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## **‘Greening’ the former Boiler House at Penrhys**



Project number: 157.01

Client: Boiler House Project Committee

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## Table of Contents

1	
1.	Report summary ..... 4
1.1.	Recommendations..... 4
2.	Introduction ..... 6
3.	Background information ..... 8
3.1.	History..... 8
3.2.	Site location..... 9
3.3.	Background and rationale for the project..... 13
4.	Energy use in buildings..... 15
5.	Estimating energy demand for the Boiler House ..... 18
6.	‘Greening’ through improving building fabric..... 21
6.1.	Insulation..... 22
	Roof insulation ..... 22
	Wall insulation ..... 23
	Floor insulation..... 23
6.2.	Windows and doors ..... 24
7.	Renewable energy options ..... 26
7.1.	‘Greening’ electricity at the Boiler House ..... 26
	Using a green electricity supplier ..... 26
	Wind power..... 27
	Solar photovoltaics ..... 30
7.2.	Heating, cooling and ventilation..... 32
	Biomass boilers ..... 33
	Ground-source and air-source-heat pumps ..... 35
	Solar thermal ..... 37
	Ventilation..... 39
8.	Water..... 40
9.	Passive solar design ..... 42
10.	Summary ..... 43
11.	Funding sources..... 45
	Low Carbon Buildings Programme ..... 45
	Community Sustainable Energy Programme ..... 45
12.	Sources of further information ..... 46
	Appendix 1: Wind speed data for Penrhys ..... 47
	Appendix 2: Solar irradiation for the UK..... 48
	Appendix 3: Regional rainfall..... 49
	Appendix 4: Carbon dioxide emissions factors ..... 50

## Table of Figures

Figure 1:	Ordnance Survey map showing Penrhys estate and boiler house location.... 9
Figure 2:	Plan of the Penrhys Boiler House and property boundary (scale: 1/1250) . 10
Figure 3:	Service sector energy consumption by end use ..... 15
Figure 4:	Energy use in the Services Sector ..... 16
Figure 5:	Typical heat loss from a commercial property in the UK ..... 22
Figure 6:	Example of solar PV and two 6 kW wind turbines at Blackpool Solarium 27

Figure 7: Annual total horizontal irradiation for the UK .....	48
Figure 8: Regional rainfall (mm) between 1971 and 2000.....	49

## Table of Plates

Plate 1: View of the front of the building	11
Plate 2: View of the rear of the building	11
Plate 3: Detail of the roof	11
Plate 4: Internal stairs	11
Plate 5: Ground floor	12
Plate 6: First floor	12
Plate 7: View of internal walls	12
Plate 8: View of internal walls	12
Plate 9: View of loading bay	12
Plate 10: View of ceiling structure	12

## Table of Tables

Table 1: Comparison of typical energy consumption benchmarks	19
Table 2: Comparison of best practice energy consumption benchmarks	19
Table 3: Example of potential running costs for energy (exc. VAT)	20
Table 4: Example of running costs for a 100% green electricity supplier	27
Table 5: Comparison of Proven wind turbines	29
Table 6: Averaged wind speed data at 25 m above ground level for the Boiler House location	45
Table 7: Monthly averaged insolation (kWh/m <sup>2</sup> /day) for the Boiler House location	48
Table 8: Emissions factors	50

# 1. Report summary

This report has been produced by Science Shops Wales for the Boiler House Project Committee, Penrhys. Science Shops Wales is an independent unit within the University of Glamorgan which carries out research on behalf of community groups.

The purpose of this report is to provide an initial assessment of the techniques and technologies available to 'green' the former Boiler House at Penrhys in order to refurbish and transform it into a community centre. Such a major refurbishment offers an important opportunity to achieve energy savings and reduce emissions through improving the building's fabric and services.

The main aims of the work reported here can be summarised as:

1. To determine feasible options, including renewable energy technologies, for 'greening' the building;
2. To give an idea of potential costs in order to provide input into the project business plan. It should be noted that throughout this report all costs are examples only and exclude VAT.

The results of our preliminary desk-based research and an initial site visit indicate that:

- **The Boiler House site offers both opportunities and constraints for the proposed project;**
- **There are a number of key elements which must be considered in 'greening' the Boiler House: building fabric, power, heating, ventilation and water;**
- **It is important to take an integrated approach to 'greening' right from the start of the project;**
- **If the Group is successful in taking the project forward professional consultation and advice should be taken with regard to the refurbishment of the building in general, reducing energy demand, exploiting passive solar design and renewable energy options.**

## 1.1. Recommendations

1. The Group need a clear understanding of potential energy demand and end use in the Boiler House. This is important in order to select the most appropriate technology and to size selected systems. A key factor influencing energy demand is the intended use of the building: services/activities provided, number of users, hours of use. This is still unclear. One option for estimating energy demand is to use publicly available benchmarks for typical energy use based on building type.
2. It is important to reduce demand for energy as well as supply energy in a 'green' way. These are two sides of the same sustainability 'coin'. One of the most effective ways the project can reduce energy demand and so manage running costs is by enhancing the thermal performance of the building fabric e.g. insulating walls, floors and the roof space, fitting double glazed windows and so on. Cavity wall insulation might be the simplest option for the Boiler House if the cavity space is sufficient to meet Building Regulation requirements. Insulation on top of the existing floor might be appropriate but is dependant on the condition of the floor and internal requirements of the building. There are numerous materials on

the market suitable for insulating the roof space. Doors and windows also need to be energy efficient e.g. using double glazed windows. Using more energy efficient fittings and appliances can also make a significant difference to energy use.

3. Appropriate use of passive solar design should also be considered e.g. siting windows, making the best use of the thermal mass available within the building and ensuring adequate/natural air circulation.
4. The most practical starting point when selecting renewable energy technologies is to consider the aspect of and restrictions at the site and what services already exist. At the present this appears to be electricity only: the building does not appear to have a mains gas connection.

In order to provide 'green' electricity within the building the Group could consider using a 100% green energy supplier and/or supplement their electricity supply with solar PV.

The Group has indicated a particular interest in the use of wind turbines and of building mounted, vertical axis wind turbines. The author does not recommend building mounted wind turbines. Ideally wind turbines should be installed clear of any obstructions such as trees and buildings. This can be difficult when a turbine needs to be close to a building it will supply. However, the proposed site has very limited land attached and is also close to the main road circling the estate. There appear to be potential health and safety implications for a mast (ground) mounted wind turbine based on the information available. The Group should consult the local authority for advice.

The lack of a mains gas connection at the site and restricted ground space suggests that a practical option is to use an air-source-heat-pump to provide space heating with hot water supplied using point source electric heaters. Alternatively, depending on the demand for hot water, an air-source-heat-pump could be combined with solar thermal panels for hot water production. Whether point source heating or solar thermal is used depends to large degree on the volume of hot water needed and at what rate i.e. it depends on building use.

However, the group might consider connecting to mains gas and installing a highly efficient condensing boiler or installing a biomass boiler. Again it is possible to combine these systems with solar thermal panels for hot water. However, the Group should consider the CO<sub>2</sub> emissions associated with fossil fuel use in the case of gas and also for the transport of biomass fuel to the site. Fossil fuel prices are also likely to rise in future. It is also vital to ensure a reliable, local biomass fuel supplier is available.

5. Water use within the building can be reduced by e.g. installing controlled flush toilets and urinals, low flow taps and shower heads, water efficient appliances (water use is indicated on appliance energy labels), and pro-active building management to detect/report and deal with leaks and the use of water metering.
6. The burden of legislative and regulatory needs, planning and permitting requirements should not be underestimated and often pose problems for this type of project. Wind turbines in particular can offer challenges in relation to gaining planning consent.

## 2. Introduction

We use energy to power our homes, businesses and industry, produce our food, provide transportation and for countless other uses. Energy demand around the world, including the UK and Wales, is increasing rapidly.

Currently, over 80% of the world's energy needs is met by fossil fuels: natural gas, coal and oil<sup>1</sup>. The use of fossil fuels to produce energy releases harmful greenhouse gas emissions (such as carbon dioxide) and contributes to climate change. In addition, fossil fuels are increasingly concentrated in fewer and often less stable parts of the world. As a result, governments around the world, including the UK, are seeking to reduce harmful emissions and to ensure secure, clean and affordable energy supplies<sup>2</sup>.

For example, in 2000 the UK Government set a target of 10% of our electricity to come from renewable energy sources such as wind and solar by 2010 with an aspiration to double that level by 2020. At the moment the UK generates around 5% of its electricity from renewable energy sources. The Government also announced a goal of cutting carbon dioxide emissions (CO<sub>2</sub>) by 60% compared to 1990 levels by 2050, with real progress by 2020<sup>3</sup>.

Reducing the use of and therefore demand for energy is vitally important in achieving these goals. An important area where significant reductions can be made is in buildings. In the UK, buildings are responsible for around 40% of all the energy consumed<sup>4</sup>. More than half of the energy used is for space heating. Buildings are also responsible for more than 40% of the UK's CO<sub>2</sub> emissions. The efficient use of energy in all our buildings is therefore a primary objective of local, regional and national government policy.

A significant proportion of the existing buildings in the UK lack adequate insulation, heating controls and other measures to reduce energy use and emissions. However, most buildings are refurbished at some point during their lifetime. Refurbishments therefore offer an important opportunity to achieve energy savings and reduce emissions through improving the building's fabric and services.

This report has been produced by Science Shops Wales (SSW) for the Boiler House Project Committee. The Group is a 'grass-roots' group of local residents from the Penrhys Estate, Rhondda Cynon Taff. They are seeking to purchase the former boiler house on the estate with the aim of refurbishing and regenerating it for the benefit of the local community.

In March 2009 the Group approached SSW for assistance in assessing the options for 'greening' the building. A site visit and initial meeting took place on 25<sup>th</sup> March 2009. Desk-based research has been employed to complete this report drawing on publicly available datasets and information, supplemented by on-site observations. In addition, range of suppliers, manufacturers and other organisations were consulted including:

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<sup>1</sup> IEA (2007) *Key World Energy Statistics*

<sup>2</sup> DTI (2007) *Meeting the Energy Challenge: A white paper on energy*

<sup>3</sup> BERR, *Renewable Energy*

<sup>4</sup> Sustainable Energy Group, University of Southampton

- Dimplex
- Eco Hometec
- Broag Remeha
- Cotswold Energy Efficiency Centre
- Ecovision Systems
- Earth Energy
- Good Energy
- Future Heating
- EON
- Cel-f-solar
- Wood Energy
- Natural Power Wales
- USwitch

The main goals of this report are to contribute to the Business Plan for the purchase of the building by providing:

- An overview of appropriate options for ‘greening’ the building including renewable energy sources;
- A brief outline of relevant legislation and planning permissions associated with such technologies;
- Guidance on likely costs for each technology in order to assist the group in generating capital/operating costs;
- A list of potential sources of funding for renewable 'green' technology installations.

The report is structured as follows: section 3 provides background information for the site and the project; section 4 looks at energy use in buildings; section 5 covers benchmarks for estimating energy consumption in the Boiler House; section 6 outlines the elements of greening the fabric of a building; section 7 covers renewable energy options for power, space and water heating; section 8 outlines rainwater harvesting; section 9 describes passive solar design in buildings; section 10 provides the summary and main conclusions; section 11 suggests potential sources of funding; section 12 lists sources of further information. Additional information is contained in appendices.

## 3. Background information

### 3.1. History

The boiler house lies on the high saddle ridge of Penrhys on the slopes of Mynydd Ty'n-tyle<sup>5</sup>. It overlooks the valleys of Rhondda Fawr and Rhondda Fach and comes under the remit of Rhondda Cynon Taff County Borough Council. The building dates back to the construction of the Penrhys Estate in the late 1960's.

The area has a very rich history. Until the late 16th century, Penrhys was an important site for Christian pilgrims. It was also previously the site of a monastery and manor house/farm and a small pox hospital was built there in 1907.

The estate was developed in 1966 as a new modern council housing development. When it was officially opened in 1968, it consisted of 951 houses and numerous community facilities (shops, nightclub, leisure centre, schools etc.). At the time it was the largest public-sector housing venture in Wales. There are now approximately 300 houses standing with 250 in occupation<sup>6</sup>. The majority of community facilities have closed and the estate generally is in a run-down condition.

