funding apply as for grid-connected systems.
Date of next call	See above
Contact for more information	http://www.est.org.uk/solar

Table 9.1: Potential Grant Funding Sources – this list is not exhaustive, but includes the main schemes that are applicable

The two most likely general funding sources are Clear Skies and the EDF (SWEB) Green Energy Fund. At time of writing, the Clear Skies Scheme is currently being reviewed and application deadlines for 2005 have yet to be confirmed. Community grant deadlines have been quarterly up to now and decisions are made 6-8 weeks after the deadline.

The EDF scheme deadlines have typically been every 6 months with the next one due 1 June 05, although this may be increased to quarterly depending on the number and rate of applicants. Decisions on applications can take some time and expected decision dates should be queried on application.

The PV grants funding programme has a quarterly deadline for systems over 5KW. Smaller systems are approved on a rolling basis and grants are fairly automatic.

The chances of obtaining funding are very good on all three counts. The potential for awareness-raising is a key factor for both Clear Skies/EDF funds along with evidence of community support and benefit, and the Symes Community Building would score highly on these. A GSHP would be looked upon favourably as relatively few grants have been issued for this technology. Considering these factors, there is good potential of securing a 70-100% grant for a GSHP installation.

10 BREEAM Assessment

A bespoke BREEAM (Building Research Establishment Environmental Assessment Method) spreadsheet has been prepared to assess the building. Under a range of environmental categories and building functions, credits can be awarded for certain measures to obtain a rating. The incorporation of renewable energy measures will have a significant effect on the overall score and will help to achieve an 'Excellent' rating.

Appendix D lists the main elements relating to renewables and the criteria for scoring credits. The 'Energy and Transport' section has the highest score weighting (25%) of all the categories.

11 Conclusions

11.1 Summary of Options Appraisal

A range of options for the incorporation of renewable energy systems into the Symes Community and Library Building has been presented, along with the issues surrounding their installation and use. On-site 'embedded' renewable energy systems now offer ways for buildings to dramatically reduce their carbon emissions and reliance on fossil fuels. This is especially true for new build projects, where systems can be integrated into the building design. When combined with energy efficient design and a green electricity tariff, the building can approach a carbon-neutral status, with zero net carbon emissions resulting from its day to day running.

The options appraisal undertaken for this report has shown that PV, solar water heating, ground source heat pumps and roof-mounted wind power are all technically feasible for the proposed building. Each would contribute to some degree in meeting the overall energy demand and there is scope to 'pick and mix' between the various technologies and design smaller or larger systems for each one. Ultimately, capital cost considerations are likely to be a critical factor in choosing a system, although an indication of lifetime costs by comparing payback periods should also be assessed. It should be noted that payback periods are sensitive to fuel prices and small increases in, for example, the cost of mains gas, may result in significant reductions in payback period. CO_2 savings resulting from each measure may also be ranked.

Table 11.1 below summarises the main results of the options appraisal:

Technology	System option considered	Capital cost after 50-60% grant [£][1]	Proportion of building heat or electricity[2] load supplied [%]	Simple payback period [yr][3]	CO_2 savings [tonnes/yr][4]	Capital cost required for CO_2 savings [£/tonne CO_2/ yr]	Main points to note
Heat							
GSHP	32kW with 10x70m boreholes	20,250	94	19	13.4	1,511	• Less space needed with borehole system than trenching • System not visible from outside building • Requires a top-up supplementary heating system (small gas boiler or electricity). Gas is assumed here. • Requires accurate heat load assessment before detailed design and costing • Local planning authority should be notified of intent to drill boreholes • Drilling costs can vary significantly depending on ground type and conditions, increasing by 50% for 'worst case' • Requires three-phase electricity supply • No routine maintenance required
Solar water heating	6m^2 panel area 'bolt-on' system	3k	2.7	60	0.6	5,263	• Can be integrated with roof or bolt-on • Can be integrated with GSHP system but requires specialist hot water tank • Figures shown assume mains gas is offset. Payback would decrease to 10-15 years if offset fuel is electricity
Electricity							
PV	20kW hybrid	49.6k	93.3	42	7.7	6,442	• Bolt-on systems assumed for 20kW arrays • Bolt-on or integrated assumed for 4.5kW array • More suitable for south-facing sloping roof area • Potential for shading obstacles should be assessed • Payback periods may vary depending on value of electricity generated. 6.5p/kWh has been assumed here
	20kW polycrystalline	45.2k	77.7	46	6.5	7,007	
	4.5kW polycrystalline	13.9k	18.7	60	1.5	9,283	
Roof-mounted wind power	1kW	1.2k	11.6	8.1	1.8	667	• Not yet accredited by Clear Skies for grant funding • Requires clarification of energy yield with estimated site annual average wind speed • Most visible renewable technology • Need to locate away from obstacles • Suppliers claim virtually noiseless operation • Potential to install several devices to increase yield

Table 11.1: Summary Table of Options Appraisal

Notes (see Section 4 for full details & assumptions):

[1] GSHP cost given as net additional cost over and above gas condensing boiler ('base case') cost, at 50% specified grant level. Costs for PV assume capital grants of 60% for roof A; 48% for roof B C21 (£4,250/kW_p); 50% for roof B polycrystalline. Grants may be higher if more than one funding source is obtained.
[2] Figures for electricity do not account for GSHP demand
[3] Assumes all generated electricity will offset imported electricity at 6.5p/kWh
[4] CO_2 factor assumed is 0.43kgCO_2/kWh for grid electricity and 0.19kgCO_2/kWh for mains gas

In order to easily compare payback periods, running costs and CO_2 savings, the various technologies are ranked in Figures 11.1 to 11.3 below. 'Base Case' is defined in Section 5. Assumptions with grant levels, etc. stated in Table 11.1 also apply unless stated otherwise. For the electricity-generating technologies, results are shown for two values of generated electricity – 6.5p/kWh and 10.5p/kWh for reasons given in Section 6.2.

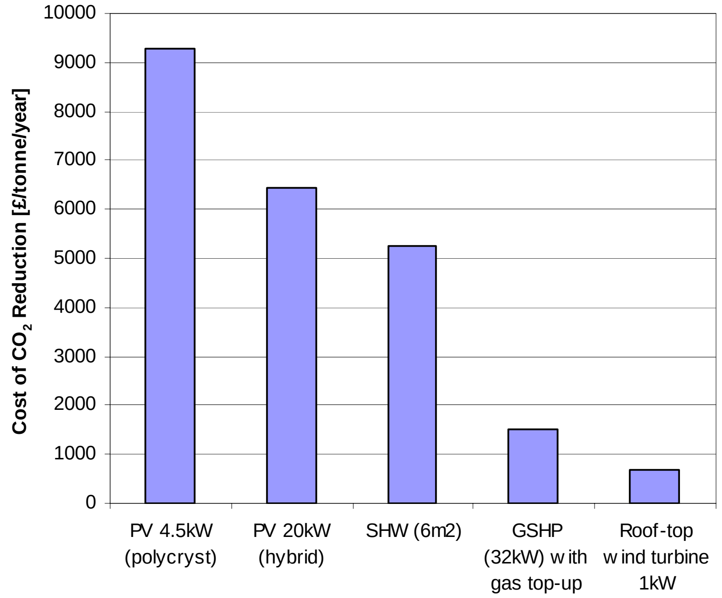


Figure 11.1: Comparison of capital spend required per annual tonne of CO_2 saved for each technology

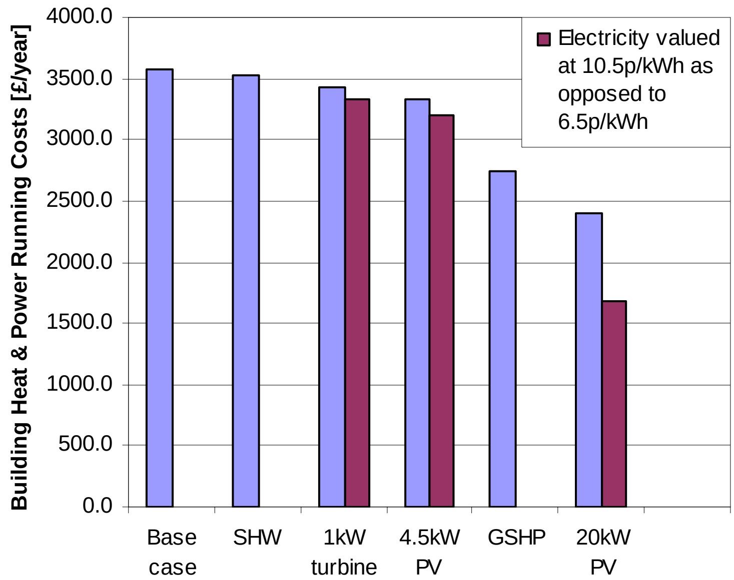


Figure 11.2: Comparison of building heat and power running costs (fuel + operation + maintenance) after the individual application of each technology.