One of the innovative features of Penrhys estate was the district heating system. Under an agreement with the National Coal Board, water was heated in a central coal fired boiler and a network of insulated pipes served each house with space heating and hot water. The cost of heating was included in the rent.

The system was designed and built during a period of low energy costs, but proved very expensive following the Oil Crisis of 1973 which increased the cost of energy. There also appear to have been issues relating to robustness of the system's infrastructure and maintenance programme as well as use of the system. Ultimately, as heating cost increases had to be absorbed into the rent the estate became uneconomic for many residents<sup>7</sup>. This resulted in many leaving the estate to move to other housing where they could have more control over their heating costs<sup>8</sup>. This outflow appears to have led to the estate's decline during the 1970s and 1980s.

Eventually the district heating scheme was shut down and the estate switched to mains gas with gas boilers installed in each dwelling. The boiler house then lay empty until a computer training company moved in and used it as a training establishment. When the company's operations ceased the building was largely disused, except for a short period when it served as a venue for the local youth club. The building has not been used for the last 12 years and has become increasingly derelict. There is no evidence/information available on prior refurbishment work.

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<sup>5</sup> The following information is sourced directly from <http://www.rhonddarecords-wales.com/-The-Boiler-House-Community-Project> , <http://en.wikipedia.org/wiki/Penrhys> and personal communications with former residents

<sup>6</sup> Personal communication

<sup>7</sup> Residents receiving state benefits had housing costs paid as part of their benefits

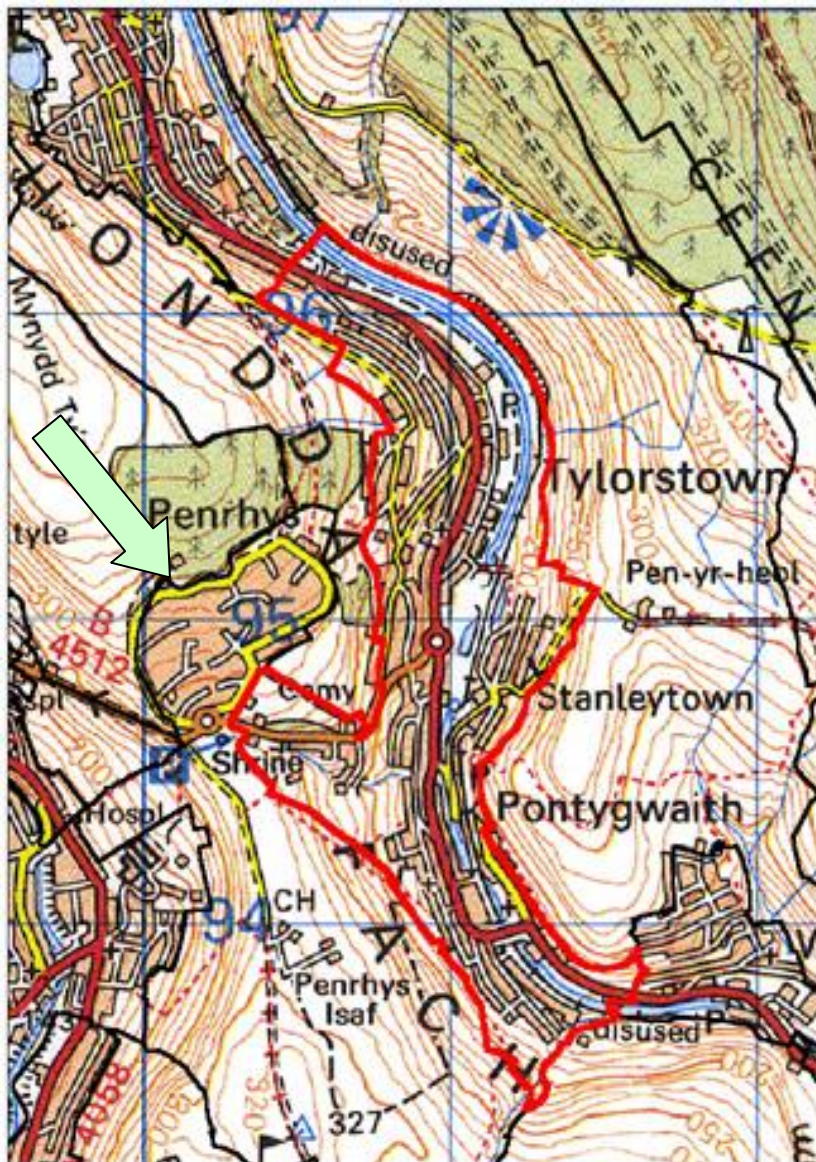
<sup>8</sup> Ibid.

### 3.2. Site location

Using the UK government's MAGIC<sup>9</sup> application gives ST000950 for the actual boiler house site, latitude and longitude 51.65, -3.44.

The site is approximately 330 metres (over 1000 feet) above sea level. It is situated above and to the north of the estate, adjacent to forestry plantation and adjoining the road which circles the estate (Figure 1). A plan of the property is provided in Figure 2. There is a sub-station at the site (Western Power ST00029504 Boiler house S/S 541800).

Figure 1: Ordnance Survey map showing the Penrhys estate and boiler house location



(Source: [http://www.ggat.org.uk/cadw/historic\\_landscape/Rhondda/Maps/Rhondda\\_019\\_map.htm](http://www.ggat.org.uk/cadw/historic_landscape/Rhondda/Maps/Rhondda_019_map.htm))

<sup>9</sup> <http://www.magic.gov.uk>



The boiler house is in an exposed location and faces roughly south east. This will affect energy use, especially in severe weather conditions. But also creates potential for the use of passive solar design and renewable energy sources.

The building appears to be of standard block and brick construction with concrete floors and a curved steel roof (Plates 1 to 8). It currently comprises seven rooms plus space for washroom facilities. The ground floor is approximately 626 square metres (m<sup>2</sup>) and the upper floor 429 m<sup>2</sup><sup>10</sup>. There is a considerable amount of rubble in the building.

The Quantity Surveyor's Report noted the following:

- The roof/steel beams/cantilevers need to be inspected by a Structural Engineer;
- An asbestos inspection is needed of soffits and other fittings. Asbestos sheets have been found to the rear of the building (asbestos has also been found in another community building);
- A damp survey is required.

**Plate 1: View of the front of the building**



**Plate 2: View of the rear of the building**



**Plate 3: Detail of the roof**



**Plate 4: Internal stairs**



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<sup>10</sup> Information obtained from The Penrhys Boiler House Project: Stage One Proposal, November 2001 supplied by the Group

**Plate 5: Ground floor**



**Plate 6: First floor**



**Plate 7: View of internal walls**



**Plate 8: View of internal walls**



**Plate 9: View of loading bay**



**Plate 10: View of ceiling structure**



### **3.3. Background and rationale for the project**

The Boiler House Project Committee identified a need for community facilities on the Penrhys Estate. The project seeks to purchase and regenerate the former boiler house for the benefit of the local community and the surrounding area.

**The overall aim of the project is to establish an independent and sustainable centre providing activities and opportunities for the community in the fields of enterprise; education and training; sport, leisure and health.**

The Boiler House Project Committee currently comprises nine members. It is a very recently formed 'grassroots' group of local residents who have come together with the specific aim of regenerating the boiler house.

The individuals in the group have a range of skills and experience between them as well as knowledge of the local community. However, none of the group has ever attempted such a large undertaking of this type before. This is a major refurbishment project which comprises upgrading the building's structure, fabric and services in a cost effective way while complying with new standards and legislation. In addition, the Group wants it to be as sustainable ('green') as practicable. The project therefore presents significant challenges for the group.

The Group contacted the local authority (Rhondda Cynon Taff County Borough Council) in August 2008 when the property originally came up for auction. They have since engaged advice to develop a business model and business plan in order to purchase the site and have also investigated potential funding sources.

They have conducted a very brief assessment of the activities and services residents' would like to see the building provide. The Group have also engaged the local community via a number of fund raising and awareness raising activities.

An initial door-to-door survey of residents suggests important uses for the building are:

- Youth club and children's activities;
- Gym and sports hall;
- Community centre and café;

Other potential uses include: adult training; business facilities; adult social activities (such as bingo and dancing); recycling second hand goods; possibly paintball and outward bound courses in the future. One group member wanted to see an "oasis" created: somewhere to find peace.

The Group have also obtained a Quantity Surveyors Report for the property for materials and fittings required to "make good" the building. It is very much a Schedule of Works and does not specifically address 'greening' the building. .

The Group is currently in the process of developing a business plan detailing:

- What they want to do with the property;
- How much it will cost;

- Where funds will come from.

A viable business model is critical to this project moving forward:

- In order to achieve the stated aims of the project;
- In order to demonstrate to the local authority and prospective funding organisations that the Group is capable of managing the project.

A business model should cover key aspects including:

- Infrastructure: capabilities and competencies required, partner organisations, benefits the project will deliver;
- Offering: products and services, what makes this project different, why people will use it;
- Customers: the target audience, how the project will reach customers (marketing);
- Finances: costs and revenues

**Refurbishment or “greening” of the boiler house cuts across all of the above elements and is a vital part of a viable and sustainable project.**

## 4. Energy use in buildings

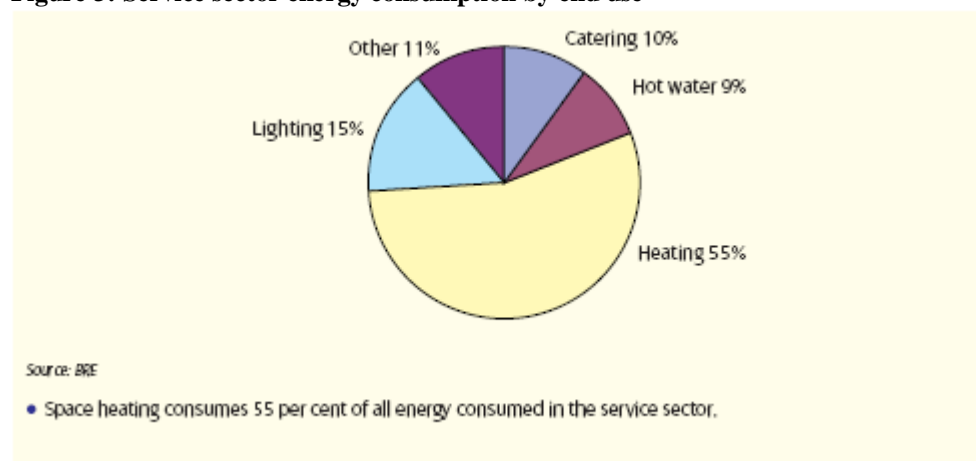
This section considers energy use in buildings and how energy efficiency and savings can be improved. In the UK, buildings are responsible for around 40% of all the energy consumed<sup>11</sup>. More than half of the energy used is for space heating. Buildings are also responsible for over 40% of the UK's CO<sub>2</sub> emissions. Therefore the built environment offers huge potential to reduce energy use as well as harmful emissions.

In the UK, energy efficiency in the built environment is supported by a range of legislation, standards, regulations and financial incentives. For example, the Building Act 1984 aims to conserve fuel and power and regulates the “design and construction of buildings, demolition of buildings, and the provision of services, fittings and equipment in or in connection with buildings”. The Building Regulations 2006 apply in England and Wales to new buildings as well as alterations and refurbishments of existing buildings (domestic, commercial and industrial). Amongst other things, the Building Regulations promote<sup>12</sup>:

- Standards for most aspects of a building's construction, including its structure, fire safety, sound insulation, drainage, ventilation and electrical safety.
- Energy efficiency. The changes to the regulations on energy conservation came into effect in April 2006 aim to save one million tonnes of carbon per year by 2010.

It is important to consider both energy demand as well as energy supply in order to make buildings more sustainable. A clear understanding of energy end use will enable a better appreciation of what needs to be supplied: electrical power, space heating, water heating. As can be seen from Figure 3, heating and lighting are the major end uses of energy in non-domestic buildings (i.e. in the Services Sector which includes offices and leisure centres).