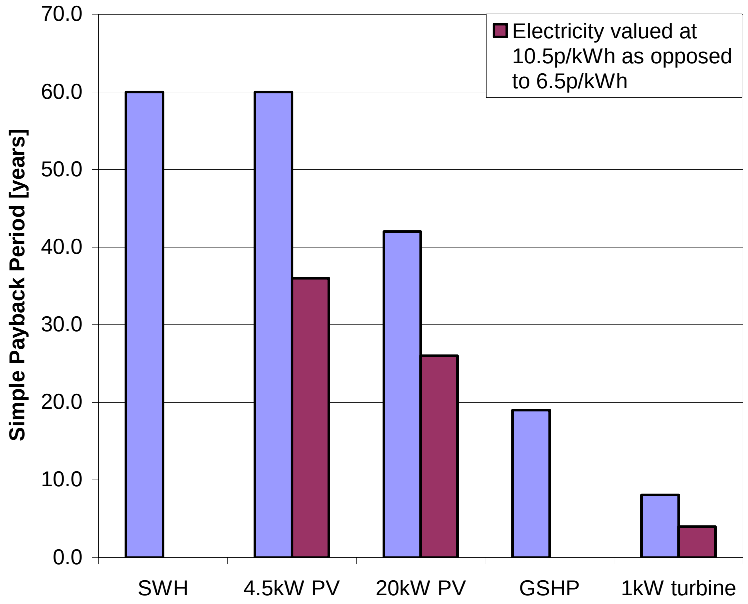


Figure 11.3: Comparison of simple payback period for each technology

11.2 Recommendations on Technologies Considered

<u>Ground Source Heat Pump</u>

A ground-source heat pump would be a worthwhile renewable energy measure to consider for the following reasons:

- In terms of whole-life costs, a GSHP starts to become competitive with mains gas at a 60% grant level on capital cost. A Clear Skies grant of 50% can be combined with other potential funding sources e.g. EDF Green Energy Fund, to make this option economically attractive. Considering the community-based nature of the building, CSE's experience would indicate that there is a good chance of obtaining the level of grant needed (around 90%) to make this option competitive on capital cost with a condensing gas boiler. Specific payback periods will require capital grant levels as follows:

  - 15 year payback requires a 59% grant
  - 10 year payback requires a 69% grant
  - 5 year payback requires an 80% grant

- Running costs will be less than a conventional gas condensing boiler due to annual savings in fuel and maintenance. The example shown in this report indicates that savings of £825 per year may be achieved.

- In terms of carbon savings, a GSHP will be the most significant and save the most CO_2 of the technologies considered. If a 'green' electricity power supply is sourced, the building could achieve zero net carbon emissions, although tariffs may be more expensive and affect payback periods.

- A borehole option would require a narrow strip of land alongside the building and nothing outside will be visible following the installation, hence planning consents relating to visual impact will not be affected. A trench-based system would require a larger area of land e.g. Morrison's carpark, and, although cheaper, may not be an acceptable option.

- The existing plans for the building are compatible with a GSHP i.e. underfloor heating and a high level of insulation.

More detailed costings should be obtained from an installer once the accurate design heat loss is established for the building. Borehole costs can vary significantly according to drilling conditions, increasing by as much as 50% for 'worst case' scenarios. The most appropriately-sized heat pump can then be specified with recommendations for a top-up supplementary heating system – either a small gas boiler or electric immersion heating. The initial assessment described in this report indicates that a gas supplementary system is likely to be marginally more cost-effective due to lower running costs, especially if a gas supply to the building is intended in any case e.g. for kitchen use.

A GSHP installation would be essential to the building as a whole in achieving zero net carbon emissions. However, the building would also need a 'green' power supply and an electric supplementary heating system. Such an installation would be the first of its kind in Bristol and, combined with the building's BREEAM 'Excellent' rating, would be an important exemplar for the area.

Solar Water Heating

Cost-effectiveness for the SHW system will depend on the fuel it will displace i.e. mains gas or electricity. For the latter, the payback period would be more attractive, making this a recommended stand-alone option. However, should a GSHP also be considered, the viability of SWH will depend on the contribution of the GSHP to water heating. If this is high, the economics of SHW are not likely to be viable. Although technically possible, integration of a solar system with a GSHP will require careful design and additional expense for suitable heat exchanger tanks. A SWH system would be additional to the supplementary heating system (gas or electric) for the GSHP and would not be a replacement. Carbon savings will be relatively low, again depending on displaced fuel type.

The roof area available should accommodate SHW panels in addition to PV if necessary, as relatively little space is required for the system size proposed. Visibility will depend on which roof is considered.

Photovoltaics

PV systems are still one of the most expensive of the renewable technologies and have relatively high payback periods even after application of a 60% grant on capital cost. Nevertheless, on new build, systems can be very flexible in design and the Symes building could easily accommodate a 20kW system to supply a significant proportion of electricity demand, or, for example, a 4kW system which would generate a relatively small amount, but would also be highly visible and help raise the profile of the building. The decision will therefore depend on funds available. A larger system would incur higher capital costs, but economy of scale would generally make this option more cost-effective in the long-run. This is evident from the 20kW system considered above achieving the highest annual savings in total heat and power running costs.

Avoided costs of conventional roofing materials being replaced with PV should be taken into account once details are known and may benefit economics significantly.

A GSHP is likely to be more cost-effective and result in higher carbon savings over a PV system. Therefore, it is recommended that PV be given a lower priority than a GSHP in this case.

Roof-mounted Wind Power

One or more roof-mounted wind turbines would be a simple, highly visible and relatively cost-effective measure to install, and is recommended for these reasons. A single turbine would contribute a modest amount to electricity supply and carbon savings, so multiple devices could be considered. However, devices are not fully commercially available at time of writing and are not yet accredited for the DTI's Clear Skies grant programme. Moreover, little data has been released concerning the performance of these systems at various annual average wind speeds and manufacturer's claims should be treated with caution.

As well as being highly visible, a roof-mounted turbine may also be vulnerable to vandalism and would need to be located with care in this respect.

General Comments

No planning barriers are foreseen for the technologies considered and recent changes in national and local planning guidance generally encourage the use of renewable energy in new developments. The building will play a high profile role in the local area and will therefore present a good opportunity for users and the local community to experience renewable energy at first hand. The incorporation of renewable energy systems will assist in achieving an 'Excellent' rating under the BREEAM assessment and creates potential for the centre to become a regional exemplar in sustainable energy building design and use.

11.3 Next Steps

Capital and running costs will be the major influence in any decision resulting from this report's recommendations. Although costs and resulting payback periods stated are mostly rough estimates based on initial installer quotes and specified grant levels, they should help to rank the options in terms of cost-effectiveness.

The extra capital costs required to incorporate renewable options will need to be considered within an agreed budget for the building and these will largely depend on grant availability. It is therefore recommended that funding bids are submitted as soon as possible, should any measures be taken-up. Most grant applications will, at some stage, require detailed installer quotes and these should be obtained at an early stage. Timing will also be important and lead times should be sought from suppliers in order to fit with the main project schedule.

In the case of the GSHP, a more detailed quote should be obtained once accurate building heat loss parameters are known. The economic analysis should then be re-assessed based on new capital costs and the final design of the system. Opportunities to visit existing installations should be explored to gain first-hand knowledge of experienced users. Case studies are presented in Appendix B.

Appendix A

GSHP CALCULATIONS

Heat Loads

Floor Area [m2]	877
Design Heat Loss [W/m2][1]	50
Design Space Heat Load [kW]	**43.9**
Annual energy required [kWh][2]	**109600**
Equivalent full-load hours [Hrs]	2499
Water Heating	
Hot water tank capacity [litres]	210
Refills per day	2
Entry temp [degC]	10
Exit temp [degC]	65
Temp rise [degC]	55
Max recovery time [mins]	60
Daily energy required [kWh]	26.86
Design Water Heat Load [kW]	13.43
Annual energy required [kWh]	**9804**
Total Annual Energy Required [kWh]	**109600**

Notes

1 General figure for Part L new-build
2 Based on based on suggested figure in 'Energy Efficiency in Buildings; CIBSE Guide F, 2004 for community centre
3 CoP will vary depending on system design and during operation
4 Figure suggested by supplier for 32kW system
5 Estimate only
6 Based on Southern Electric dual rate tariff
7 Competitive tariff for typical consumption level
8 Assumes capital cost is included in general GSHP cost
9 Contigency sum

Carbon factors used:-
0.43kgCO2/kWh for grid electricity
0.19kg/CO2/kWh for mains gas