**Figure 3: Service sector energy consumption by end use**



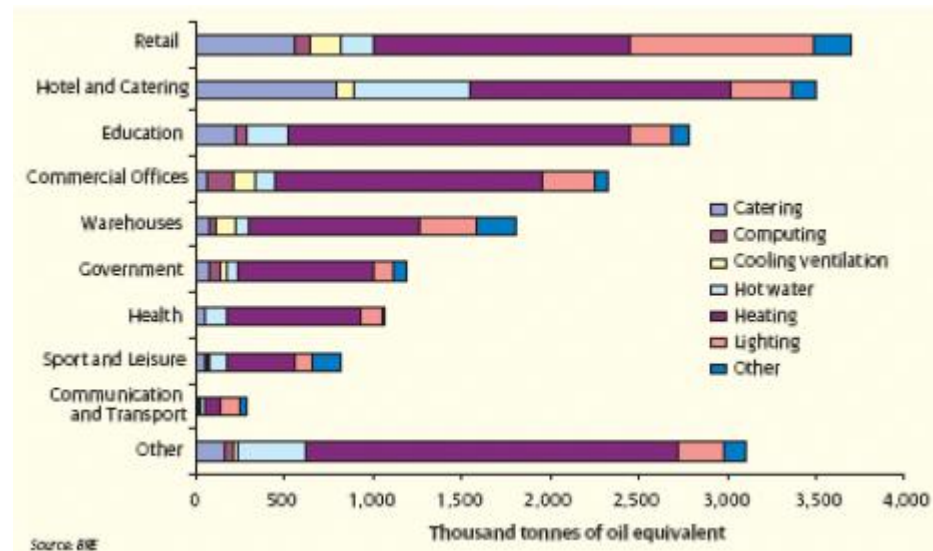
(Source: BERR)

<sup>11</sup> Sustainable Energy Group, University of Southampton

<sup>12</sup> <http://www.planningportal.gov.uk/england/government/en/400000000001.html>

Energy consumption and end use varies between different business sectors (Figure 4). For example, the retail sector is the major user of electricity for lighting. Energy consumption has also changed over time. For example, the service sector's electricity consumption is now double what it was in 1990 largely due to the increased use of computers and other information communication technology (ICT) equipment.

**Figure 4: Energy use in the Services Sector**



(Source: BERR)

In order to realise the full benefits of renewable energy sources, overall demand for energy must be reduced. The more energy efficient countries and communities are the greater the impact of renewable energy investments: the more energy efficient a building is, the smaller the renewable energy generation system can be and consequently the smaller the cost of the system.

It should also be noted that in the majority of cases the potential energy outputs and cost savings of renewable energy systems quoted by manufacturers and suppliers assume use in well insulated buildings. In addition, many grants require buildings to meet current applicable building regulations with regard to insulation and energy performance.

Saving energy and managing energy efficiently has many benefits:

- It saves money, which can then be used to support other activities/needs;
- It demonstrates good management and environmental responsibility;
- It can help lower maintenance costs and extend equipment life;
- It reduces pollution from CO<sub>2</sub>, acid rain and particulates;
- It helps to meet UK government energy and emissions reduction targets;
- It is necessary to comply with regulations and legislation;
- It helps to ensure a comfortable environment for users of a building.

Energy efficiency and energy savings (as well as CO<sub>2</sub> emissions) can be improved by:

- Enhancing the thermal performance<sup>13</sup> of the building fabric e.g. insulating walls, floors and lofts, double glazing, draught proofing;
- Using more energy efficient appliances/equipment/machinery. For example, by using ‘A’ and ‘A+’ rated appliances and restricting the maximum wattage of equipment;
- Fuel switching e.g. from oil-fired heating to gas-fired heating;
- Generating renewable energy on-site e.g. for power and/or heat;
- Optimising the use of passive solar e.g. to provide heat and light;
- Effective and appropriate controls e.g. thermostats;

Unregulated energy use (such as computer equipment), can be addressed by purchasing energy efficient equipment<sup>14</sup> and by turning off appliances such as computers rather than leaving them on stand-by when they are not being used.

Energy conservation is covered in Part L of the Building Regulations. Key areas which are regulated are:

- Building fabric/structure (thermal performance);
- Lighting;
- Heating;
- Power;
- Water;
- Ventilation.

If the Group intends to apply for a grant under the current or any future Low Carbon building Programme (LCBP) or similar grant schemes the building will need to meet the building regulations applicable at the time of any refurbishment.

Further information on buildings regulations can be found at: <http://www.planningportal.gov.uk/>

Further advice on energy efficiency can be obtained from:

- Community organisations <http://www.est.org.uk/>
- Public sector and not for profit organisations <http://www.carbontrust.co.uk/>. A free energy survey might be available.

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<sup>13</sup> Thermal performance is the extent to which a material or building element reduces heat loss. A good (high) thermal performance results in a low U-value.

<sup>14</sup> Such as by using the European Energy Star rated equipment programme and product database at [http://www.eu-energystar.org/en/en\\_021b.shtml](http://www.eu-energystar.org/en/en_021b.shtml)

## 5. Estimating energy demand for the Boiler House

This section considers potential energy demand within the Boiler house. It is important that the Group has an understanding of potential energy demand within the property, albeit this is a very much ‘guesstimate’ at this stage.

To do this the Group needs to consider what activities/services will be provided, how many people are likely to use the building per week and for how many hours per week e.g. will the building be open evenings only (20 hours) or 7 days per week (80 hours). This is important in order to:

- Understand what needs to be supplied: electrical power, space heating, water heating;
- Understand the potential running costs;
- Understand the potential contribution from renewable energy sources.

Heat losses from the building also need to be properly assessed. A consultant engineer will be required should the Group be successful in purchasing the building.

Records of the building’s previous annual energy use are not available. Potential energy use can be estimated based on floor area using existing benchmarks and information from several sources<sup>15</sup>. In order to provide a base case, the estimated energy use in this report assumes mixed fuel use within the building and covers:

- Electricity (for appliances);
- Fossil fuel for heating.

The Group has indicated intentions to provide: reception area, sports rooms, a café/bar area and showers. The Carbon Trust provides energy benchmarks for local authority buildings which include community centres<sup>16</sup>. The benchmarks indicate a typical energy use of 33 kWh/m<sup>2</sup>/yr for electricity and 187 kWh/m<sup>2</sup>/yr for heating fuel in a mixed fuel building. A benchmark study of energy use in public buildings in Northern Ireland suggests a similar consumption of 39 kWh/m<sup>2</sup>/yr for electricity and 183 kWh/m<sup>2</sup>/yr for heating fuel in mixed fuel community centres. The Group is also considering converting some space into computer rooms. The Building Research Establishment (BRE) indicates an energy consumption of 54 kWh/m<sup>2</sup>/yr for electricity and 151 kWh/m<sup>2</sup>/yr for heating in a typical small office. These figures underline the need for an accurate assessment of energy consumption and a clear understanding of proposed building use.

For a 1000m<sup>2</sup> of floor space, these benchmarks suggest a typical annual energy consumption of:

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<sup>15</sup> Murray, J., Pahl, O., Burek, S. (2008) Evaluating the scope for energy-efficiency improvements in the public sector: Benchmarking NHS Scotland’s smaller health buildings, *Energy Policy*, Vol. 36, pp. 1236–1242; *Energy Benchmarks for Public Sector Buildings in Ireland*; Dr. Heather Thompson, presentation, *Improving Energy and Carbon Management*;

<sup>16</sup><http://www.carbontrust.co.uk/Publications/publicationdetail.htm?productid=ECG087&metaNoCache=1>

**Table 1: Comparison of typical energy consumption benchmarks**

	Electricity (kWh/yr)	Heat (kWh/yr)	Total (kWh/yr)
Carbon Trust	33,000	187,000	220,000
Northern Ireland benchmark	39,000	183,000	222,000
BRE	54,000	151,000	205,000

However, implementing energy efficiency and saving measures can significantly reduce consumption as can be seen in Table 2.

**Table 2: Comparison of best practice energy consumption benchmarks**

	Electricity (kWh/yr)	Heat (kWh/yr)	Total (kWh/yr)
Carbon Trust	22,000	125,000	147,000
Northern Ireland benchmark	29,000	140,000	169,000
BRE	33,000	79,000	112,000

An average of the three typical benchmarks gives a consumption of 42 kWh/m<sup>2</sup>/yr for electricity and 173 kWh/m<sup>2</sup>/yr for heating. An average of the three best practice benchmarks gives a consumption of 28 kWh/m<sup>2</sup>/yr for electricity and 114 kWh/m<sup>2</sup>/yr for heating<sup>17</sup>. These figures can be used to provide a ‘guesstimate’ of potential energy consumption in the boiler house (based on a mixed fuel building).

As the building stands now, assuming no improvements to the building fabric, fittings and appliances, the heat load for the building is estimated to be about 100 kW. Bringing the building up to modern building standards and achieving a 50w/m<sup>2</sup> heat loss could reduce this heat load to 50 kW<sup>18</sup>.

The approximate total useable floor space (Gross Internal Area) in the Boiler House is 1055 m<sup>2</sup>. Assuming the building is brought up to current standards and using 30 kWh/m<sup>2</sup>/yr for electricity and 115 kWh/m<sup>2</sup>/yr for heating gives an estimate of 31,650 kWh/yr of energy for electricity and 121,325 kWh/yr for heating with a total combined consumption of 152,975 kWh/yr. These figures have been rounded down respectively to 30,000 kWh/yr, 120,000 kWh/yr and 150,000 kWh/yr for ease of calculation.

**These figures are estimates only. They have a significant margin for error. Such figures are only useful as examples at this early stage of the project. Benchmarks are also available for electricity only buildings.**

Using conventional energy supply as a baseline enables comparison with alternative renewable energy sources in terms of cost and CO<sub>2</sub> emissions. The government’s

<sup>17</sup> Rounded to 30 kWh/m<sup>2</sup>/yr for electricity and 115 kWh/m<sup>2</sup>/yr

<sup>18</sup> Maintaining a design temperature of 21°C while coping with down to -3°C external temperature

Market Transformation Programme (MTP)<sup>19</sup> provides emissions factor information. This can be used with potential consumption data to suggest approximate annual CO<sub>2</sub> emissions:

- 44,310 kWh x 0.43 kg CO<sub>2</sub> = 12,900 kg CO<sub>2</sub> for national grid electricity
- 182,515 kWh x 0.19 kg CO<sub>2</sub> = 22,800 kg CO<sub>2</sub> for gas heating, which can be compared to
- 182,515 kWh x 0.25 kg CO<sub>2</sub> = 30,000 kg CO<sub>2</sub> for oil heating

Potential running costs based on the above consumption has been calculated assuming the following<sup>20</sup>:

**Table 3: Example of potential running costs for energy (exc. VAT)**

	<b>Cost per unit (pence/kWh)</b>	<b>Standing charge (pence/day)</b>	<b>Climate Change Levy (pence/kWh)</b>	<b>Total cost per annum (exc. VAT)</b>
Electricity	9 p/kWh	12 p/day	0.456 p/kWh	£2,880.60
Gas <sup>21</sup>	3 p/kWh	8 p/day	0.159 p/kWh	£3,820.00

<sup>19</sup> [www.mtprog.com](http://www.mtprog.com)

<sup>20</sup> Personal communications with USwitch.com, enquiry for commercial rates for a standard single rate metre, for 1000 m<sup>2</sup> floor space, postcode district CF43, most up to date prices available but subject to change

<sup>21</sup> It is assumed the Boiler House is not connected to the gas mains. The cost of connection will need to be taken into account when calculating overall costs.

## 6. 'Greening' through improving building fabric

This section looks at the role of the building fabric in achieving energy savings and 'greening' the building. Building fabric (or the building envelope) plays a crucial role in improving energy efficiency, reducing costs and complying with Building Regulations. It is important to balance ventilation and daylight requirements while providing comfortable temperatures and lighting levels for building users.

Building regulations now stipulate that if an element of the building fabric is being refurbished, its energy efficiency must be improved. The physical elements of the building fabric comprise:

- Foundations;
- Ceilings;
- Walls;
- Windows;
- Doors;
- Roof.

Up to two thirds of heat generated within a building can be lost through the building fabric. Further heat can be lost through gaps and vents in the fabric e.g. from poorly fitted doors and windows<sup>22</sup> and air tightness is a crucial element (Figure 5). Installing insulation and modern windows and doors are crucial.

New buildings are built to higher standards of insulation but older buildings such as the Boiler House may have none at all. It is not clear whether the property has insulation installed. An initial site visit suggests that it does not.

The local climate also plays a part to in the energy use of a building e.g. temperature, prevailing wind, light levels. For instance, buildings in more exposed locations will generally have higher heating costs than those in more sheltered places. The direction a building faces and the amount of shading from other buildings or trees also affects the amount of daylight and heat from the sun entering the building. This can affect light levels, internal temperatures and natural ventilation.

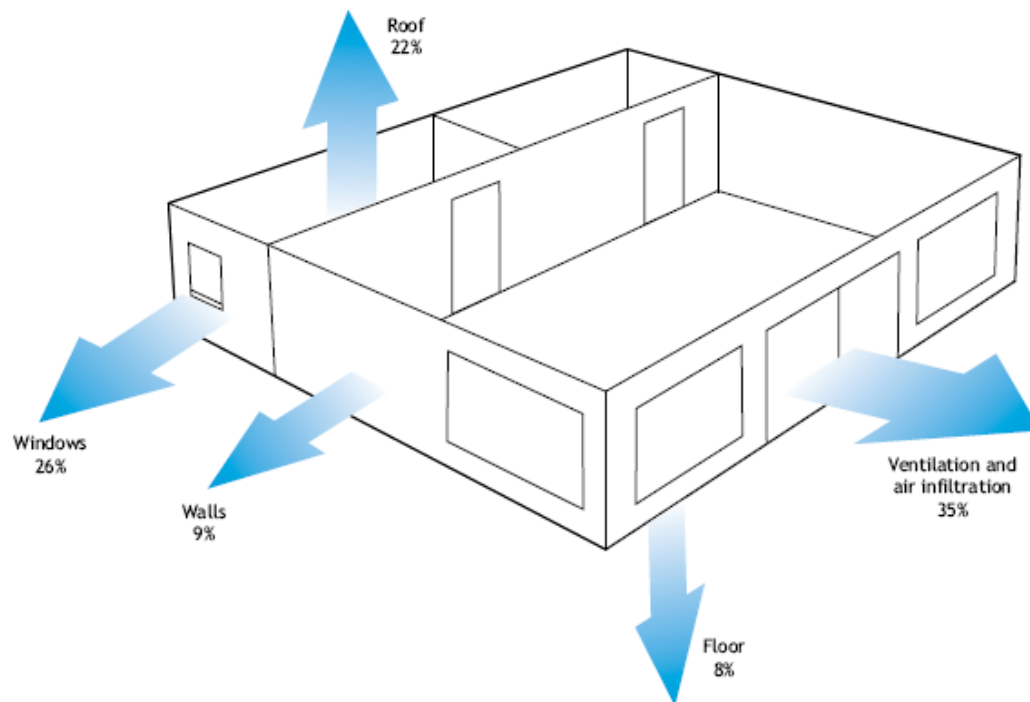
Equally important is the appropriate positioning of building elements such as windows and doors which play an important role in insulation. Appropriate positioning means considering the impact of the sun (solar radiation) and wind on a building (see Section 9 Passive solar design).

**If the Group is successful in taking the project forward professional consultation and advice should be taken.**

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<sup>22</sup> Carbon Trust, Building Fabric: Energy saving techniques to improve the efficiency of building structures

**Figure 5: Typical heat loss from a commercial property in the UK**



(Source: Carbon Trust )

## **6.1. Insulation**

Insulation materials and techniques should be appropriate to building needs based on:

- The type of construction;
- The local climate which affects heat losses and gains and can vary throughout the day and through the seasons;
- The intended use of the building e.g. the heating requirements for a warehouse, a leisure centre, a café or an office will all be different.

The quality and properties of the insulation materials used are important. The effectiveness of any insulation is also affected by construction issues such as draught sites within the building.

### **Roof insulation**

The roof can account for around 22% of the heat loss in a building. There are two main categories of roof insulation system:

- A warm roof: insulates the roof between and above/below the rafters to keep it warm;
- A cold roof: insulates at ceiling level, between and above the joists, and normally requires the roof space to be ventilated.

Generally, a cold roof approach is seen as cheaper and easier to achieve. The main advantage of the warm roof method is the ability to create a habitable space in the roof area. A warm-roof is easier to install when re-roofing a building.

The structural integrity of the existing roof of the boiler house first needs to be assessed. Any changes to the design of the roof also need to be taken into consideration when selecting insulation options.

## Wall insulation

The walls of a typical commercial building can account for around 9% of the overall heat loss. The boiler house walls appear to be of standard block and brick construction (block-built inner with a brick-built outer skin). It is assumed there is no cavity wall insulation.

Wall insulation includes foam, wool and bead materials for cavity walls and boards or cladding for solid wall constructions. In a cavity wall construction, filling the cavity with insulation is generally the cheapest and easiest solution. The insulation needs to be at least 50mm to be effective and so is limited by the width of the cavity.

Several options exist with regard to insulation of solid wall constructions (or where cavity wall insulation would not be effective). There are two main approaches:

- Internal: insulation/plaster board laminates or wooden battens in-filled with insulation. This method can reduce internal space within a building next to external walls (which tends to be more of an issue in small domestic dwellings or around narrow stairwells). Appropriate vapour control is important;
- External: insulation boards with reinforced render or cladding. This option will affect the external appearance of a building but can be a very effective option as it enables the building masonry (walls) to act as a thermal mass<sup>23</sup> and store heat. Effectiveness of this option is affected by the weatherproofing of the cladding and joints at the eaves and base of the walls. The new render may be subject to local planning regulations.

Cavity wall insulation might be the simplest option if the cavity is sufficient to meet Building Regulation requirements.

## Floor insulation

Around 8% of heat loss occurs through the floors of a building. Heat loss occurs both through the floor surface and where the floor meets the wall edges. Building Regulations require floors in new buildings to be insulated.

There are two main types of floor:

- Suspended – can be ground or upper floors and above unheated spaces (usually timber or concrete construction);
- Solid floors – ground floor (usually concrete).

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<sup>23</sup> Thermal mass refers to the ability of dense materials such as concrete to store heat as their temperature rises (e.g. when in sunlight). Heat is then released when the surrounding temperature falls (e.g. in the evening and at night).

Both suspended floors and solid floors can be insulated. In multi-storey buildings, floors above ground level can also be a source of heat loss and insulating between ceiling and floor levels should be considered.

For example, a timber suspended floor can be insulated with glass or mineral wool on the underside between the joists, with blown insulation or with rigid insulation boards (e.g. expanded polystyrene sheets). A solid concrete floor can be insulated with polystyrene-like sheeting.

The existing ground floor in the boiler house is assumed to be of solid concrete construction. If the existing floor is in good condition and does not need to be replaced it would not really be cost effective to dig it out<sup>24</sup> to install insulation.

A solution is to install insulation on top of the existing concrete floor. This can be cost effective if elements such as doors, stairs, and skirting boards will not be affected by raising the floor level due to the added thickness of the insulation. The final floor covering can then be laid on top of the new floor. As the boiler house project proposes a major refurbishment, this might be a practical option.

However, passive solar design (see Section 9) allows the possibility of using the floor as a source of thermal mass to provide heating (and cooling). In this instance you might not want to insulate over the top of the floor.

Providing an idea of potential costs for insulating the property is very difficult as there are a plethora of products and systems on the market. External wall insulation cladding systems in particular are bespoke and cannot be quoted for on a square metre basis. The Building Regulations specify the U-value for specific thermal elements (walls, floors and roofs) which can be achieved by a variety of products and techniques.

**The group will need to seek further advice to get an approximate idea of cost.**

## **6.2. Windows and doors**

Windows and doors can have a significant effect on the overall energy performance of a building. They can reduce the need for lighting and mechanical cooling/ventilation. They are also a source of cold spots and draughts and can account for around a quarter (26%) of the heat loss. However, they can also lead to glare and overheating in a building.

The new Building Regulations set much tougher standards for windows both in refurbishments and new buildings. Double glazing is now mandatory in a major refurbishment, but triple glazing could be considered especially for windows in north facing walls<sup>25</sup>. External and internal shading and options such 'low-E' glass can help to maintain comfortable light and temperature levels.

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<sup>24</sup> Condition needs to be assessed.

<sup>25</sup> Thermal performance of glass can now be specified using the British Fenestration Rating Council Scheme which classifies windows using an A to G rating; 'A' rating being the best.

Doors should be up to modern standards and well-insulated. Refurbishment opportunities for frequently used entrances and doorways include lobbies and revolving doors.

The materials used should be considered carefully. Metal doors and windows tend to be more conductive around the frames and so less energy efficient. However, wood and uPVC can perform similarly and choice of materials can therefore be a matter of personal preference. Environmental impacts should be considered, for example uPVC is a plastic based on chlorine chemistry, has high-embodied energy and a high environmental impact both in production and disposal.

## 7. Renewable energy options

This section considers renewable energy options for the Boiler House. Renewable energy, or ‘green’ energy, can be defined as energy obtained from flows in the natural environment which can be renewed at the same rate as they are used. Renewable energy sources include solar, wind, bio-energy, hydro-power, wave, tidal and geothermal. They can be used to provide electricity, space and hot water heating, and cooling.

Renewable energy sources can provide secure, indigenous energy as well as reduce future energy costs and harmful emissions. Many communities in Wales are now exploring renewable energy sources as a way to provide sustainable, low cost energy supplies as well as local educational, training and business opportunities.

In smaller projects, such the Boiler House, renewable energy usually supplies a proportion of the needs. The shortfall then has to be supplied by other means e.g. the national electricity grid. Renewable energy therefore tends to offset running costs rather than producing a profit.

Renewable energy options should always be evaluated taking into account local climatic conditions, site constraints, planning, overall impacts, regulations, capital and running costs, CO<sub>2</sub> emissions and other factors.

### 7.1. ‘Greening’ electricity at the Boiler House

Installing renewable energy technologies on site such as wind turbines and solar photovoltaics (PV) is a potential option for ‘greening’ the boiler house. It would also provide an exemplar within the local community. However, the group should explore and compare all options.

#### Using a green electricity supplier

A straight forward approach would be to select a ‘green’ electricity provider to supply power to the building. For example, Good Energy supplies domestic and business users and guarantees that 100% of the electricity supplied is from renewable sources.

This option can be just as ‘green’ as installing onsite renewable energy sources. It has several benefits:

- It avoids potential legal and planning issues;
- Reduces the capital outlay required;
- Reduces potential maintenance costs;
- Supports UK green energy suppliers.

Table 4 shows illustrative annual running costs with Good Energy based on the example consumption of 30,000 kWh/yr<sup>26</sup>. This option could reduce the project’s CO<sub>2</sub> emissions by 12,900 kg per annum<sup>27</sup>.

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<sup>26</sup> Personal communications with Goodenergy, based on Profile 2 commercial single rate meter. CCL not applicable.

<sup>27</sup> Based on displacing 0.43 kg CO<sub>2</sub>/kWh for national grid electricity

**Table 4: Example of running costs for a 100% green electricity supplier**

	<b>Cost per unit (pence/kWh)</b>	<b>Standing charge (pence/day)</b>	<b>Climate Change Levy (pence/kWh)</b>	<b>Total cost per annum (exc. VAT)</b>
Electricity	14.30 p/kWh	8.71 p/day	0.00 p/kWh	£4,321.79

More information can be found at <http://www.goodenergy.co.uk>

## Wind power

The Group has shown a particular interest in the use of wind turbines. The UK has some of the best wind resource in Europe; in fact Britain has about 40% of Europe's total wind energy and wind energy has an important role to play in achieving the government's goals for renewable energy.