All costs are estimates

GSHP with Gas Boiler Top-up

Heating Fuel Costs

GSHP	
Heat Pump CoP[3]	3.7
% of total annual energy to supply[4]	94
Annual heat energy output [kWh]	103024
Annual electrical energy input [kWh]	27844
% of supply during on-peak[5]	35
% of supply during off-peak	65
On-peak tariff excl. VAT [p/kWh][6]	7.39
Off-peak tariff excl.VAT [p/kWh]	2.73
Annual fuel cost of heat pump [£]	**1214**
Gas Boiler Top-up	
Gas boiler seasonal efficiency [%]	90
% of total annual energy to supply	6
Annual heat energy output [kWh]	6576
Gross annual energy required [kWh]	7307
Gas tariff incl CCl excl. VAT [p/kWh][7]	1.65
Annual gas standing charge [£]	32
Annual fuel cost of top-up gas boiler [£]	**153**
Elec Immersion Top-up[8]	
% of total annual energy to supply	6
Annual elec energy input [kWh]	6576
Annual fuel cost of top-up immersion [£]	**287**
Total Annual Fuel Cost -GSHP with gas top-up [£]	**1367**
Total Annual Fuel Cost -GSHP with elec top-up [£]	**1501**

Capital Costs

32kW GSHP [£]	43000
Marginal cost cf 44kW gas boiler	38500
Grant level [%]	50
GSHP marginal cost including grant [£]	19250
Top-up gas condensing boiler (10kW) [£]	1000
Total Capital Cost with gas top-up [£]	**20250**
Total Capital Cost with elec top-up [£]	**19250**

Annual Operation & Maintenance Costs

GSHP [£][9]	50
Top-up gas condensing boiler (10kW) [£]	75
Total Annual O&M Cost with gas top-up [£]	**125**
Total Annual O&M Cost with elec top-up [£]	**50**
Simple payback compared to all gas (gas top-up) [yrs]	**19.1**
Simple payback compared to gas (elec top-up) [yrs]	**19**
CO2 emissions (gas top up) [tonnes/yr]	**13.4**
CO2 emissions (elec top-up) [tonnes/yr]	**14.8**

Gas Boiler Only

Heating Fuel Costs

Gas boiler efficiency [%]	90
Gross annual energy required [kWh]	121777.8
Gas tariff incl CCL excl. VAT [p/kWh]	1.6
Annual gas standing charge [£]	168
Annual fuel cost of gas boiler [£]	2116
Total Annual Fuel Cost [£]	**2116**

Capital Costs

Gas condensing boiler (44kW) [£] + hot water tank	4500
Total Capital Cost [£]	**4500**

Annual Operation & Maintenance Costs

Gas condensing boiler (44kW) [£]	200
Total Annual O&M Cost [£]	**200**
CO2 emissions [tonnes/yr]	**23.1**

Table A1: GSHP calculations and assumptions

Appendix B

FURTHER INFORMATION & CASE STUDIES

Solar Water Heating

Websites
The Solarserver Forum for Solar Energy http://www.solarserver.de/index-e.html
The Solar Club http://www.cse.org.uk/solarclub/f_solarclub.html
Manufacturers sites with useful information include http://www.solar-design.demon.co.uk/index.htm and http://www.thermomax.com/

Written Material
Tapping the Sun: A Solar Water Heating Guide, Centre for Alternative Technology 1994
Solar Water Heating A DIY Guide, Centre for Alternative Technology 1994
The Practical Solar Handbook, a step by step guide to installing your own solar hot water system, Anthony Bushell 1994
Side by Side Testing of Eight Solar Water Heating Systems, ETSU 2001
Downloadable reports from the DTI, relevant reports under solar
http://www.dti.gov.uk/renewable/pdf.html

Case Studies
DTI Case studies online http://www.dti.gov.uk/renewable/caseStudies/all.html
Caddet case studies online http://www.caddet-re.org/technologies/index.php

Summaries of some useful case studies

Location	Scale	Technology	Application	Web Address
Oxford,	An experimental solar house	5m^2 solar thermal collectors	Pre-heat hot water	www.caddet-re.org/infostore/details.php?id=3143&section=general
Phoenix House, Leicester,	Leicester City Council buildings – 140 people.	2m^2 Viessmann Duosol evacuated-tube solar collector.	Pre heats water to 45°C for a condensing boiler	http://www.dti.gov.uk/renewable/index.html
New Walk Centre, B-Block, Leicester	Leicester City Council admin centre, 400 staff & council restaurant	Six Viessman Calorsol-W classic flat solar collectors. Total area = 10m^2	Pre heats 400 litres of water from 10-15°C to 45°C (in summer)	http://www.dti.gov.uk/renewable/index.html
Cossington Street Sports Centre, Leicester	Leisure centre – 2500 gallons of water	Hitachi NEG.SK21D evacuated-tube solar collector (3m^2)	Heating 2500 gallons of water from 1°C to 30°C in seven days.	http://www.dti.gov.uk/renewable/index.html
Ashtead, Surrey	A private house	3m^2 of collector plates enclosed within 30 evacuated glass tubes.	Domestic hot water	http://www.dti.gov.uk/renewable/index.html
Carmarthen, Dyfed	Small diary farm	Flat plate collector total area 8m^2.	Hot water for domestic and farming purposes.	http://www.dti.gov.uk/renewable/index.html