Wind technology is among the most mature and cost effective renewable energy technology currently available. The most common (and arguably the most efficient) turbine design is a free standing, three blade horizontal axis turbine, which is free to rotate into the wind on a tall tower or mast. The blades drive a generator to produce electricity.

A two-way metre is required for grid connected systems. Turbines usually have a lifetime of 20 to 25 years (with regular service checks) or around 120,000 hours of operation. Wind turbines up to 50 kWp are supported by the government's Low Carbon Building Programme (LCBP). A typical 6 kW turbine is shown in Figure 6.

**Figure 6: Example of solar PV and two 6 kW wind turbines at Blackpool Solarium**



(Source: <http://www.tlcp.co.uk/projects/BlackpoolSolarium.html>)

The size and generating capacity of a wind turbine installation for a particular site will depend on the amount of power required (which is dependant on the annual amount of energy needed to run all appliances and other equipment at the site) as well as on the local wind conditions.

The amount of electricity generated by a wind turbine is highly reliant on the speed and direction of the wind which in turn is affected by a number of factors including geographic location, height of the turbine above ground level, topography, surface roughness and nearby obstructions. Valleys tend to lower wind speeds, while hills and ridges can increase wind speeds as the wind is forced to flow over or around them. Urban environments, such as a town or city, are also to reduce the annual energy output from a wind turbine installation due to the impact of the buildings.

Generally speaking the ideal site for a wind turbine installation is a smooth topped hill with clear exposure, free from too much turbulence and avoiding large obstructions such as trees and buildings. In the UK, where generally the prevailing wind is from the southwest, a southwest facing slope potentially could offer a suitable site. Penrhys appears to be a viable location in this respect.

However, ideally wind turbines should be installed clear of any obstructions such as trees and buildings. For example, a garden shed can create turbulence in an area up to ten times the height and width of the shed. This can be difficult when a turbine needs to be close to a building it will supply. However, the proposed site has very limited land attached. It is also close to the main road circling the estate. There appear to be potential health and safety implications for a mast (ground) mounted wind turbine based on the information available. The Group should consult the local authority for advice.

The Group has also indicated a particular interest in the use of wind turbines and of building mounted, vertical axis wind turbines. The author does not recommend building mounted wind turbines. As well as issues relating to turbulence, there are also potential problems with vibration and structural issues. Building mounted turbines generally will not perform as well as mast mounted ones. In addition, vertical axis turbines are arguably not as efficient as horizontal axis turbines. **The author does not recommend the use of building mounted or vertical axis turbines.**

Annual operation and maintenance costs also need to be considered and are normally a small percentage of the overall project costs. However, they can be expected to increase slightly as a turbine ages. The Group also needs to consider equipment warranties and maintenance contracts.

#### **Use of wind turbines at the Boiler House**

The minimum wind speed at which a wind turbine will rotate and generate useful power is typically 4 metres per second (m/s) and is called the cut-in speed. The rated speed of a turbine is the minimum wind speed at which the wind turbine will generate its designated rated power. For example, 10 kW wind turbine, may not generate 10 kW until wind reaches a given wind speed. For example, the rated wind speed of the Entegrity EW 50kW turbine is 11.3 m/s. Wind turbines also shut down at high wind speeds to prevent damage, usually this is about 25 m/s. Ideally, an average annual wind speed of at least 6 m/s is required in order for a wind project to be viable.

Directly observed annual wind speed and wind direction data for the boiler house were not obtained. However, the BERR wind speed calculator gives a mean annual speed 5.4 m/s at 25 m above ground level at this location while the NASA meteorological

database suggests and annual average of 6.47 m/s (Appendix 1). Anecdotal evidence suggests that actual wind speed might be greater than this.

In order to enable proper assessment of the potential at Penrhys, wind speed and direction should be measured over several months, ideally over a 12 month period. This site specific information can then be correlated with historical data from the UK Meteorological Office to provide a more comprehensive picture of wind potential.

Indicative costs for smaller wind turbine installations are £2,500 to £6000 per kW. An example of costs, potential power production and payback periods<sup>28</sup> for three Proven, mast mounted, horizontal axis wind turbines (grid connected) are shown in Table 5. A single 15 kW turbine could potentially supply around half of the property's electricity consumption (based on an annual consumption of 30,000 kWh).

**Table 5: Comparison of Proven wind turbines**

Rated output	Cost	Power production	Payback period
2.5kW	£11,000 to £15,000	2,500-5,000 kWh	7 - 10 years
6 kW	£19,000 to £24,000	6,000-12,000 kWh	5 - 8 years
15 kW	£40,000 to £46,000	15,000-30,000 kWh	3 - 7 years

(Source: [http://www.provenenergy.co.uk/windturbines\\_buy\\_our\\_products.php](http://www.provenenergy.co.uk/windturbines_buy_our_products.php))

A wind turbine has the potential to generate surplus power when the building is not in use and generate income. This can be used to offset costs. For example, Good Energy pays generators 15p/kWh for electricity under its HomeGen Scheme<sup>29</sup>. This includes the Renewable Obligation Certificates (ROCs).

The Renewable Obligation (RO) scheme is the main support available for renewable electricity production in the UK. It places an obligation on UK electricity suppliers to source an increasing proportion of their electricity from renewable sources. A Renewables Obligation Certificate (ROC) is a 'green' certificate issued to an accredited generator for eligible renewable electricity generated<sup>30</sup>. In the example above, Good Energy are purchasing ROCs from generators rather than buying electricity from them.

Generators who produce enough electricity to justify the costs involved can export to the National Grid and are entitled to apply for ROCs if their system has been accredited by Ofgem. It is easier now for small scale generators to apply for ROCs as they can use agents to act on their behalf e.g. EON, npower. Agents will do all the paperwork and administer the scheme on the generator's behalf, usually for a fee.

Further information is available at <http://www.berr.gov.uk/files/file46838.pdf> and <http://www.nfpa.co.uk/nfpas/trackrecord.htm>.

<sup>28</sup> Based on an ideal site and average wind speed of 5m/s

<sup>29</sup> Personal communication, prices may vary

<sup>30</sup> One ROC is issued for each megawatt hour (MWh) of eligible renewable output generated. For the period April 2008 to March 2009 the value of a ROC was £35.76. Double ROCs are payable as of April 2009 for electricity generated by wind and solar photovoltaics (PV) i.e. approximately £74 per MWh.

### **Legal and planning considerations**

A wind energy installation will require planning permission. Planning permission should be obtained before grant funding is accessed. Projects classified as small scale wind developments (less than 50 MW) require permission from the Local Planning Authority (LPA), in this case Rhondda Cynon Taff County Borough Council.

The project may be required to and indeed should produce an Environmental Statement. Effects such as visual impact, noise, potential ecological impacts (e.g. on birds, flora and fauna), as well as bearing on any archaeology in the area and the historical landscape need to be considered. There are guidelines regarding the distance between a wind turbine site and other structures such as homes and buildings, and also roads and railways (BERR, 2007). Many areas are designated for purposes of protecting the landscape, wildlife, ecology or archaeology e.g. National Park, Site of Special Scientific Interest (SSSI), Area of Outstanding Natural Beauty (AONB), Important Bird Area, Ancient Woodland, RSPB reserves, Local Nature Reserves, Scheduled Monuments, World Heritage Sites. In addition, any consequences for MOD activities and installations, telecommunications equipment, air and radar facilities may need to be assessed.

The project will also need permission from the local electricity company to connect to the grid: the wind turbine installer/supplier will often take on this administrative task.

**If the Group is successful in taking the project forward professional consultation and advice should be taken.**

Further information can be obtained from British Wind Energy Association <http://www.bwea.com>.

### **Solar photovoltaics**

Solar photovoltaic (PV) systems use photovoltaic cells to convert energy from the sun directly into electricity. They produce no greenhouse gases, such as CO<sub>2</sub> or noise when in use, are modular, reliable and very low maintenance.

A typical grid connected system operates in the same way as a grid connected wind turbine system. Electricity generated by the PV system is used to power on-site loads. When the PV system output is greater than the on-site demand the excess is exported to the grid. When demand is greater than the PV system can supply e.g. at night, the balance is drawn from the grid.

The components of a typical (grid-connected) system include:

- The PV array (of PV panels);
- The inverter;
- The import / export meter (two-way meter);
- The connection to the grid.

Solar PV can be installed on the ground or used on most buildings with a roof or wall that faces south (ideally, although installations can be effective in other orientations). It is assumed the existing roof of the boiler house will need to be replaced. A new roof could incorporate integrated PV tiles.

The panels should not be overshadowed by other buildings, large trees or other obstructions. If the panels are overshadowed the system will generate less electricity. The proposed roof (or wall) must be strong enough to support the weight of the panels.

The electricity produced depends very much on the intensity and angle of the sunlight reaching the PV panels and on the efficiency of the panels. The other factors which affect how much energy a PV system will generate are:

- Geographic location;
- Direction the PV installation faces;
- The angle at which the panels are mounted;
- Any obstructions/shading of the panels;
- Size of the PV installation;

Indicative costs are £4,000 - £7,000 per kWp<sup>31</sup> depending on the type of panel installed, size of the system and how it is mounted.

Solar PV panels up to 50 kWp are covered by the government's Low Carbon Building Programme (LCBP). However the fund available for this technology appears to be fully subscribed. Updates are available on the LCBP website.

### **Use of solar PV at the Boiler House**

In order to assess the feasibility of further exploiting solar technologies at Penrhys, information on local solar radiation or "sunshine" (also called insolation) is required. On a clear day, the energy from sunshine on the earth can reach 1 kilowatt per square meter (kW/m<sup>2</sup>)<sup>32</sup>. Northern Europe typically receives about 1000 kWh/m<sup>2</sup> per year of solar energy: southern UK and most of Wales can achieve 1050 kWh/m<sup>2</sup> to 1100 kWh/m<sup>2</sup> per year (Appendix 2). In the UK, the solar energy available varies with the seasons: on an average day in July, the UK receives approximately 5 kWh/m<sup>2</sup> per day, which is enough to heat the water for a generous hot bath. While in January this could be as little as 0.5 kWh/m<sup>2</sup> to 0.6 kWh/m<sup>2</sup> per day.

Actual insolation measurements for Penrhys were not obtained. However, the NASA surface meteorology and solar energy data available online from Atmospheric Science Data Centre were used and reflect the trends indicated for the UK as a whole (Appendix 2).

As an example of possible system size and cost to supply half of the Boiler House electricity requirements (based on 30,000 kWh/yr), assuming that typically 1 kW of PV panels produces 850 kWh of electricity per year<sup>33</sup>:

50% of 30,000 kWh is 15,000 kWh  
15,000 kWh ÷ 850 kWh = 17.6 kWp

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<sup>31</sup> Kilowatt-peak (kWp) is the peak output of a PV panel under ideal condition (i.e. laboratory conditions of 1000w/m<sup>2</sup>; 25°C ambient temperature; air mass 1.5). So, a 1 kWp PV panel will generate 1 kW under ideal conditions. This does not necessarily reflect the power which might be generated under average conditions once installed. Different panels with the same peak output rating can behave differently in actual use.

<sup>32</sup> Incident on a horizontal surface

<sup>33</sup> Personal communications with various suppliers

Therefore, approximately 18 kWp of PV panels will be required to meet 50% of the Boiler House needs. Panels come in different rated capacities e.g. 170 watts (w), 210 w. Performance varies between different panels and so will affect the number of panels required.

Assuming a cost of £4,500 per kWp installed this would give a potential capital cost of £81,000 for 18 kWp. In comparison, meeting 10% of the building's needs would require around 4 kWp of panels at a cost of £18,000. Many suppliers try to meet a third of the demand which would require around 12 kWp of panels at a cost of £54,000.

Again, a PV installation has the potential to generate an income which can be used to offset costs. For example, Good Energy pays renewable electricity generators 15p/kWh under its HomeGen scheme.

The Group should bear in mind that PV is likely to improve in efficiency and reduce in price over the next three to five years. As PV has a life span of about 20 years, it might be advantageous to watch developments and wait until more efficient and cost effective products become available.