Photovoltaics

Websites
The Solarserver Forum for Solar Energy http://www.solarserver.de/index-e.html
Suppliers sites with useful information include http://www.solarcentury.co.uk and http://www.becosolar.com
US Department of Energy PV information http://www.eren.doe.gov/pv/

Written Material

Photovoltaics and Architecture, ed Randall Thomas, Spon Press 2001. Downloadable from http://www.dti.gov.uk/renewable/pdf/pvguide.pdf but the illustrations in the pdf are very poor quality.
National Survey Report of PV Applications in the UK IT Power on behalf of the DTI 2002. Downloadable from http://www.iea-pvpsuk.org.uk/exchange/infoexch_nsroverview.shtml
Photovoltaics in Buildings – Guide to the Installation of PV Systems DTI 2002. Downloadable from http://www.dti.gov.uk/renewable/install_guide.htm
Annex on photovoltaics from planning policy guidance note 22 on renewable energy http://www.planning.dtlr.gov.uk/ppg/ppg22/annex/index.htm
Downloadable reports from the DTI, relevant reports under solar http://www.dti.gov.uk/renewable/pdf.html
Comparison spreadsheet, wind/solar and inverters http://www.almac.co.uk/proven/PAGES/factshee.htm
US PV factsheets http://www.eren.doe.gov/erec/factsheets/pvbasics.html

Frequently asked questions
International Energy Agency FAQs http://www.oja-services.nl/iea-pvps/faqs/home.htm
British Photovoltaic Association FAQs http://www.pv-uk.org.uk/faq/faqs.html

Case Studies
DTI Case studies online http://www.dti.gov.uk/renewable/caseStudies/all.html
Caddet case studies online http://www.caddet-re.org/technologies/index.php
UK case studies from the British PV Association http://www.pv-uk.org.uk/uk/index.html

Location	Scale	Technology	Application	Web Address
Northumbria University, Newcastle	465 modules each rated at 85 Wp. System is expected to produce 25,000kWh/year	465 high efficiency crystalline silicon modules – five of which make up a single architectural cladding unit. Orientated 25° to the vertical.	Contribution to the Universities Electricity supply.	www.caddet-re.org/infostore/details.php?id=2996
Woking Town Centre	14 Schlumberger pay-and-display machines	Swivel head unit containing 10W PV cells – 30cm by 20cm. 15 ampere hour buffer battery, 26 ampere hour solar battery charger.	Powers pay-and-display machines for street parking.	www.dti.gov.uk/renewable/
Bretford Parish, Evesham, Worcstershire	150 units each with a capacity of 75Wp to power a 9W florescent lamp	SEPCO Solar PV panels controlled by SEPCO's Light Control Unit (LCU-1) Gel battery	Power to light bus stops and eventually bus timetables.	www.caddet-re.org/infostore/details.php?id=3561
Oxford	Single house,	48 BP Solar 585 Saturn modules with capacity for 4Kw peak of electricity, SMA 5Kw inverter.	Power for domestic use.	www.caddet-re.org/infostore/details.php?id3143
Nationwide	200 BP Amoco Service Stations – individual daily average of 15-20 kW	At each station 220 high efficiency BP Solarex solar panels – each panel incorporates 36 BP Solarex Saturn cells	Electricity fed into National Grid - equivalent to the power demands for pumps and lights beneath the canopy.	www.caddet-re.org/infostore/details.php?id=3482

Ground-Source Heat Pumps

Websites
John Cantor Heat Pumps http://www.heatpumps.co.uk/
Groundswell - UK online newsletter http://www.earthenergy.co.uk/eegrswel.html
The IEA Heat Pump Centre http://www.heatpumpcentre.org/
Alliant Energy Geothermal Information Office http://www.alliantenergygeothermal.com/

Heat Pump Association (HPA), www.feta.co.uk.