**If the Group is successful in taking the project forward professional consultation and advice should be taken.**

Further information can be found at Solar Trade Association <http://www.solar-trade.org.uk>.

## **7.2. Heating, cooling and ventilation**

Conventional space heating and hot water systems include:

- Oil;
- Natural gas;
- Electric.

Currently, more than two thirds of heating in the UK is provided by gas via the nationwide gas grid<sup>34</sup>. One option for heating and hot water provision is a modern gas-fired, highly efficient condensing or non-condensing boiler.

However, although the Penrhys Estate is connected to the mains gas grid the Boiler House does not appear to be connected<sup>35</sup>. The cost of connection would have obtained and taken into account. Accurate information on such costs was not obtained but could range from £10,000<sup>36</sup>.

The latest Building Regulations set minimum efficiency standards for both new and replacement boiler installations. However, it is better to consider selecting systems with higher levels of efficiency in order to benefit from greater economy.

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<sup>34</sup> DTI (2007) *Meeting the Energy Challenge: A white paper on energy*

<sup>35</sup> According to information provided by the Boiler House Group

<sup>36</sup> Personal communications

Condensing boilers can be extremely efficient as they use additional heat exchangers to recover heat that would otherwise be lost in the flue gases. Modern condensing boilers can reduce fossil fuel use, CO<sub>2</sub> emissions and running costs. They are flexible: for example they can be used with under-floor heating or radiators<sup>37</sup>. A condensing boiler with low temperature under-floor heating can result in 90% efficiency over a full heating season. An efficient non-condensing boiler can be 80% to 85% efficient while a standard boiler might be 70% efficient or less. All boilers require an ongoing maintenance regime and this should be budgeted for.

High efficiency boilers require both system design and controls to be integrated in order to gain maximum benefit. Without an integrated approach, a condensing boiler will only operate as well as a standard boiler. As a major refurbishment, the Boiler House project can take such an integrated approach.

An example of a high efficiency condensing gas boiler system for the property is based on an 80 kW heat load<sup>38</sup>. It assumes the installation of two 40 kW condensing boilers with an under-floor heating distribution system. Using two boilers rather than a single 80 kW boiler in a fully automated system enables great flexibility in operation to meet a changing demand with minimum management. It gives a maximum output of 80 kW and down to a minimum of 7 kW.

2 x 40 kW condensing boilers = £4,000

Installation = £2,000

1055 m<sup>2</sup> x £25/m<sup>2</sup> = £26,375 (under-floor distribution pipes and standard floor insulation)

1055m<sup>2</sup> x £17/m<sup>2</sup> = £17,935 (screed)

This gives a total installation cost of approximately £50,310 (excluding gas mains connection costs). The Group needs to consider future potential price rises for fossil fuels.

**If the Group is successful in taking the project forward professional consultation and advice should be taken.**

Alternatives to conventional boilers include biomass boilers and heat pumps.

## **Biomass boilers**

Biomass (also called bio-energy or bio-fuel) can be defined as organic matter of recent origin and includes:

- Woody biomass i.e. forest products, untreated wood products, energy crops, short rotation coppice (SRC) such as willow;
- Non-woody biomass i.e. animal waste, industrial and biodegradable municipal products from food processing and high energy crops such as rape, sugar cane, maize.

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<sup>37</sup> Specific type of radiators

<sup>38</sup> Assuming 70w/m<sup>2</sup> for under-floor heating to the correct standard

Biomass has environmental and economic advantages. It is carbon neutral if produced sustainably and can also reduce materials going to landfill and utilise an otherwise wasted energy resource. However, any project also needs to consider the use of fossil fuels and the associated emissions involved in transporting biomass to site. Biomass is most cost-effective and sustainable when a local fuel source is available which results in local investment and employment.

Biomass boilers can provide hot water as well as space heating. As with any heating system, it is important to size a biomass boiler correctly. They are most efficient when working at maximum output and so it is better not to oversize a system. The size of a boiler depends on the size of the building, how well it is insulated, load profile (i.e. base and peak loads which depend to large extent on building use), how exposed the building is and local climatic conditions.

The cost of biomass boilers varies depending on the fuel choice and level of automation required. As an example, depending on load profile, a 45 kW boiler with a 2000 litre accumulator tank might meet the needs of the boiler house for the assumed heating requirement<sup>39</sup>. A boiler of this capacity might cost around £30,000. However, a fuel store is also essential. Fully containerised systems are available (including boiler, fuel store, feed-in/fuel extraction mechanism) at a cost of around £70,000<sup>40</sup>. This does not include the cost of the distribution system e.g. under-floor heating or radiators.

Small-scale commercial applications usually use wood pellets or wood chips. Wood pellets are compact, have low moisture content (about 10%) and high energy content. Assuming the boiler uses wood pellets providing around 4800 kWh per tonne<sup>41</sup>, the annual fuel requirement and running costs would be:

120,000kWh/yr ÷ 4800 kWh/tonne = 25 tonnes  
25 tonnes @ £150/tonne = £3750 per year (base case for gas is £3,820)

Additional operating costs include an annual service for which a budget of £500 to £1000 should be allowed.

The fuel store in the containerised system used in this example is designed around delivery vehicle capacity rather than hours of fuel use as the more deliveries needed the greater the costs. It is 12m<sup>3</sup> which, assuming 650 kg of pellets per m<sup>3</sup>, holds about 7.8 tonnes of fuel.

When looking at a biomass system, the Group needs to consider the following:

- Fuel: a reliable, preferably local, fuel supplier is essential. Boilers have strict parameters for moisture content of fuel (as well as other properties). A reliable source of fuel appropriate to the boiler selected is crucial;
- Space: space for the boiler and additional equipment (biomass boilers are larger than fossil fuel equivalents), sufficient storage space is crucial (lack of space will

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<sup>39</sup> 120,000 kWh/yr ÷ 45 kW = 2,666 give a full load hours equivalent of 2,666 hours during the year

<sup>40</sup> Personal communications

<sup>41</sup> <http://www.biomassenergycentre.org.uk>

require more frequent deliveries and consequently higher running costs); access /parking/room for manoeuvring at the site for delivery vehicles is often overlooked;

- Regulations: the installation must comply with all safety and building regulations;
- Planning: if a building is listed or in an area of outstanding natural beauty (AONB) then the Local Authority Planning Department must be consulted.

Biomass boiler systems up to 45 kWth<sup>42</sup> are covered by the government's Low Carbon Building Programme (LCBP).

**If the Group is successful in taking the project forward professional consultation and advice should be taken.**

Further information on the use of wood as a renewable source of energy can be found at <http://www.nef.org.uk/logpile/index.htm> and from the Carbon Trust website at <http://www.carbontrust.co.uk/publications/publicationdetail?productid=CTG012> .

## **Ground-source and air-source-heat pumps**

Heat pumps use renewable energy from the sun to provide heating (and also cooling) in a range of applications e.g. schools, community buildings, offices, shops, and homes.

The benefits of ground-source and air-source-heat-pump systems include:

- No combustion (at point of use);
- No need for flues or ventilation associated with conventional boilers;
- Long life and low maintenance costs.

Heat pumps work by moving heat from one place to another. Heat sources include soil, air, and water. For example, a heat pump system can take low temperature heat from a source such as the ground and deliver it at a higher temperature inside a building e.g. for space heating or pre-heating hot water. They are very similar to refrigerators which remove heat from the inside of a fridge and discharge it the outside via the fins at the back.

A ground source heat pump uses the earth as a source of heating (or cooling) by exploiting energy from shallow ground which has been heated by the sun. A typical ground-source-heat-pump system comprises:

- The "ground loop" made of pipe buried in the ground (either in a vertical boreholes or horizontal trenches). The pipe absorbs heat from the ground via a liquid in a closed system;
- The heat pump which has three main parts: an evaporator which absorbs the heat in the ground loop; a compressor which raises the temperature of the refrigerant within the heat pump; a condenser which gives up the heat to the heating distribution system;
- The distribution system e.g. a storage buffer tank and under floor heating.

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<sup>42</sup> Kilowatt thermal

Air-source-heat-pumps work on the same principles as ground-source-heat-pumps but extract heat from the external air. They generally require less space, do not require boreholes or trenches and can be wall or roof mounted and so are very suitable for urban environments. The efficiencies of air-source-heat-pumps are improving. However, they are affected by more variable temperatures as a result of extracting heat from the air rather than the ground.

There are running costs as well as emissions associated with such systems as electricity is required to power the heat pump. In establishing cost savings and reductions in environmental impacts (reduced CO<sub>2</sub>) it is important to consider the type of heating fuel being displaced. Generally the cost savings (and CO<sub>2</sub> reductions) will be greater if electricity, coal, Liquid Petroleum Gas (LPG) or oil is normally used for heating. The advantages tend to be less when mains gas is available. It is also possible to combine heat pumps with a renewable energy sources such as solar photovoltaics (PV) in order to generate the electricity to power the compressor and pump. Alternatively a 'green' electricity supplier could be used. Systems can also be programmed to take advantage of cheap rate and off-peak electricity.

Important factors in system sizing are the temperature required (which is dependent on building use), the energy efficiency of the building, and local climatic conditions (i.e. ambient air temperature). Ground-source and air-source-heat-pumps tend to work best with under-floor heating systems but can be used with special radiators. Energy efficiency measures are extremely important in order to reduce overall heating demand and so make systems more efficient and cost effective.

Indicative costs for ground-source-heat-pumps are £1,500 to £2,000 per kW installed (excluding the distribution system e.g. under-floor heating) although this will vary depending on geology, the type of property, location and size of the system. Vertical boreholes tend to be more expensive than horizontal trench installations. So a 50 kW system might cost around £75,000. The author suggests that the property is not suitable for a ground-source-heat-pump (neither trenches nor boreholes) due to lack of space. Air-source systems can be cheaper as they avoid the cost of digging trenches or boreholes e.g. £850 to £1,200 per kW installed.

Sufficient space is required to house the heat pump, buffer/accumulator tank, pipe work and other related equipment (a plant room) which can cost around 25% of the total cost. In general it is usually more cost effective to install such systems as part of a new construction or major refurbishment project.

As an illustration, to provide space heating for the boiler house (assuming a 50 kW heat load) with an air-source-heat-pump and under-floor heating:

50 kW @ £850 = £42,500 (heat pump)

1055 m<sup>2</sup> x £25/m<sup>2</sup> = £26,375 (under-floor distribution pipes and standard floor insulation)

1055m<sup>2</sup> x £17/m<sup>2</sup> = £17,935 (screed)

This gives a total installation cost of approximately £86,810.

However, overall cost is dependant on a number of elements. For example, the under-floor heating installation assumes the existing concrete floor meets current building

standards. If it does not then higher performance insulation will need to be fitted which will increase costs.

A rough estimate of running costs can be calculated by assuming a Coefficient of Performance (COP)<sup>43</sup> of 4:1<sup>44</sup>. A heat pump uses electricity. Therefore, we can divide the kWh for heating by 4 to calculate approximate annual running costs for space heating:

120,000 kWh/yr ÷ 4 = 30,000 kWh/yr  
30,000 kWh/yr x 9p/kWh = £2,700 (base case for gas heating is £3,820)

An air-source-heat-pump system could be used to provide space heating for the Boiler House with electric point source hot water heaters for the proposed café, washrooms and showers. This might be the most practical option as building use and anticipated numbers of users is not clear at this stage.

However, such a system could also be combined with solar thermal panels to provide hot water. This type of system would probably be better for a constant/heavy load profile i.e. high numbers of users, seven days a week.

Ground-source-heat-pumps up to 45 kWth<sup>45</sup> are covered by the government's Low Carbon Building Programme (LCBP). Air-source-heat-pumps can be funded under the Big Lottery Community Sustainable Energy Programme.

**If the Group is successful in taking the project forward professional consultation and advice should be taken.**

For further information see <http://www.heatpumpnet.org.uk/> and <http://www.heatpumps.org.uk> .

## **Solar thermal**

Solar thermal systems use energy from the sun to heat water. They can be used to pre-heat water (e.g. for washing) and supplement, rather than replace, a conventional a water heating system.