Written Material

Brochure on Heat Pumps from the IEA Heat Pump Centre
http://www.heatpumpcentre.org/products/download/hpc_ifs2.pdf
BSRIA – Ground Source Heat Pumps a Technology Review. Order it online at
http://www.bsria.co.uk/bookshop/pages/pubdescrip.asp?ID=1319
A Resource Audit and Market Survey of Renewable Energy Resources in Cornwall, CSMA Consultants Ltd, Western Hydro Ltd, GeoScience Ltd, Feb 2001 - contact
'Closed Loop Ground-Coupled Heat Pumps'. IEA Heat Pump Centre Informative Fact Sheet 2. 2002
'Heat Pumps for Buildings: Key Points'. Roger Hitchin, BRE. November 2003
Energy Efficiency Best Practice Programme 'Domestic Ground Source Heat Pumps: Design and Installation of Closed Loop Systems', March 2004 www.est.co.uk/bestpractice.

Case studies

There are a range of case studies for ground source heat pump installations within the UK. For example from the IEA Heat Pump Centre at http://www.heatpumpcentre.org/cases/home.htm and from Kensa Engineering at http://www.kensaengineering.com/casestudies.htm and from Geo Science at http://www.earthenergy.co.uk/casestudies.html

Location	Scale	Technology	Application	Supplementary Heating?	Web Address
Noss Mayo, Devon, UK	Family house, three storey	Vertical closed loop ground source, single borehole. Reverse cycle water-to-air heat pump, fresh air intake incorporated with air circulation system.	Space heating / cooling and domestic hot water.	Supplied, but never fitted.	www.heatumpcentre.org/cases/res_06.htm
Streatley, Berkshire, UK	Family house, 2 storey.	Horizontal ground loop, three coils each 200mlong, water-to-water heat pump	Space heating to 20°C and pre-heating for domestic hot water	Immersion for hot water	www.heatpumpcentre.org/cases/res_08.htm
West Grimstead, Wiltshire, UK	Family house and annex, 2 storey, floor area 288 m^2	Horizontal single loop 200m long, water-to-water heat pump	Space heating to 18°C and domestic hot water	Wood burning stoves	www.heatpumpcentre.org/cases/res_07.htm
Garston, UK	'Dream House 2000', two storey. The INTEGAR project – BBC 1	Vertical closed loop ground source, two boreholes. Reverse cycle water-to-water heat pump.	Space heating / cooling	Information not supplied	www.earthenergy.co.uk/bryceroad.html
Marazion, Cornwall, UK	4 bungalows though individual coils, floor area 68m^2 Penwith Housing Assoc.	Horizontal ground-source heat pump, slinky coils, 4KW	Space heating to 21°C and domestic hot water	Yes – immersion to raise hot water temperature.	www.earthenergy.co.uk/marazion.htm
Dudley Rd, W. Midlands, UK	Black Country Housing Association, multiple properties	Vertical closed loop, 2 bore holes (50m deep) Common reverse cycle heat pump.	Under floor heating / cooling	Yes – gas condensing boilers and mini CHP plant.	www.earthenergy.co.uk/bryceroad.html

Charlestown, St Austell, Cornwall, UK	Junior and Infant School (200 Pupils)	Closed loop vertical ground source heat pump, ten boreholes, twin reverse cycle heat pumps can incorporate fresh air.	Space heating / cooling	No	www.earthenergy.co.uk/charles.html
St Mary's, Isles of Scilly	Health and Community Centre. Floor area 400m^2	Closed loop vertical ground source heat pump – 4 boreholes, underground reverse cycle heat pump.	Under floor heating / cooling, pre-heating for domestic hot water	No	www.earthenergy.co.uk/ios.html

Tolvaddon Energy Park - Camborne, Cornwall - December 2001

This Energy Park is the flagship of the UK Governments Regional Development Agency regeneration for Cornwall. Funded by a combination of Government and "Objective 1" European money, the project aims to be a showpiece of the very best of environment-friendly construction techniques that can be used in modern buildings. As a by-product, people working for the high-tech companies that are tenants of the Energy Park enjoy a high quality work environment. Each of the nineteen buildings is heated by its own GeoKitten geothermal heat pump. The GeoKittens are connected to over forty 70m vertical ground arrays which were installed by local firm Carnon Contracting, and were designed by GeoScience. The GeoKitten was the only range of heat pumps manufactured anywhere in the EU that would suit every building. Heating distribution is via "wet" underfloor heating systems. Total cost around £150,000.