They produce no greenhouse gases or noise when in use, are modular, reliable and very low maintenance. Such systems are not generally used for space heating in the UK due to prohibitive cost and climatic conditions. Solar thermal systems can be combined with conventional fossil fuel boilers, biomass boilers, ground-source and air-source-heat-pump systems.

As for solar PV, ideally solar hot water systems should be oriented between south-east and south-west, avoid shade and other obstructions and ensure panels are tilted to the appropriate angle. There are two main types of system:

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<sup>43</sup> The term coefficient of performance (COP) is used to describe the ratio of useful heat movement to work input. In this case 4 units of heat out to every 1 unit of electricity input.

<sup>44</sup> NOTE: the COP could be lower than 4:1 in which case electricity use and running costs would be greater

<sup>45</sup> Kilowatt thermal

- Flat plate/flat panel collectors;
- Evacuated tube collectors.

Again retrofitting is more costly than integration into a new-build, although this is less of a barrier in a major refurbishment such as at the Boiler House. The collector panels represent a significant proportion of the cost of a solar thermal hot water system. The simpler flat plate design is less expensive than the evacuated tube type and it can be argued is the best value for money system for the UK climate. Maintenance of such systems is low requiring a routine annual check which could be conducted by a caretaker and more detailed inspection by an engineer every 3-5 years.

The main elements of a typical system in the UK are:

- Solar thermal collectors (evacuated tubes or flat panels);
- Heat transfer medium (antifreeze mixture or water) and circulation system (pumps and pipes);
- Hot water store (hot water cylinder);
- Control units.

Solar hot water heating systems tend to be most economical in larger installations and where there is a high level of demand for hot water, such as in a café or leisure centre.

In order to provide an example, we assume a hot water requirement of 500 litres per day (equivalent to a busy office plus, assuming 100 users per day, 5 litres of hot water per user<sup>46</sup>). Solar thermal panels differ in size and rated capacity however as a guide a flat plate collector is often quoted as delivering approximately 450 kWh/m<sup>2</sup>/yr<sup>47</sup>. Therefore, a 10m<sup>2</sup> system could provide approximately 4,500 kWh/yr. Based on one 2m<sup>2</sup> panel for every 100 litres of water suggests that a system of five panels would meet the assumed demand. Such a system would comprise a 500 litre cylinder and 10m<sup>2</sup> of flat plate collector panels.

5 x 2m<sup>2</sup> panels @ £500 per panel installed = £2,500  
 500 litre store = £8,000<sup>48</sup>

This gives a total installation cost of approximately £10,500.

Solar thermal hot water installations up to 45 kWth<sup>49</sup> are covered by the government's Low Carbon Building Programme (LCBP).

**If the Group is successful in taking the project forward professional consultation and advice should be taken.**

Further information can be found at Solar Trade Association <http://www.solar-trade.org.uk> .

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<sup>46</sup> This is estimated demand only and could be significantly less

<sup>47</sup> Carbon Trust

<sup>48</sup> NOTE: using two 250 litres stores could be cheaper at around £3000 to £4000

## Ventilation

Ventilation is the controlled and intentional movement or flow of air from the outside of a building to the inside in order to ensure good air quality within the building. It comes under Part F of the Building Regulations. The Building Regulations provide guidance on the effectiveness of ventilation systems in different applications e.g. Part F specifies a minimum air supply rate of 10 litres per second (l/s) per person in an office building.

Ventilation should not be confused with air leakage which is air entering or leaving a building unintentionally e.g. through draughty windows and doors, and which can lead to heat loss and increased heating costs.

Adequate ventilation is necessary to control humidity, moisture and air quality. This is important for the comfort and health of people using the building as well as to prevent damage to the building fabric (such as rotting of the building fabric and mould).

There are main two categories of ventilation system:

- Mechanical or forced ventilation: such as through an air handling unit as part of an air conditioning system;
- Natural ventilation: such as an unpowered fan, operable windows or temperature and pressure differences between spaces e.g. Windcatchers.

The less natural air flow within a building the more mechanical (i.e. powered) ventilation will be required (see Section 9 Passive solar design).

**If the Group is successful in taking the project forward professional consultation and advice should be taken.**

## 8. Water

Water stress is a growing concern within the UK<sup>50</sup>. Vital elements of the UK's strategy to address sustainable water use are water conservation measures and matching the quality of supply to the quality required.

The Boiler House project might consider utilising a rainwater harvesting system. Rainwater harvesting systems can reduce demand for mains water (and therefore reduce water bills and running costs) and help local drainage by limiting the volume of rainwater reaching the ground. If properly stored, rainwater can be used for flushing toilets, in appliances such as washing machines and for horticultural purposes.

In a rainwater harvesting system, water is generally collected from the roof and distributed via guttering to storage tanks which are often stored below ground although above ground systems are available. It is then delivered on demand by a submersible pump in the storage tank direct to where it is needed. Storage tanks can be large e.g. a 2280 litre tank (2.28 m<sup>3</sup>) might be 2220 mm long and 1200 mm high and so suitable space is an important consideration.

Water systems are affected by a range of policies, guidance and standards such as the Water Framework Directive, Water Supply Act, Private Water Supply, Code for Sustainable Homes, Building Regulations Part H and Part G, various BS standards and Planning Policy Statement (PPS). A primary concern of regulations, standards and guidance is cross-contamination of rainwater with the mains water supply. Careful planning and hygiene control is required when storing rainwater to ensure that storage tanks or butts remain pest and disease-free. Careful consideration is also required for water tank storage and positioning / gravity etc.

In order to size and cost a system, water demand and the resource available need to be assessed. Demand can most easily be understood from previous water bills. As has already been pointed out, the Group needs a clear understanding of building and numbers of users.

Meteorological Office records suggest 1400 mm to 1800 mm average annual rainfall for the Penrhys area (Appendix 3). Assuming a conservative 1400 mm rainfall per annum, a roof area<sup>51</sup> of 626 m<sup>2</sup> and a drainage factor of 0.9 suggests approximately 788 m<sup>3</sup> per year could be harvested.

Clearly, there is potential for rainwater harvesting at the Boiler House. However, there are other ways to significantly reduce water use within a building for a much smaller capital outlay including:

- Controlled flush toilets and urinals;
- Low flow taps and shower heads e.g. spray taps save around 80% of the water and energy used for hand washing;
- Water efficient appliances (water use is indicated on appliance energy labels);

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<sup>50</sup> Environment Agency (2008) *Water resources in England and Wales – current state and future pressures*

<sup>51</sup> This is an approximate figure and does not take into account the pitch of the roof

- Pro-active building management to detect/report and deal with leaks and the use of water metering.

These options should be implemented whether or not a rain water harvesting system is employed.

The Group should keep in mind possible future UK and regional policy, legislative and regulatory changes. In future, water use by businesses might be restricted much as hosepipe bans are imposed on households. At the moment the UK government is focusing on education rather than legislation to encourage sustainable use.

Further information on water conservation can be found at <http://www.environment-agency.gov.uk/homeandleisure/drought/38559.aspx> .

## 9. Passive solar design

Passive solar building design is another way of using renewable solar energy. It uses sunlight to provide useful energy without the need for powered mechanical systems such as ventilation. It is also therefore a key approach to ‘greening’ a building.

In passive solar design the building acts as a solar energy collector and uses natural heat flow to provide thermal comfort (i.e. heating and cooling). Sunlight is converted into usable heat (e.g. using thermal mass) or air movement for ventilation. A good example of passive solar design in action is a solarium or conservatory on a building. Passive cooling uses the same principles to reduce summer cooling requirements.

Passive systems have many benefits including:

- Reduce dependence on fossil fuels;
- Have little to no operating costs;
- Have low maintenance costs;
- Emit no greenhouse gases in operation.

Passive solar systems need to be carefully optimised to yield the best performance. Energy conservation measures such as insulation are crucial.

Specific attention is paid to the site and location of a building, prevailing climatic conditions, building design and construction, solar orientation, placement of glazing and shading elements, and thermal mass. It is necessarily much easier to incorporate passive design into a new build. However the benefits can be significant if incorporated correctly and potential application in the Boiler House should be explored.

Thermal mass plays a critical role in passive solar design. Thermal mass refers to the ability of dense materials such as concrete to store heat as their temperature rises (e.g. when exposed to sunlight). Heat is then released when the surrounding temperature falls (e.g. in the evening and at night). Without this thermal mass a building would quickly overheat on sunny days and cool down very quickly. There are various passive design systems e.g. Trombe Wall, but each system incorporates south facing glass (e.g. windows) and different distributions of thermal mass in the walls and floors. It may therefore be possible to apply passive solar design principles at the Boiler House.

**Professional consultation and advice should be sought.**

## 10. Summary

Understanding potential energy demand and end use in the Boiler House is a crucial step in refurbishing and ‘greening’ the building. It is important in order to select the most appropriate technology. A key factor influencing energy demand is the intended use of the building: services/activities provided, number of users, hours of use. This is still unclear. It is possible to use publicly available benchmarks for typical energy use based on building type in order to give approximate demand.

Reducing demand for energy as well as supplying energy in a ‘green’ way are two sides of the same sustainability ‘coin’. In order to realise the full benefits of renewable energy sources (or traditional ones) energy use must be as efficient as possible. It should also be noted that in the majority of cases the potential energy outputs and cost savings of renewable energy systems quoted by manufacturers and suppliers assume use in well insulated buildings. In addition, many grants require buildings to meet current applicable building regulations with regard to insulation and energy performance.

One of the most effective ways the project can reduce energy demand and manage running costs is by enhancing the thermal performance of the building fabric e.g. insulating walls, floors and the roof space, fitting double glazed windows and so on. Cavity wall insulation might be the simplest option for the Boiler House if the cavity space is sufficient to meet Building Regulation requirements. Insulation on top of the existing floor might be appropriate but is dependant on the condition of the floor and internal requirements of the building. There are numerous materials on the market suitable for insulating the roof space. Doors and windows also need to be energy efficient e.g. using double glazed windows.

Using more energy efficient fittings and appliances can also make a significant difference. For example, by installing highly efficient light fittings, using ‘A’ and ‘A+’ rated appliances and restricting the maximum wattage of equipment.

The project should also consider employing passive solar design principles e.g. when placing windows, making the best use of the thermal mass available within the building and ensuring adequate air circulation.

Water use within the building can be reduced by e.g. installing controlled flush toilets and urinals, low flow taps and shower heads, water efficient appliances (water use is indicated on appliance energy labels), and pro-active building management to detect/report and deal with leaks and the use of water metering.

There are a number of renewable energy technologies which the Group might consider for power and heating. A practical starting point for selecting technologies is to consider the main aspect and restrictions at the site and what services to the building already exist. At the present this appears to be electricity only: the building does not appear to have a mains gas connection.

In order to provide ‘green’ electricity within the building the Group could consider using a 100% green energy supplier and/or supplement their electricity supply with solar PV.

The Group has indicated a particular interest in the use of wind turbines and of building mounted, vertical axis wind turbines. The author does not recommend building mounted wind turbines. Ideally wind turbines should be installed clear of any obstructions such as trees and buildings. This can be difficult when a turbine needs to be close to a building it will supply. However, the proposed site has very limited land attached and is also close to the main road circling the estate. There appear to be potential health and safety implications for a mast (ground) mounted wind turbine based on the information available. The Group should consult the local authority for advice.

The lack of a mains gas connection at the site and restricted ground space suggests that a practical option is to use an air-source-heat-pump to provide space heating with hot water supplied using point source electric heaters. Alternatively, depending on the demand for hot water, an air-source-heat-pump could be combined with solar thermal panels for hot water production.

However, the group might consider connecting to mains gas and installing a highly efficient condensing boiler or installing a biomass boiler. Again it is possible to combine these systems with solar thermal panels for hot water. However, the Group should consider the CO<sub>2</sub> emissions associated with fossil fuel use in the case of gas and also for the transport of biomass fuel to the site. Fossil fuel prices are also likely to rise in future. It is also vital to ensure that a reliable, local biomass fuel supplier is available.

The burden of legislative and regulatory needs, planning and permitting requirements should not be underestimated and often pose problems for this type of project. Wind turbines in particular can offer challenges in relation to gaining planning consent.

## 11. Funding sources

Potential funding sources include:

### Low Carbon Buildings Programme

Grants for the installation of micro-generation technologies are available to public sector buildings (including schools, hospitals, housing associations and local authorities) and charitable bodies. Grants of up to 50% of total project costs for the following technologies are available:

- Solar photovoltaics (PV);
- Solar thermal hot water;
- Wind turbines;
- Ground source heat pumps;
- Automated wood pellet stoves;
- Wood fuelled boiler systems.

The current Phase 2 of the programme will come to an end in June 2009. However, it appears further funding will be made available. Further information on Phase 2 of the government's Low Carbon Building Programme (LCBP) can be found at <http://www.lowcarbonbuildingsphase2.org.uk/index.jsp> including application process, supported technologies and accredited suppliers.

### Community Sustainable Energy Programme

The Community Sustainable Energy Programme will fund community-based organisations for the installation of microgeneration technologies, such as solar panels or wind turbines and energy efficiency measures including loft and cavity wall insulation. It will also provide funds for project development grants that will help community organisations establish if a microgeneration and energy efficiency installation will work for them.

Further information can be found at: <http://www.communitysustainable.org.uk/>

Other potential sources of funding include:

- The community itself
- The Big Lottery Fund <http://www.biglotteryfund.org.uk>
- The Coalfield Regeneration Trust <http://www.coalfields-regen.org.uk>
- Environment Wales <http://www.environment-wales.org>
- The Co-operative Community Fund and Foundation <http://www.co-operative.coop/ethicsinaction/communities/fundsandfoundations/>
- The Ashden Trust <http://www.ashdentrust.org.uk>
- Many large energy utilities and technology providers can provide a source of support for community projects.

## 12. Sources of further information

- A very useful resource of Welsh renewable energy installations is provided by the Community Energy Network (CEN) and PLANED. This covers installations in the county of Pembrokeshire and provides an interactive map as well as individual case studies [http://www.planed.org.uk/leaderplus/energy\\_map.htm](http://www.planed.org.uk/leaderplus/energy_map.htm)
- British Wind Energy Association <http://www.bwea.com>
- Small Wind Industry Strategy <http://www.smallwindindustry.org>
- Heat Pump Association <http://www.heatpumps.org.uk>
- Ground Source Heat Pump Association <http://www.gshp.org.uk>
- Solar Trade Association <http://www.solar-trade.org.uk>
- Energy Saving Trust <http://www.energysavingtrust.org.uk>
- Carbon Trust <http://www.carbontrust.co.uk>
- Centre for Alternative Technology <http://www.cat.org.uk>
- UK Rain Water Harvesting Association (UKRWHA) <http://www.ukrha.org/>
- Envirowise <http://www.envirowise.gov.uk/>
- Buildings regulations can be found at: <http://www.planningportal.gov.uk/>
- National Energy Foundation's Log Pile website at <http://www.nef.org.uk/logpile/index.htm>
- Heat Pump Network <http://www.heatpumpnet.org.uk/>

## Appendix 1: Wind speed data for Penrhys

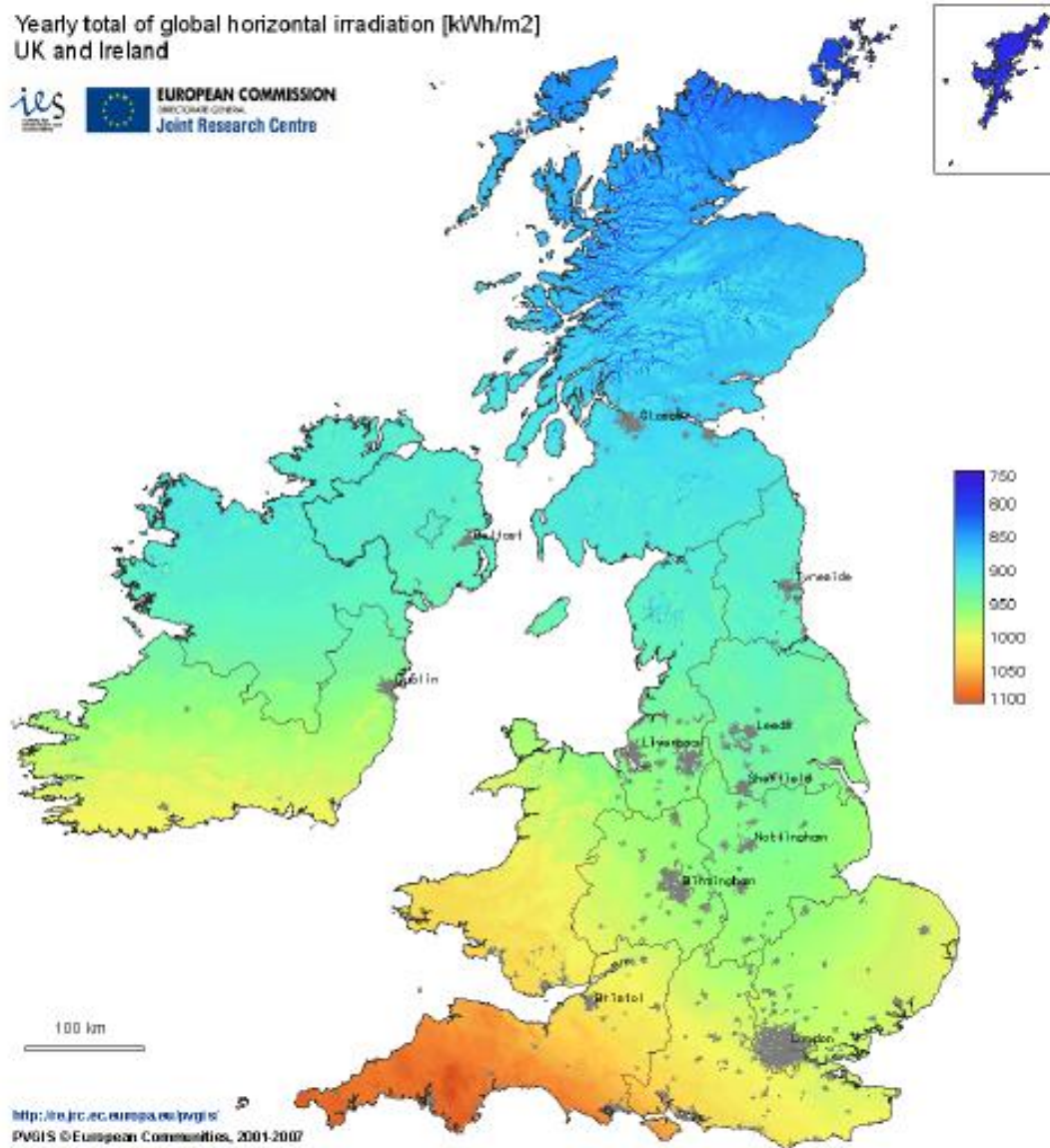
**Table 9: Averaged wind speed data at 25 m above ground level for the Boiler House location**

Monthly Averaged Wind Speed Adjusted For Height And Vegetation Type (m/s)													
Height 25 meters													
Vegetation type 0.6-m perennial groundcover (100%)													
Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
51.646													
Lon - 3.439													
10-year Average	7.92	7.40	7.21	6.21	5.63	5.20	5.15	5.29	5.93	6.80	7.28	7.65	6.47

(Source: NASA)

## Appendix 2: Solar irradiation for the UK

Figure 7: Annual total horizontal irradiation for the UK



(Source: Joint Research Centre)

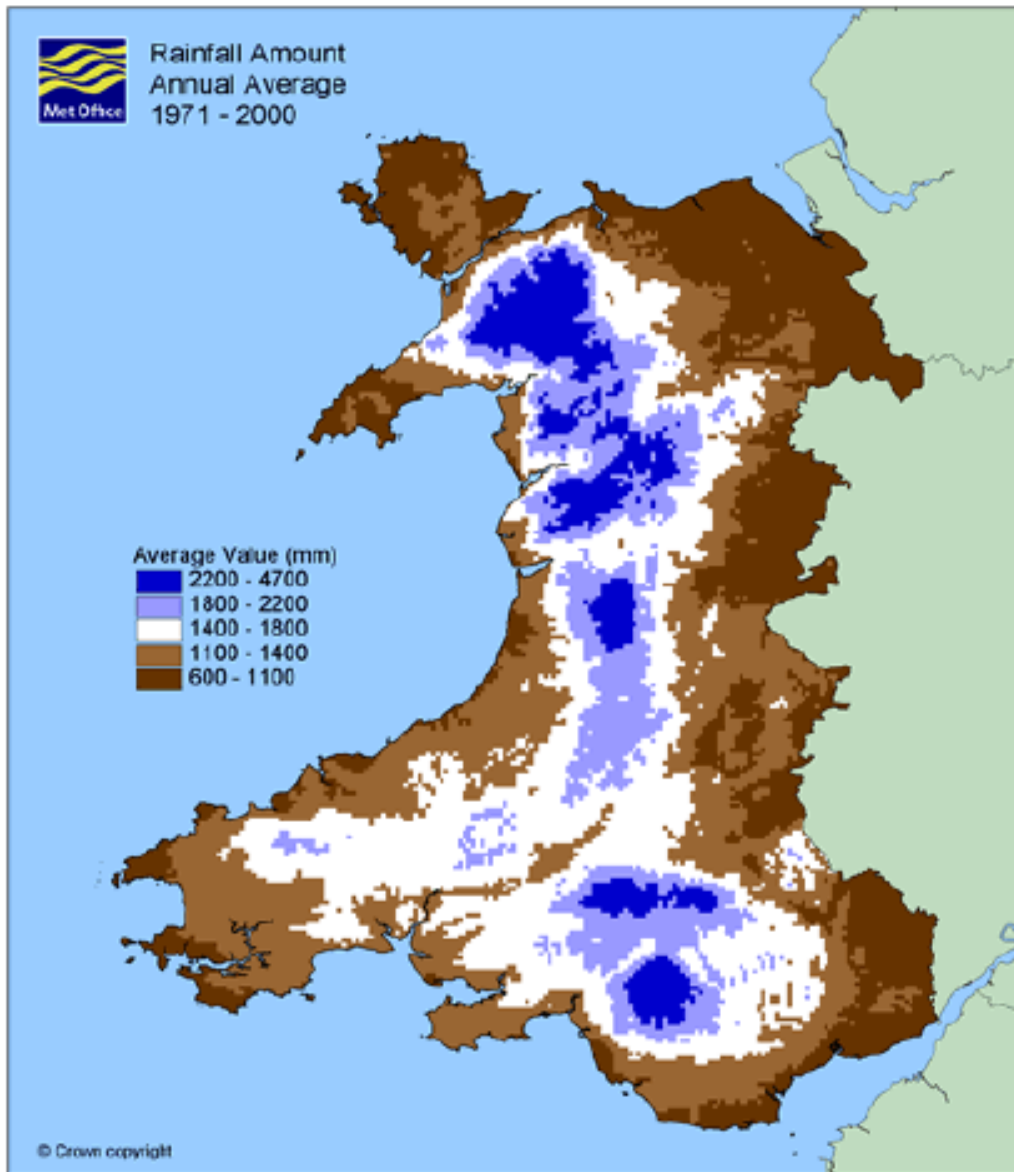
Table 7: Monthly averaged insolation (kWh/m<sup>2</sup>/day) for the Boiler House location

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m <sup>2</sup> /day)													
Lat	51.65	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lon	-3.44												
22-year Average		0.74	1.35	2.23	3.54	4.55	4.73	4.69	4.00	2.76	1.59	0.92	0.59

(Source: NASA)

## Appendix 3: Regional rainfall

Figure 8: Regional rainfall (mm) between 1971 and 2000



## Appendix 4: Carbon dioxide emissions factors

Table 8: Emissions factors

Energy source	kgCO <sub>2</sub> /kWh
Gas	0.185
Oil (domestic only – fuel oil)	0.268
Electricity (use)	0.537*
Electricity (savings - ie marginal)	0.430

(Source: Market Transformation Programme, [www.mtprog.com](http://www.mtprog.com) )