Figure B1: A 40 kW GeoKitten is delivered to site

See http://www.tolvaddon.co.uk for further information.

Roof-Mounted Wind Power

As this technology is still at an early stage, little information exists on performance reviews and case studies. Information on the two devices thought to be approaching commercially availability can be found at:

http://www.windsave.com

http://www.renewabledevices.com/swift.htm

Appendix C

BREEAM ASSESSMENT – CRITERIA FOR POTENTIAL CREDITS FROM RENEWABLES

BREEAM Category	Topic	Credit Aim	Credit Criteria	Compliance Requirements and Additional Guidance
Health and Wellbeing	Thermal Zoning	To optimise the level of heating control available to building individual occupants	1 credit is awarded where control is available for temperature to take account of load variations	Compliance requirements: As current BREEAM Offices guidance. Additional guidance: None
Energy	Heating Controls	To recognise and encourage specification of boiler controls in line with best practice guidance	1 credit is awarded EITHER where systems with a power output greater than 100kW achieve controls consistent with band level 2 of Table 2 - Heating Controls, Fuel Efficiency Book 10 (EEBPP). OR where systems with a power output less than 100kW achieve controls consistent with band level 1 of Table 3 - Heating Controls, Fuel Efficiency Book 10 (EEBPP)	Compliance requirements: The assessor should ask the design team to provide details of heating system controls. The assessor should check specification with Tables 2 or 3 depending on the power output of the system. Additional guidance: None
	Carbon Intensity of Heating System(s)	To recognise and encourage the specification of energy efficient boiler systems	Up to 3 credits are available: 1 credit is awarded where the carbon intensity of the boiler system is 5% better than the intensity benchmarks required by regulation. 2 credits are awarded where the carbon intensity of the boiler system is 10% better than the intensity benchmarks required by regulation. 3 credits are awarded where the carbon intensity of the boiler system is 15% better than the intensity benchmarks required by regulation	Compliance requirements: The assessor should ask the design team to confirm the carbon intensity of boiler. The Building Regulations: Part L2 2002 provides details of calculating carbon intensities for standard heating plant and CHP systems. Additional guidance: The Building Regulations Part L2 Table 5 contains the maximum allowable carbon intensity figures heating plant. Go here to view part L2: http://www.odpm.gov.uk/stellent/groups/odpm_buildreg/documents/page/odpm_breg_027774.hcsp
	CHP / Renewable Energy Feasibility Study	To encourage the specification of renewable energy technology	1 credit is awarded where a feasibility study for combined heat and power plant or renewable energy generation has been commissioned	Compliance requirements: The assessor should ask the design team to provide details of the findings from the feasibility study. Additional guidance: None
	Use of Alternative Heating and/or Cooling Source	To encourage the use of alternative sources of heating/cooling	1 credit is awarded where the majority of heating/cooling demand is met by the use of alternative (low energy) sources of heating and/or cooling such as ground source heat pumps, groundwater cooling etc. Where such systems are installed they should typically provide the greater of: - 100% of cooling demand - 75% of heating demand - 50% of combined heating and cooling demand	Compliance requirements: The assessor should ask the design team to provide calculations showing the proportion of annual heating and/or cooling demand met by such systems. Additional guidance: Where no mechanical cooling has been specified then this credit may only be awarded if credit Hea 14 (Thermal Comfort Modelling) has also been achieved.

Pollution	NOx Emissions of Heating Source	To prevent local pollution	Up to 4 credits are available dependant on (except standby): 1 credit is awarded where maximum dry NOx emission levels from burners in boiler plant are 140 mg/kWh delivered heating energy or less. 2 credits are awarded where maximum dry NOx emission levels from burners in boiler plant are 89 mg/kWh delivered heating energy or less. 3 credits are awarded where maximum dry NOx emission levels from burners in boiler plant are59 mg/kWh delivered heating energy or less. 4 credits are awarded where maximum dry NOx emission levels from burners in boiler plant are 39 mg/kWh delivered heating energy or less	Compliance requirements: As current BREEAM Offices guidance. Additional guidance: None
	Zero Emission Energy Source	To reduce atmospheric pollution by encouraging locally generated renewable energy to supply a significant proportion of the building's energy demand	1 credit is awarded where at least 10% of either the heat demand or the electricity consumption within the building is supplied from local renewable energy sources	Compliance requirements: As current BREEAM Offices guidance. Additional guidance: None

Table D1: Main renewables-related elements of BREEAM assessment criteria